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Optimisation of the Food Dairy Coop Supply Chain

A dissertation presented to the Department of Food
Business and Development,
National University of Ireland, Cork,
In complete fulfilment of the requirements for the
Degree of Ph.D.

By

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DECLARATION

I declare that this thesis has not previously been submitted as an exercise for a degree at the National University of Ireland, or any other university, and I further declare that the work embodied in it is my own.

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Carrie Quinlan

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THESIS PUBLICATIONS AND PRESENTATIONS

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Quinlan, C. , Shalloo L., Keane, M. and O'Connor, D. Modelling the Impact of Changes in Regional and National Milk Supply on The Irish Dairy Processing Sector. Young Researcher Seminar, AESI conference November 25th 2011.

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ABSTRACT

In the European Union under the Common Agricultural Policy (CAP) milk production was restricted by milk quotas since 1984. However, due to recent changes in the Common Agricultural Policy (CAP), milk quotas will be abolished by 2015. Therefore, the European dairy sector will soon face an opportunity, for the first time in a generation, to expand. Numerous studies have shown that milk production in Ireland will increase significantly post quotas (Laepple and Hennessy (2010), Donnellan and Hennessy (2007) and Lips and Reider (2005)).

The research in this thesis explored milk transport and dairy product processing in the Irish dairy processing sector in the context of milk quota removal and expansion by 2020.In this study a national milk transport model was developed for the Irish dairy industry, the model was used to examine different efficiency factors in milk transport and to estimate milk transport costs post milk quota abolition. Secondly, the impact of different milk supply profiles on milk transport costs was investigated using the milk transport model. Current processing capacity in Ireland was compared against future supply, it was concluded that additional milk processing capacity would not be sufficient to process the additional milk. Thirdly, the milk transport model was used to identify the least cost locations (based on transport costs) to process the additional milk supply in 2020. Finally, an optimisation model was developed to identify the optimum configuration for the Irish dairy processing sector in 2020 taking cognisance of increasing transport costs and decreasing processing costs.

It is hoped that the results from this thesis will help improve the decision making process around the inevitable changes in the milk processing sector in Ireland.

Chapter 1: Introduction to the Research

1.1 Introduction to Research

In Ireland the dairy industry is one of the most important indigenous industries and comprises a vital part of the agri-food sector accounting for 29% of agricultural output in 2010 (Bord Bia 2010a). Milk production in Ireland is primarily grass based; therefore it varies widely on a seasonal basis throughout the year. Supplies are highest during the months from mid-April to August and lowest during the months of December and January (Promar and Prospectus 2009). This results in low processing plant capacity utilisation, with approximately 60% of peak capacity being utilised on an annual average basis. It also results in a product range, which is dominated by commodity products such as butter, milk powders and cheese. The processing sector is highly export orientated with approximately 85% of all manufactured output being exported (Promar and Prospectus 2009).

1.2 Background to Research

In the European Union under the Common Agricultural Policy (CAP), milk production has been restricted by milk quotas since 1984. However, due to recent changes in the Health Check (2008) of the Common Agricultural Policy (CAP), Irish milk quotas will increase by 9.3% between 2007 and 2013 (Shalloo, 2011) with their eventual abolishment in 2015. In parallel to this development worldwide demand for dairy products is expected to rise as a result of global population growth and projected increases in per capita disposable income. Rabobank forecasts growth of 2.5% annually up to 2014 (Department of Agriculture. Food and Fisheries, 2010).

Consequently, numerous studies have been done on the expansion capacity of Ireland post milk quota elimination. Laepple and Hennessy (2010) forecasted an increase of 45% in milk output post milk quota abolition. Lips and Reider (2005) found that the potential for increased milk production post milk quotas was comparatively greater in Ireland, with a projected (38.6%) relative to the average of all EU member states. Donnellan and Hennessy (2007) also revealed that Ireland had capacity to increase milk supply by 20% using existing resources on dairy farms.

In response to policy reforms the Department of Agriculture, Fisheries, and Food published Food Harvest 2020; a vision for smart, green growth in the agriculture and food industries. Supported by a number of implementations to secure Ireland's competitiveness on the international marketplace, it also aims to ensure that the country can play its part in meeting the increased global demand for food. Food Harvest 2020 sets ambitious, yet achievable targets, which include a 50% increase in milk production by 2020. If that opportunity is to be grasped, significant structural and operational changes need to be implemented. Smart plus green, with excellent implementation, will deliver growth. As the capability of Ireland Inc. to produce more milk grows over the next ten years, this growth must be market, customer and consumer led, in order to maximise value-added for the nation and for all stakeholders in the industry. Innovation is the driving force for companies that want to be part of this growth, and it is critically important that the food and beverage industry lead the way in applying science and technology to develop new market-led products. The key driver will be the emerging needs and demands from the market and from customers. Ireland has an excellent reputation all around the world for

producing, selling and marketing high quality food, and this will have to be further built upon over the next decade if the dairy industry is to step up to the challenge of succeeding as a world class industry (Department of Agriculture, Food and Fisheries, 2010).

In order to realise the potential of the dairy sector the Food Harvest report recommended that the processing industry must move toward a small number of scaled operators who have the scale and culture to drive efficiency and value added in line with key international competitors who have already achieved consolidationDepartment of Agriculture, Food and Fisheries, 2010). Numerous other reports conducted on the Irish dairy industry have recommended similar strategies. Promar and Prospectus (2009) notes that the industry is fragmented in its current structure and in need of urgent consolidation, the report concluded that existing structures are now inefficient and out-dated in comparison with Ireland's international peers. Bloxham (2009) recommended a radical rationalisation plan for the Irish dairy industry, stating that the number of plants producing butter, powder and cheese needed to be reduced. The Irish Co-operative Organisation Society (Irish Farmers Journal, 2009) and Bord Bia (2010b) also recommended that processors need to work more closely together and develop synergies.

Taking this into consideration this thesis set out to answer the following questions:

> Will milk supply increase post milk quota abolition?

> Does Ireland need additional capacity to process milk?

> If so, what processing sites should be expanded?

> How many sites should be expanded?

➢ Are economies of scale available in dairy processing?

➢ Should milk processors co-operate with each other?

In endeavouring to streamline the dairy industry, all components of costs must be investigated. Milk transport is a component of these costs and requires examination; clear savings have been highlighted in previous studies (Quinlan 2005). As there is an obvious gap in literature on milk transport costs in Ireland, it was decided to examine milk transport activities in detail in this thesis.

Both economic theory and international studies suggest that as plant size increases dairy processing costs fall due to economies of scale (Buschendorf, 2008; Boysen and Schröder, 2009). There is limited literature on processing costs in Ireland. Therefore, in this study processing costs were examined in detail.

This thesis will contribute to the current debate around the future structure of the Irish dairy industry as it enters a period when significant expansion is possible for the first time in 3 decades.

1.3 Research Questions and Sub-questions

The research question that guided this study was: *What is the least cost industry configuration for the Irish dairy industry post milk abolition in 2020*?

The main research question was broken down into the following research sub-questions:

Sub-question 1: *What are the effects of various efficiency factors on milk transport costs in Ireland? What are the effects of different milk production patterns on milk transport costs in Ireland?*

Sub-question 2: *Will milk production increase post milk quota abolition, if so where will it increase? How many processing plants should Ireland have post milk quota abolition? Where should the plants be located? How large should each plant be? Where should the milk to be processed at each plant should be sourced? How should milk be collected?*

Sub-question 3: *What will the total processing and transport costs be post milk quota abolition? What is the capital requirement for the Irish milk processing sector post milk quota abolition?*

1.4 Research Objectives

The objectives of this study were: (i) to develop, validate and describe a national milk transport model for simulating milk transport activities in Ireland and (ii) to develop a model to determine the least cost dairy processing sector configuration in 2020 taking cognisance of regional milk supply, processing and milk transport costs.

1.5 Framework of Thesis

This thesis can be broken down into ten chapters.

Following this introduction, chapter 2 introduces the conceptual framework of the study.

Chapter 3 provides an overview of the Irish dairy industry; the chapter is concluded with a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of the Irish dairy industry.

Location theories (classical location theory, least cost site, interdependency and market areas, regional science and new economic geography) are discussed in Chapter 4. The applications of operation research-based techniques to location problems are also reviewed in this chapter.

Chapter 5 outlines the research methodology used in this study.

Chapter 6 details the transport implications for the elimination of milk quota regime in 2015. In this chapter the transport model is described in detail and an application of the model is demonstrated.

In Chapter 7, milk transport costs and carbon emissions from milk transport associated with alternative milk supply patterns and output levels in Ireland are estimated.

Chapter 8 uses regional and national milk supply change projections post milk quota abolition and current processing capacities to determine milk transport costs in the Irish Dairy Industry in 2020.

Chapter 9 establishes the least cost configuration for the Irish dairy processing sector taking into account expected expansion by 2020 and includes both transport costs and processing costs.

Chapter 10 consists of the conclusions, recommendations and limitations of this research.

1.6 Conclusion

This chapter introduced both the conceptual and contextual basis for the research presented in this study. Chapter 1 presented the research question, sub-questions and research objectives that guided this study. In Chapter 2 the conceptual framework for this study is presented.

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Chapter 2: Conceptual Framework

2.1 Introduction

This chapter presents the conceptual framework arising from a review of key empirical research and relevant literature on transport costs and processing costs in the dairy industry, which form the basis for this study. The conceptual framework of this study can be divided into a number of interlinking topics: least cost location theory, transport costs, processing costs and operational research techniques used in solving location problems.

2.2 Least cost location theory

Location theory dates back to Von Thunen (1826), according to Von Thunen identifying the least location cost involves balancing the cost of transportation, land and profit (Rosenberg, 2011). According to Weber (1909 and 1929) three factors; transportation costs, labour costs and agglomeration forces should be used to determine the optimum-manufacturing site (Al-Nowaihi and Norman, 1992).Hotelling (1929) dealt with interfirm competition between duopolists in location and price of an identical good. He claimed that firms should locate where the greatest profit is generated and this was determined by identifying production costs at various locations, and then taking into account the size of the market area that each location is able to control (D'Aspremont *et al.,* 1979). Losch (1954) analysis the optimum placement of the individual enterprise in different sites can be

determined from the cost and demand curves (Al-Nowaihi and Norman, 1992). Isard's theory stated that optimum plant location is at the point of minimum transportation costs, however if there is factor substitution between all inputs the optimum location will very with the level of output (Al-Nowaihi and Norman, 1992). Krugman theory on the optimum location is based on the interaction of three factors: increasing returns of scale, transportation costs and demand (Al-Nowaihi and Norman, 1992).

2.3 Transport costs

Keane (1986) examined the effect of various efficiency factors on milk transport in Ireland; including tanker size, frequency of collection, transport mileage and supplier size. Clear savings in milk transport costs were highlighted in his study. Quinlan *et al.* (2006) broke milk transport costs down into six components namely transport driving, assembly driving, on-farm routine activities, plant non-pumping, farm pumping and plant pumping. This study concluded that when the number of processing sites is reduced the transport-driving component of milk transport increases and in turn milk transport costs increase; therefore milk transport activities were central to the strategic plans for the future of the Irish dairy industry. Butler *et al.* (2005) citied that milk transport is a challenging logistical problem that has long been of interest to operational researchers for many years (Butler *et al*. 2005). Cornell (1998) developed the US dairy sector simulation model to simulate milk transport costs in the US associated with different milk tanker sizes and different milk transport wage rates. The US Dairy Sector Simulator was seen as an important

tool, which was able to provide useful policy guidance in the dairy processing sector. Dooley *et al.* (2005) also developed a milk transport simulation model to estimate transport costs in New Zealand, this model used to evaluate alternative transport management strategies for the New Zealand dairy industry.

2.4 Processing costs

According to Hsu and Li (2009) average processing costs decrease with increasing scale as a result of economies of scale. Many studies have identified common sources of economies of scale as the division of labour, technological development and scale, the economies of massed reserves and dynamic economies through learning processes (Searcy and Flynn, 2009, Promar and Prospectus 2009, 2003 and Hay and Morris, 1991).

2.5 Optimum costs

Hsu and Li (2009) stressed that the optimum dairy processing sector structure involves a balancing of decreasing average processing plant cost with increasing scale against increasing milk transportation costs. Stollsteimer (1963) developed a linear programming model that simultaneously determined the number, size and location of pear packing plants in California that minimised the combined transportation and processing costs. O'Dwyer (1968) developed a linear programming model that determined the optimum number, location, and size of dairy manufacturing plants in Ireland. Wouda *et al.* (2002) developed a mixed integer model that optimised the supply network for a leading dairy manufacturer in

Hungary by minimising total processing and transport costs. Buschendorf (2008) developed a mixed integer processing model that optimised the German dairy processing sector taking into account regional increases in milk supply in Germany projected for after 2013.

2.5 Conceptual framework of the thesis

The conceptual framework guiding this study illustrates the relationship between location theory transport and processing costs and operational techniques used in solving location problems, which are strongly linked to determining the least cost processing structure.

2.6 Summary

This chapter presented the conceptual framework of this research. Chapter 3 provides an overview of the Irish dairy industry and the Common Agricultural Policy. A SWOT analysis is performed on the Irish dairy-processing sector.

Figure 2.1: Conceptual framework of the thesis

Krugman (1991); Isard (1969); Losch (1954); Hotelling (1929); Weber (1909); Launhardt (1882), Von Thunen (1826)

Least Cost Theory

Quinlan et al. (2006); Butler at al. (2005); Dooley et al. (2005); Quinlan et al. (2005); Shanahan(1996); Keane (1996); Mellalieu and Hall (1983)

Transport Cost
Capital costs
Running costs
Labour costs

Components of milk transport
Transport driving
Assembly driving
On-farm pumping
Plant pumping
Non-pumping activities at the plant
Non-pumping activities at the farm

Structure of the Irish Dairy Processing Industry
Milk production patterns
Location of milk supply
Current number of plants and processing capacity
Current location of plants
Current catchment areas
Current product mix
Location and qty of milk supply post milk quota

Geary et al. (2010); Hargens et al. (2003); Krell (1993).

Processing costs
Fixed costs
Variable costs

Factors affecting processing costs
Product mix
Capacity of plants
Seasonality of milk production

Leduc et al. (2009); Buschendorf (2008); Hellmann and Verburg (2008); Wouda et al. (2002); O' Dwyer (1968); Stollsteimer (1963)

Optimum cost, balance increasing transport costs and decreasing processing costs
How many plants when total costs are at a minimum?

Source: Author

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Chapter 3: Competitiveness of the Irish Dairy Industry

3.1 Introduction

The purpose of this chapter is to provide the reader with a background to the Irish dairy industry. Firstly, the Common Agricultural Policy is discussed. Secondly, the Irish dairy industry is examined in detail. Finally, the major issues facing the industry are identified using a SWOTanalysis .

3.2 Common Agricultural Policy

Since Ireland joined the European Union in 1973, the Irish dairy sector came under the governance of the Common Agricultural Policy. As a result policy, in particular EU policy plays a very important role in agriculture in Ireland. In this section the Common Agricultural Policy is examined in detail.

Upon joining the European Union in 1973 Ireland enjoyed the benefits of the CAP. The CAP has its roots in 1950s Western Europe, whose societies had been damaged by years of war, and where agriculture had been crippled and food supplies could not be guaranteed (Europa, 2012).The introduction of the CAP was an attempt by the founding European Economic Council (EEC) members to become self-sufficient in food and agriculture at regional level. The tools used by the CAP to support agriculture were import tariffs (border taxes which are charged by the EU on imports from third countries), export subsidies (paid to those who export outside the community) and intervention (buying prices that the national intervention agencies are obliged to pay for produce which meets the required quality standards, unless

buying-in has been suspended) and subsidised consumption. These tools ensured farmers received a relatively steady income and were lifted out of poverty. Farmers depended on CAP funding for a livelihood (Department of Agriculture, Food and the Marine, 2012).

The CAP succeeded in achieving its objective. In the 1980's production had grown to a level, which surpassed EU demand. This had negative effects on the environment, for example water pollution and soil impoverishment. Public storage for surpluses became increasingly expensive. Criticisms of the CAP at this time included all of the support funding was not reaching primary producers, the CAP did not always distribute support equitably between large and small producers, and the development of excessively intensive farming practices in some Member States had an adverse impact on the environment and animal welfare (Europa, 2012).

The first significant reform of the CAP saw the introduction of milk quotas in 1984. Quotas were a means to control milk production and overall EU expenditures on agriculture. Each country got a quota of the amount of milk, which they were, allowed produce. Quotas restricted member countries on the amount of milk that they could produce through very large fines for excess production. Quotas stabilised production however 10% still had to be exported outside EU(Europa, 2012).

There was a further reform of the CAP in 1992 referred to as the MacSharry reform. This saw the introduction of direct payments. Substantial cuts were made in the level of support prices for products; to counteract this, income support payments linked to

production were made directly to farmers to compensate them for the price cuts. In recent years environmental objectives, landscape preservation, the viability of rural economies and their cultural heritage, food quality and animal health and welfare standards have become prominent issues. This is reflected in reforms such as Agenda 2000, the Luxembourg Agreement in 2003 and recent policy adjustments mainly Healthcheck 2008. In these reforms there were further price cuts applied to intervention prices and decoupling of price supports (bundling of all production-linked payments into a single farm payment to be paid to farmers on the basis of their historic entitlements during the period of 2000-2002). In the most recent reform (Healthcheck 2008) it was decided that milk quotas would be abolished in 2015 (Department of Environment, Food and Rural Affairs, 2012).

The Irish dairy industry has developed strongly since Ireland's entry to the EU in 1973. The industry has developed an extensive infrastructure both in Ireland and overseas. A summary of the reforms to date and the main points from each reform is provided in Figure 3.1. The next section examines the evolution of the dairy industry in Ireland.

Figure 3. 1:The CAP: Reforms to Date

1973: Ireland joins EEC	1984: Introduction of milk quotas	1992: Mac Sharry Reform	2000: Agenda 2000	2003: Luxembourg Agreement	2008: Health Check
Price Support -CAP was saviour to Irish farmers on Entry to EEC - Productivity improved - EU agricultural markets stabilised - Income support for Farmers	Production control - Butter mountains in EU - Reduced surpluses - Negative environmental impacts - Quotas introduced to control production - Reduced international friction	Price Cuts and compensation Direct payments were based on the area on which certain crops were planted. In order to be eligible for these payments farmers also had to set aside a certain amount of their land and limit the amount of agriculture per hectare.	More Price Cuts and second pillar of CAP formed - 15% cut in intervention prices for butter and skimmed milk powder in three steps starting 2005-2006 - More emphasis on measures for rural development and the environment (second pillar of CAP)	Single Farm Payments - Decoupling of single payment from production - Cross compliance: Payment linked to environmentally friendly production methods - Modulation: Reduction in direct payments for bigger farms to finance new rural development policy - An extra 10% cut in intervention price for butter over 4 years (compared with agenda 2000)	Phasing out milk quotas - 1% increase in quotas every year from 2009-2010 to 2013-2014 - Elimination of quotas in 2015 - Decoupling of support

Source: Own diagram

3.3. History of the Irish Dairy Industry

In the Early 19th century Ireland was the world's leading exporter of dairy produce, in particular butter. Dairy farming was concentrated in Munster (in particular Limerick, north Kerry, north and north-west Cork and west Tipperary), and in southwest Ulster and adjoining parts of Leinster and Connacht (in particular Cavan, Monaghan, Sligo and Roscommon) (Breathnach, 2000). Production of butter occurred at the farm level. Butter was then sold onto local merchants, who sold the butter onto merchants at ports. Butter was exported mainly to the UK. The introduction of the centrifugal separator in the late 19th century saw the movement of dairy processing to centralised plants, which were called creameries. The early growth in the dairy processing industry resulted in the establishment of a creamery in almost every town and village in the dairying regions of the country, as proximity to a perishable and bulk raw material such as milk is a very important locational determinant. Creameries were both privately and co-operatively owned. By 1906, there were 800 creameries in Ireland (Table 3.1) (Daly, 1991). The creamery system also had a positive impact on the quality of life in rural Ireland, it acted as a meeting point for people in communities where they could discuss current affairs.

Table 3. 1: Distribution of creameries by province, 1906

Province	Proprietary	%	Co-operative	%	Total
Munster	365	76.5	112	23.5	477
Ulster	28	14.7	162	85.3	190
Connacht	16	26.2	45	73.8	61
Leinster	20	35.7	36	64.3	56
Ireland	429	54.7	355	45.3	784

Source: Daly, 1991

The slump in agricultural prices after World War I created very difficult circumstances for the creamery sector. The newly-independent Irish Government stepped in via the establishment of a statutory authority (the Dairy Disposal Company, DDC) with responsibilities to rationalize the industry, effectively creating a joint state-owned and co-operatively-owned national dairy sector (Breathnach, 2000). Also, in 1928, the State introduced a licensing system, which controlled the establishment of new creameries. The DDC had a profound impact on the Irish dairy industry. Apart from the virtually complete elimination of the private creamery sector (due to the lower tolerance of the private sector to the low-profit or loss-making situations which resulted), the DDC had overseen a reduction in the number of co-operative creameries from 336 to 215 between 1920 and 1940 (Breathnach 2000).

After a decade of relative stagnation in the 1950s, the Irish dairy industry entered a phase of rapid expansion in the 1960s. The State became more actively involved in promoting growth, investment and change in the industry as they tried to prepare the industry for membership of the EU. Improvements in technology also facilitated milk to be transported longer distances. A number of sectorial studies were carried out in pursuit of this objective; one carried out in 1963 by Knapp recommended the amalgamation of dairy co-operatives into larger groups in order to achieve economies of scale and specialisation. Larger processing plants were also required in order to absorb the growing output of milk that resulted from new Government supports: national milk output rose from 480 million gallons in 1960 to 740 million gallons in 1973. It was also important to diversify processing away from butter, which was the sole product of the great majority of creameries, to alternative products such as cheese and milk powder. (Breathnach 2000). Analysis shows that 80% of creameries in Munster were within six miles of each other, while improvements in transport and roads had long made such proximity redundant. Taking on board the remit recommended by Knapp, the Irish Agricultural Organisation Society (IAOS) in 1966 published detailed proposals for the reorganisation of the dairy industry from 192 to 19 units. The idea was to amalgamate neighbouring plants therefore the milk supply would gravitate to the processing plant nearest to the primary producer. The amalgamation process took off and the 192 units were reduced to just 46 by 1978. However, a geographical patchwork of milk supply territories emerged rather than the rational and compact geographical units that were planned. Many co-operatives were resistant to

amalgamation as they feared local job losses and also they did not want to lose control of their co-operatives especially to their rivals (Breathnach, 2000).

With the introduction of milk quotas in 1984, a limit was placed on the expansion of milk production and consequently on the scope for expansion for dairy processors. Against this background and with the increasing globalisation of economic activities, overseas expansion (particularly in the UK and the US) through acquisition of existing facilities has been a principal focus of the larger processors in the Irish industry. Turning to change within Ireland; expansion was only possible by merging or acquiring other processors (O' Connell *et al*. 1997). In 2004, the three largest cooperatives (Kerrygroup, Glanbia, and Dairygold) accounted for approximately 67% of Irish milk intake.

At the same time as making these acquisitions, some Irish cooperatives were restructuring their capital bases. This has involved these cooperatives establishing holding companies to manage and own downstream processing operations. At one level the development of these hybrid cooperative-private capital businesses responded to desires to raise equity in a situation where farmers were unable or unwilling to provide capital. At another level however it responded to a general bias in capital markets and in management circles against cooperatives (Breathnach, 2000).

In January 2012 as a result of rationalisation and amalgamation, the industry has gradually concentrated into a tiered structure. Geographically, the result is an

industry dominated by three large processors located adjacent to each other in a band running through mid-Munster and south Leinster which is the heartland of dairy farming in Ireland. Many of the larger processors have more than one processing site in this region, with liquid milk plants also located in the main urban centres outside the region. The three large processors are; Glanbia, Dairygold and Kerry. Between them they have nine processing plants. The second tier of processing companies is divided between the North East (the second dairying region in Ireland), the West (a region relatively new to dairy farming) and the South (O'Connell *et al.* 2007). Processors in the North East include Lakelands and Town of Monaghan. Connacht Gold and Arrabawn process most of the milk in the West. Other dairies in the South are Carbery, Newmarket, North Cork, Boherbue, Tipperary and Wexford creameries. In 2008 Ireland had in total 10butter plants, 11 powder plants, 9 cheese plants and 7 casein plants. There is intense rivalry among dairy processors in Ireland (Irish Dairy Board, 2009). Vigorous local competition also pressures domestic firms to look abroad in order to grow, they are forced to look outward in the pursuit of greater efficiency and higher profitability. This is happening with Irish dairy processors, they are currently present in America, Asia, Middle East and throughout Europe. A summary of the evolution of the Irish dairy processing sector is provided in Figure 3.2.

Figure 3.2: Evolution of Irish processing sector

Early 19th century: Ireland was world's leading exporter of dairy produce (butter)

Butter sold to local merchants→ blended together→ exported at ports

↓

Late 19th century: Introduction of creamery system (centrifugal separator)

Processing moved to factory (privately-owned +proprietary creameries)

↓

1906: 800 creameries

Butter produced from cream, skim milk used on farm for feeding calves and pigs

Creamery created a new social interaction pattern for rural Ireland

↓

1927: Slump in agricultural prices and frequent milk wars

Establishment of Dairy Disposal Company

Aim: to close down any insolvent dairies and regulate establishment of new

creameries

↓

1940's: 215 creameries: mostly cooperative creameries

Co-operation between co-operatives to diversify away from butter

Expanding product mix: cheese + chocolate crumb

↓

1960's: rapid expansion+ government supports

Milk output rose from 480m gallons in 1960 to 740m gallons in 1973

Knapp report 1966: recommended amalgamation of co-operatives from 192 to 19

units

↓

1964: First major amalgamation: to form Waterford co-op

↓

1978:46 co-ops **1990**: 35 co-ops **2008**: 23 co-ops

Industry not efficient from economic or geography point of view

Source: Own diagram

3. 4 Milk Production Sector and Dairy Processing Sector

The following section examines the production and processing sectors in Ireland in detail.

3.4.1 Milk Production Sector

<u>Seasonality of Milk Production Sector</u>

With the exception of liquid milk producers, Irish dairy farmers have continually adjusted the date of calving, so that through compact calving, the majority of the herd calves during spring to maximise the quantity of grass in the lactating cow's diet. While this maximizes production cost efficiency from a grass-based production perspective, it also results in increasing supply levels in the peak months of April to August inclusive(Shalloo *et al*. 2004). Ireland's main EU competitors do not have a corresponding seasonality pattern. This seasonality leads to poor capacity utilization in the Irish processing sector, adding to the operating costs of processors (Promar and Prospectus, 2009).

Seasonality also causes a mismatch between market demand, which for many products is relatively constant all year round. Crucially, this seasonality also restricts the types of products that can be produced, and continues to act as a significant constraint on the Irish industry. The inability to store short shelf life products from summer to winter limits the options available in terms of the overall product mix, effectively locking processors into making storable products such as butter, hard cheese, milk powders and casein (Quinlan *et al.* 2012). The predominance of grass-based production, and the seasonality of that production in Ireland, results in inconsistency and variability in the milk produced. This inhibits the processors as they attempt to meet the demands of their customers for standard products all year round. Fundamentally, when processors cannot produce a consistent product year round, they face major problems selling certain products where consistency of texture, flavour, functionality and year round supply are essential (Promar and Prospectus, 2009).

Dairy Farmers

Ireland has a long and successful tradition as a major producer of quality dairy products. The grass based production system has provided significant competitive advantages in terms of production costs and the naturalness of Irish dairy produce. Irish dairy farmers are considered to be both technically competent and commercially focused, with major changes having taken place in the structure of the industry at production level (Promar and Prospectus, 2003).

There has been a continual reduction in the number of producers involved in milk production in Ireland since the introduction of the quota regime in 1984 (Figure 3.3) (Department of Agriculture, Food and Fisheries, 2011).

Figure 3. 3 Number of active milk quota holders in Ireland (1994-2010)
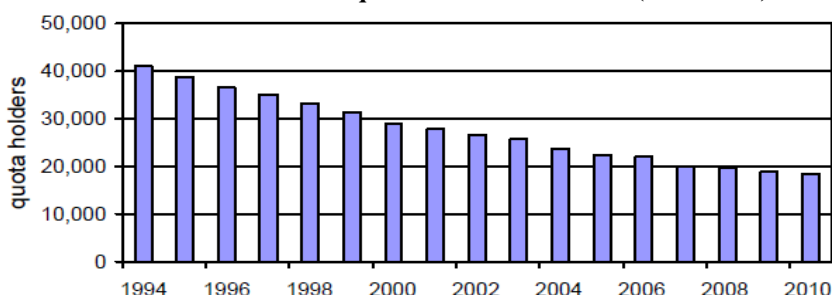
Source: Department of Agriculture, Food and Fisheries, 2011

Figure 3.4: Number of dairy cows in Ireland ('000)
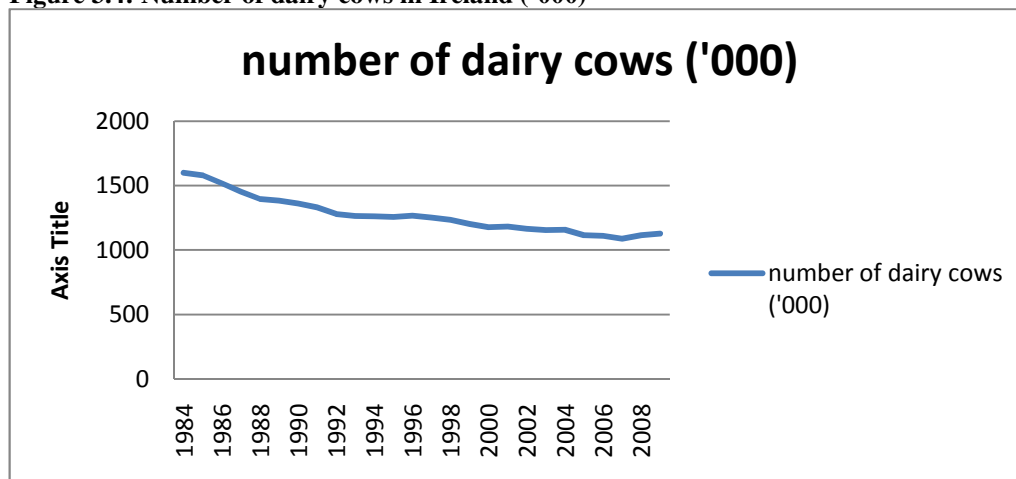
Source: CSO, 2011(a)

There has also been a reduction in the number of dairy cows since the introduction of the quota regime (Figure 3.4) (Central Statistics Office, 2011(a)).

Figure 3.5: Milk production in Ireland in million litres
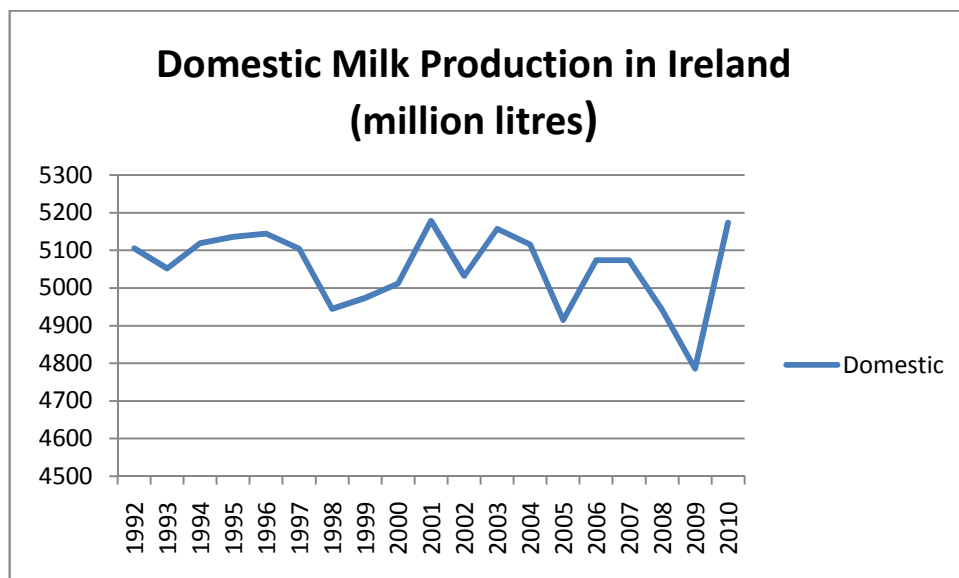
Source: CSO, 2011(b)

Even though there has been a reduction in the number of farmers in Ireland (19,000 farmers in 2009) and the number of dairy cattle, milk production has remained relatively constant over the years (Figure 3.5) (Central Statistics Office, 2011(b)). Therefore the size of dairy herd per farmer has increased.

Irish milk production sector compared with some main competitors

Milk production in New Zealand, USA and Denmark is more concentrated than in Ireland. In Ireland, the average number of dairy cows per farm is 57, in Denmark the figure is 140, in USA there are on average 172 cows per farm and in New Zealand there are about 400 cows per farm (International Dairy Federation, 2011).However, in Finland there are only 28 dairy cows per farm. Milk production in Ireland represents 0.9% of worldwide milk production, compared with 14.5% from USA and 2.9% from New Zealand. Milk

production in Denmark and Finland represents a smaller proportion of worldwide milk

production, 0.8% and 0.4% respectively (International Dairy Federation, 2011)(Table 3.2).

Table 3. 2: Milk production across various countries

	Milk Production('000 tonnes)	% of worldwide production	Number of farmers	Number of dairy cows ('000)	Average quantity of cows per farm
Ireland	5,437	0.9%	18,300	1027	57
USA	87,461	14.5%	53,127	9117	172
New Zealand	17,143	2.9%	11,700	4,680	400
Denmark	4,965	0.8%	4,120	573	140
Finland	2,334	0.4%	10,586	287	28

Source: International Dairy Federation, 2011

Costs of milk production in Ireland are lower than our European competitors such as the
Netherlands and Denmark. However production costs are higher than that in New Zealand
and Australia (Figure 3.6) (Teagasc, 2008). Their lower production costs may be due to the
larger herd sizes.

Figure 3.6:Milk production costs
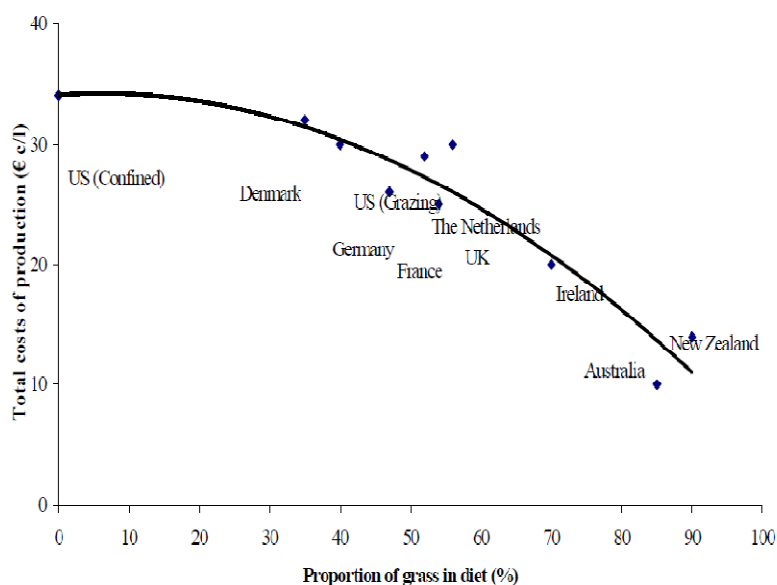
Source: Teagasc, 2008

3.4.2 Processing sector in Ireland

Utilisation of milk supply

In Ireland, approximately 10% of the milk supply is utilised for liquid milk and the remaining 90% is used in the manufacture of a range of dairy products. Butter and skim milk products account for approximately 60% manufacturing milk utilisation, Cheese and whey products account for approximately 30% and whole milk powder account for 10% (FAOSTAT, 2011) (Figure 3.7).

Figure 3. 7: **Manufacturing utilisation 2007-2009 in Republic of Ireland**
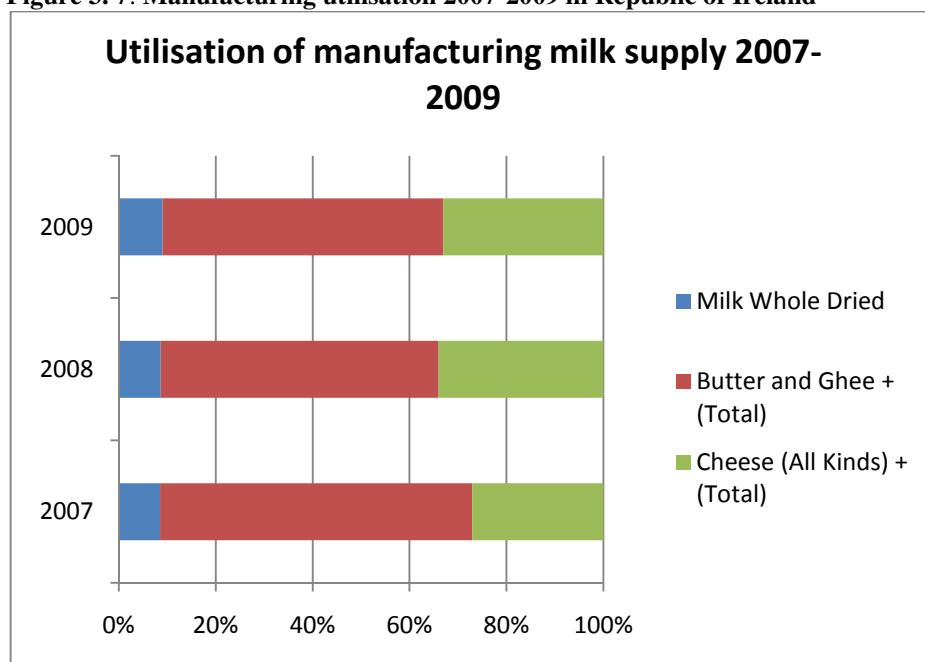
Source: FAOSTAT. 2011

Sales of dairy products

Ireland has 4% of the EU milk quota EU15, but Ireland has only 1% of the EU15 population. Ireland has the highest self sufficiency rates for dairy products in Europe (figure 3.8) (Central Statistics Office, 2011c).

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Figure 3.8: Self sufficiency in dairy products in Ireland (2010)

Self Sufficiency (%)

Legend:
— Cheese — Butter
— Cream   — Milk Powder
— Drinking Milk & Buttermilk
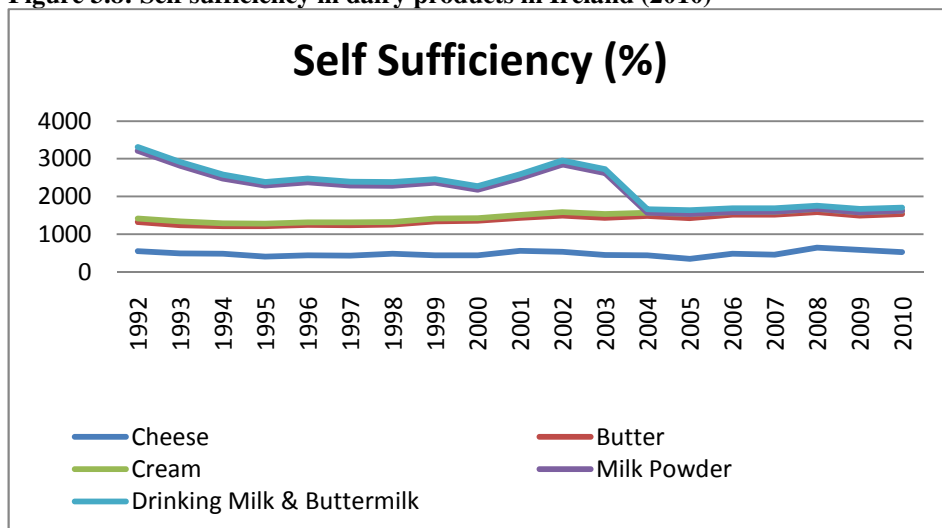
Source: CSO, 2011a

Therefore, Ireland has a very significant dairy product surplus. In Ireland; 80% of dairy products are exported; in 2010 50% were exported to the EU and the remaining 50% to North America and others (IDB, 2011) (figure 3.9).

Figure 3.9:Destinations of Irish exports (2010)

By Destination
- Britain (2009:25%)
- Mainland Europe (2009:26%)
- North America (2009:42%)
- Rest of the World (2009:7%)

40% 10% 22% 28%
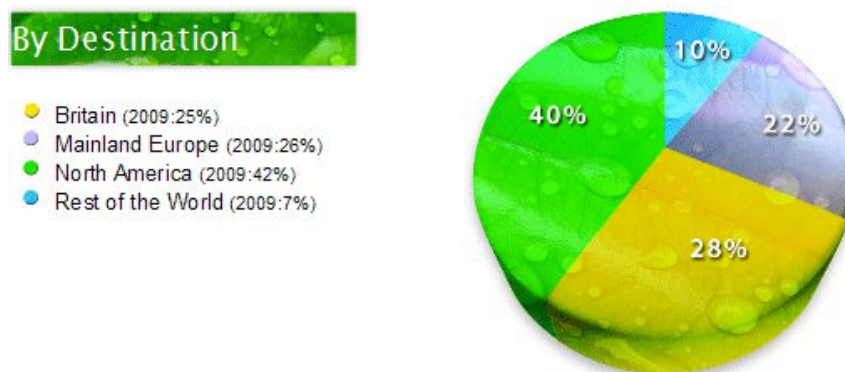
Source: Irish Dairy Board, 2011

Irish milk processing sector compared with its main competitors

While Fonterra (New Zeland), Valio (Finland) and Arla (Denmark) process 80% of their home country's milk supply in contrast Glanbia (Ireland) and Dean Foods (United States of America) process 25% and 15% of the milk supply in their home countries respectively. Therefore, Fonterra, Valio and Arla process higher volumes of milk compared with

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Glanbia. This illustrates the multiplicity of fragmented processors in Ireland and the slower rate of restructuring that has taken place at processing level.

Arla, Fonterra and Valio are owned 100% by dairy co-operatives whereas Glanbia and Dean Foods are PLC's. (Table 3.3)

Table 3.3: % of Home market milk supply processed, quantity of milk processed and ownership structure of dairy processing companies

	% of Home Market Milk Supply Processed	Quantity of milk processed (million litres)	Ownership Structure
Glanbia (Ireland)	Processes 25% of Ireland's milk supply	1,250	PLC
Arla (Denmark)	Processes 80% of Denmark's milk supply	8,243	Co-operative
Fonterra (New Zealand)	Processes 96% of New Zealand's milk supply	13,860	Co-operative
Valio (Finland)	Processes 79% of Finland's milk supply	2,000	Co-operative
Dean Foods (United States of America)	Processes 15% of USA's milk supply	13,200	PLC

Source: Company Websites

3.5 SWOT Analysis of the Irish Dairy Industry

The next section will provide a SWOT analysis of the Irish dairy industry. It will examine the strengths and weaknesses of the Irish dairy industry and also identify the existing opportunities and threats. This analysis was completed in order to help the reader gain a better understanding of the current position of the Irish dairy industry. This was complied by conducting a review of the relevant literature and reports.

3.5.1 Strengths

- Irish dairy farmers are considered to be both technically competent and commercially focused (Promar and Prospectus, 2009)

- Ireland has a comparative advantage in the production of milk

  This is due to the grass-based feeding system for its dairy herd. This is facilitated by the country's moderate climate, which makes it very suitable for grass production. The grass-based feeding system has been more cost efficient than the mainly grain-fed systems used in continental EU countries (Promar and Prospectus, 2009)

- Known as a natural producer of dairy products

  The pasture-based feeding system has the advantage of being able to be portrayed as a more natural production for dairy cows and milk production. Ireland has been able to build on this to develop an industry in which over 80% of its processed output is exported (Promar and Prospecus, 2009)

- Irish processors have become international companies with instant name recognition for dairy product buyers overseas

- Direct access to the EU market (480 million people), the largest and most affluent consumer market in the world

- World leader in R+D of important dairy ingredients. In 2008,a national functional foods research centre opened in Cork, Ireland, it is funded by government and industry (Promar and Prospectus, 2009)

3.5.2 Weaknesses

- The seasonality of milk supply is a major feature of production in Ireland

  With the exception of liquid milk producers, Irish dairy farmers have adjusted the date of calving, so that through compact calving the total herd calves around the

time of lowest milk production cost. While this maximises production cost efficiency from a grass-based production perspective, it also results in increasing supply levels in the peak months of April to September. This seasonality restricts the types of products that can be produced, and continues to act as a significant constraint on the Irish industry. If seasonality remains it will continue to constrict the ability to produce certain products that require year round milk supply (Quinlan *et al*., 2011)

- Poor capacity utilisation in the processing sector (approx. 60%)

  This is a result of seasonality; it leads to higher operating costs of processor
  (Promar and Prospectus, 2009)

- Fragmented processing industry

  Four dairy companies process 80% of milk production in Ireland. However in New Zealand, Netherlands and Denmark only one company processes 80% of milk production. The larger processors are able to take advantage of cost savings as a result of economies of scale (Promar and Prospectus, 2009).

- The rate of increase in scale of milk production has been significantly lower than that of our main competitors over the past 20 years (Promar and Prospectus, 2009)

- Lack of capital

  As a result of the fragmented industry there is a lack of capital available for activities such as R&D (Promar and Prospectus, 2003)

- 60% of products produced in Ireland are commodity type products which typically have low margins (Promar and Prospectus, 2009)

3.5.3 Opportunities

- Role for smaller niche processors

Smaller niche processors can also play an important role in the industry, these processors can succeed through innovation and specialisation

- Increasing R&D and product innovation

Given the higher prices that can be achieved in EU markets through effective market segmentation and customisation, product differentiation, branding, etc., to compete effectively the Irish industry will require a greater market and customer focus. A key element in building this market focus is the requirement for continuous re-investment through research and development and product innovation

- Abolition of milk quotas

In 2015 milk quotas will be abolished. Since 1984 quotas capped milk production. Previous to this Irelands' milk production rose by about 6% each year (Teagasc, 2008). By restricting EU production competitors fill other growing markets; therefore the EU has lost its dominant position in world markets. Quotas also hindered structural development at farm level and increased cost of milk production. The abolition of quota will now allow Ireland to significantly increase national milk supply. In EU 15 there are only six countries expected to increase milk production in line with quota increases. Ireland is one of these countries (Teagasc, 2008)

- ICOS, the voice if the Irish Co-operative movement, is pushing for radical change in the dairy sector. They are looking at ways of rationalising the number of plants and processors involved in production of base products thus eliminating duplication, cost inefficiencies and unnecessary overheads (Irish Farmers Journal, 2009)

- Development of strong brands

Brands are now more essential than ever for communicating with consumers. It is often the best means of holding market share and has the best potential for growing it

- Market opportunities in the following countries: Asia, Africa and Central America (including Mexico) (International Dairy Federation, 2011)

- Increased cheese output

  The huge depth of technological know-how for cheddar coupled with the use of existing plants could be used to pursue such a strategy

- Growing demand for food with specific health benefits

  Dairy products have an inherently good nutritional image and are uniquely suitable from a technological viewpoint. Consumers are keen to look after their health, but will be reluctant to spend too much in the process. The fortification of other dairy products with vitamins, minerals or anti-cholesterol plant sterols could, however, prove popular selling points for many new products. These will be targeted not only towards a general audience paying greater attention to their health, but more frequently niche groups such as children or older consumers (Euromonitor, 2011)

- Growth in demand in dairy products with perceived health benefits

  Consumers are demanding products lower in fat to traditional dairy products such as full-fat milk and cream. Consumers are also demanding products with specific functional ingredients such as omega 3 essential fatty acids, fibre, plant sterols, enzymes and isoflavones (Euromonitor, 2011).This trend is also sweeping Ireland. The Irish consumers are demanding products with health benefit

- Growth in demand for 'convenient' dairy products

  Convenience, driven by the acceleration of consumer lifestyles, is also altering the nature of demand for dairy products. The main causes of this acceleration are the growth of single-occupancy households due to family breakdown and later

marriage, longer working hours and a higher proportion of families with both parents working outside the home. The impact of these changes on eating habits includes a reduction in the time spent preparing food, a reduction in the number and frequency of families sitting down together to eat, fewer people eating a proper breakfast and an increase in informal eating habits such as snaking and eating on the move (Euromonitor, 2008). This trend also holds true in Ireland

- Growth in demand for products for ageing population

  Across the Developed World, birth rates are falling and life expectancy is increasing, a trend sometimes referred to as the "greying" of the population. Products with anti-ageing properties and those promoting good digestion will do particularly well in this segment. Products containing calcium, omega 3s, which may slow the onset of mental degeneration caused by Alzheimer 's disease, and probiotic yoghurts, are likely to be particularly attractive to this group (Euromonitor, 2011). In Ireland a growing proportion of the population is ageing, hence these consumers are putting pressure on dairy processors to produce what they demand

- Rising global dairy prices

  The gap between world and EU dairy prices has been closing over time due to changes in EU policy and rising world prices. As a result, world (New Zealand) milk prices are converging on EU and US milk prices (Teagasc, 2011). While volatility concerns remain, Rabobank expects a general trend of relatively high product and milk prices because the cost of producing exportable milk will remain high (Irish Farmers Association, 2012)

3.5.4 Threats

- Ageing plant in need of replacement in the medium term

There are indications that another round of major capital investment may be required to replace existing plant in the medium term. Over 70% of the processors surveyed by Promar and Prospectus in 2003 indicated that part of their current technology was either in need of upgrade, or only adequate for current needs (Promar and Prospectus, 2009). Also as a result of quota abolishment there will be a need for additional processing facilities post 2015. There is currently a debate within the industry concerning who should pay for the new facilities

- Increasing costs and compliance requirements placed on processors to meet environmental, food safety and quality demands

Processors are likely to continue to face increasing pressure from numerous sources to improve their quality assurance systems so that they will be able to meet the increasing levels of environmental and food safety standards. Consumers are now demanding that companies measure the carbon footprint of their products. Processors will need to make significant investments, imposing a significant cost that will be difficult to absorb

- Price volatility

With the elimination of quotas dairy companies will need to deal with price volatility (tendency of markets to fluctuate sharply and frequently). Approximately, 7% of dairy production is traded on the international marketplace, as a result any changes in milk production from key dairy producing countries can impact trade and prices internationally (International Dairy Federation, 2011)

- During the current economic recession people are trading down i.e. they are looking for cheaper substitutes (rice, wheat) for dairy products (Euromonitor, 2011)

- Potential Food scares

There is always risk of foot and mouth disease, BSE etc.

- Global recession

The global economy is unstable; consumers have reduced their spending on non-essential and luxury items. Since this category carries products such as chilled and shelf-stable desserts, chilled snacks and cream, as consumers cut back on spending on such non-core food items, the category as a whole suffered in value terms (Euromonitor, 2011)

3.5.6 SWOT summary

The Irish dairy industry is known as a natural producer of dairy products, producers are technically competent and Irish processors sell their products worldwide. However, the processing sector is fragmented compared with international competitors and operating costs in Ireland are higher due to poor capacity utilisation. However, as a result of impending quota removal the industry is now at a crossroads, the industry has the potential to expand substantially. In order to achieve this, the Irish processing sector will need to examine the current industry structure in terms of the number of players and the type of products it produces. In the face of increasing competitive and market challenges the processing sector cannot afford to stand still.

3.6 Conclusion

The dairy industry will undergo considerable change in the years ahead because of changes in European Union Common Agricultural Policy (Hennessy and Thorne, 2006).The Irish dairy industry has had a very successful past. The purpose of this chapter was to give the reader an insight into the current structure of the Irish dairy industry. Chapter 4 examines location theories and operational techniques applied to location problems.

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Chapter 4: Location theories and applications of operation research-based techniques to location problems

4.1 Introduction

Where to locate a business is a crucial decision because this will have an important impact on profits. Typically businesses will seek locations that maximise revenues and minimise costs. Simple location decisions are rare in agriculture; most agricultural location problems are complex. The theory of optimal location has interested economists since the early 19th century. Location theory tackles the questions of what economic activities are located where and why. Numerous factors, which affect location, are considered such as localized materials and services, however most weight is placed on transport costs. Location decisions have also interested operation researchers. Operation researchers use analytical techniques to improve decision making and they have demonstrated significant efforts to apply, adapt, and even advance theoretical location models to fulfil the field's specific needs.

The purpose of this chapter is to give a brief overview of location theories. This chapter will also review the applications of operation research-based techniques to location problems.

4.2 Plant location Theory

Insights into location theory can be grouped intro three types: classical, regional science and new economic geography. Von Thunen (1826) , Launhardt (1882), Weber (1909), Hotelling (1929) and Losch (1954) contributed towards classical theory of location. Isaard (2003) provided valuable insight towards regional science and Krugman was the founder of new economic geography. A brief initial overview of the evolution of the theory of optimal location over time is shown in Figure 4.1.

Classical location theories can be broken into three stages: the first stage is called least cost theory; the second is called interdependence theory and the final stage is called maximum profit theory of location (Al-Nowaihi and Norman, 1992). Von Thunen (1826) developed the general framework for the economic analysis of location theory. He was primarily concerned with the aggregate analysis of agricultural location. He utilized the "least-cost" approach to determine the ideal location for agricultural products. Launhardt (1882)provided very significant contributions as he explained the differences in the location of industry by variations in cost and demand factors at alternative locations. Weber (1909 and 1929) developed a comprehensive theory in 1909 for the location of manufacturing activities. According to Weber three factors: transportation costs, labour costs and agglomeration forces should be used to determine the optimum manufacturing site (Al-Nowaihi and Norman, 1992). Many location studies still use the Weberian theory to better understand the decision making process. Hotelling (1929) established the foundation of locational interdependence. He claimed that firms would tend to locate toward the centre of the market area rather than disperse. He introduced the notion of competition in location decisions (Al-Nowaihi and Norman, 1992). Losch (1954) presented the maximum-profit theory in 1939. Losch's analysis assumes a free economy where the optimum placement of the individual enterprise in different sites can be determined from the cost and demand curves (Al-Nowaihi and Norman, 1992).

Isard (2003) provided the theoretical basis of a new theory called regional science. He attempted to develop a general theory of location by unifying the Thunen, Weber and Launhardt theories. His theory was based on the theory of input substitution (Al-Nowaihi and Norman, 1992).

Krugman (1991) renewed economists' interest in location theory in 1991. He founded what some term 'new economic geography'. His theory on industrial location was based on the interaction of three factors: increasing returns of scale, transportation costs and demand. According to Krugman (1991) because of economies of scale, it was not profitable to spread production throughout numerous factories instead production should be concentrated in a few factories(Al-Nowaihi and Norman, 1992).

A synopsis of the main location theories is given in Figure 4.1.

4.2.1 Classical location theory

Von Thunen

It is probably fair to say that Von Thunen (1826) was the first to recognize the importance of space and location in economic theory. Von Thunen's work was aimed at describing the influence of location factors on agricultural land use. The following are some assumptions of the Von Thunen model of agricultural land:

Figure 4. 1: Review of theory on optimal location

Von Thunen's (1826)

Investigated the impact of the distance from the market on the use of agricultural land

↓

Launhardt (1882)

Explained the location of industry as the decision resulting from two variables; differences in cost and demand at alternative sites.

↓

Weber (1909)

Formulated a theory of industrial location in which an industry is located where the transportation costs of raw materials and final product is at a minimum

↓

Hotelling (1929)

Hotelling reasoned that firms would concentrate on the mid-point of the entire market area; at this point buyers at extremities can be supplied thus not allowing competitors to enjoy location advantages. His theory became known as locational interdependence and market areas.

↓

Losch (1954)

Losch theory falls under the theory of maximum profit plant location. He states that the optimum factory location depends upon the firms' costs of production at different sites and the corresponding market area, which it can control from each site.

↓

Isard (1969)

Attempted to develop principles for a general theory of location by combining the work previously done by Thunen, Weber, Losch, and other theorists.

↓

Krugman (1991)

His model is based on the interaction of three factors: increasing returns of scale, transportation costs and demand.

↓

Porters Cluster Theory (1998)

Geographic concentrations of interconnected companies, specialized suppliers, service providers, and associated institutions in a particular field arise because they increase the productivity with which companies can compete.

Source: Own diagram

- The city was located centrally within an "Isolated State" which was self-sufficient and had no external influences.

- The Isolated State was surrounded by an unoccupied wilderness.

- The land of the State was completely flat and had no rivers or mountains to interrupt the terrain.

- The soil quality and climate were consistent throughout the State.

- Farmers in the Isolated State transported their own goods to market via oxcart, across land, directly to the central city. Therefore, there were no roads.

- Farmers acted to maximize profits (Samuelson, 1983).

According to Von Thunen (1826) in a uniformly fertile plain, with a single population cluster in its centre, prices and demand functions are fixed and known for all agricultural products. The production functions for all these agricultural products were identical at all points in this plain, and all production factors (e.g. labour, fertilisers) were available at a given location at prices that linearly increase with distance from the market. Transport cost depended on the distance from the market and the different kind of products. The gain from farming per unit area (location rent) decreases with increasing distance from the market. The minimum price of a commodity is calculated by location rent, transport costs and fixed production costs - the profit is then the difference between the costs and the fixed market price. In an Isolated State Von Thunen (1826) hypothesized that a pattern of rings around the city would develop. There are four rings of agricultural activity surrounding the city. Dairying and intensive farming occur in the ring closest to the city, as they must get to market quickly, they would be produced close to the city. Timber and firewood, which was then used for fuel/cooking and building materials was produced in the second zone. The third zone consists of extensive fields crops such as grains for bread. These products have a longer shelf life than dairy products and are lighter than wood to transport. Ranching is located in the final ring surrounding the central city. Animals can be raised far

from the city because they are self-transporting. Animals can be walked to the central city for sale or butchering. Beyond the fourth ring land is a free good (Figure 4.2) (Samuelson, 1983).

Figure 4. 2: Von Thunen Model

Central City
Intensive Farming/Dairying
Forest
Extensive Field Crops
Ranching/Animal Products
Matt T. Rosenberg, 1997

Source: Rosenberg, 2011

A limitation of his theory is that it concentrates on the forces governing the use of land and the locations of plant and industries. Most of the literature focuses on the input side of the problem, taking as given various conditions, particularly with respect to prices and demand in the target markets (Rosenberg, 2011).

Launhardt

Launhardt (1882) conceived much of that for which Alfred Weber received credit, prior to Weber's work. Moreover, his contributions are surprisingly more modern in their analytical content than Weber's. This suggests that Launhardt was ahead of his time and simply was not readily understood by many of his contemporaries (Pinto, 1977).

Launhardt explained that the optimal location of an industrial site depends primarily on the location of raw and other materials and the demand for the finished product. Therefore, the

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two most important variables according to him were differences in cost and demand at alternative sites. Other factors such as real estate prices, education of the workforce, or landscape, should be considered only after a location is found that minimizes the transportation costs. Launhardt (1832-1918) developed the location triangle and the weight triangle. He developed the location triangle by combining a principle of nodes, the pole principle and Varignon's frame (Pinto, 1977). This model was used to demonstrate the impact of the forces of attraction of three (in a polygon more) reference locations (originally 2 raw material locations and one market) vis-a-vis the (dependent) optimal (least-transport-cost) location of a processing plant.

Whether Weber was familiar with Launhardt's publications remains unclear. Regardless, location theoretic thought blossomed only after Weber's book was published (Pinto, 1977).

Weber

In the Weber theory buyers are concentrated in an area, sales prices for all competitors' commodities are equal, and therefore the only way a firm can increase profits is by minimising costs (Melvin and Greenhut, 1957). Therefore firms substitute costs at different locations with the aim of finding the site with lowest cost. Weber's theory, called the location triangle, sought the optimum location for the production of a good based on the fixed locations of the market and two raw material sources, which geographically form a triangle (Melvin and Greenhut, 1957) (Figure 4.3).

Figure 4. 3: Webers's Triangle
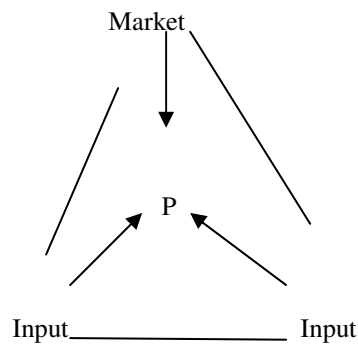
Goal: Minimize transportation costs

Source: Melvin and Greenhut, 1957

Weber (1909) sought to determine the least-cost production location within the triangle by estimating the total costs of transporting raw material from both sites to the production site and product from the production site to the market. The weight of the raw materials and the final commodity are important determinants of the transport costs and the location of production. Commodities that lose mass during production can be transported less expensively from the production site to the market than from the raw material site to the production site. The production site, therefore, will be located near the raw material sources. Where there is no great loss of mass during production, total transportation costs will be lower when located near the market. Once a least-transport-cost location had been established within the triangle, Weber (1909) attempted to determine a cheap-labour alternate location. First he plotted the variation of transportation costs against the least-transport-cost location. Next he identified sites around the triangle that had lower labour costs than did the least-transport-cost location. If the transport costs were lower than the labour costs, then a cheap-labour alternative location was determined (Britannica, 2011).

Assumptions of Weber's theory:

➢ There was a uniform transport system, culture, climate, economic & political situation

- Not all materials were evenly distributed across the plain

  o Ubiquitous – were evenly distributed

  o Localised – not evenly distributed, may be gross or pure

➢ Size and location of markets are fixed

➢ Transport costs were a function of mass & distance moved

➢ Labour found at fixed locations with the same rates and skills

➢ There was perfect competition so no industry would influence prices and revenue would be similar.

Some of the limitations of his theory include the following:

➢ Neglect of market demand. Market demand is variable and is affected by the location of competitors (Greenhut, 1952).

➢ Neglect of competition

➢ No scale effects in transport and production

Hotelling

Hotelling (1929) illustrated the impact of demand upon the location decision. Hotelling's price location model is expressed as a two-stage model; firstly firms choose location and secondly they determine prices. Consumers are evenly distributed and each consumer consumes exactly one unit of commodity irrespective of price. A consumer will purchase from the seller whose product has lowest cost (D'Aspremont *et al*.1979). He used two ice cream sellers on a beach as an example. Hotelling showed that in choosing their location they would choose to agglomerate around the market centre and produce identical products, (Al-Nowaihi and Norman, 1992). Hotelling believed that for a time each seller would want to eliminate each other by cutting prices or changing position on the beach. After failing to oust each other, (Since they are equally able to compete) they would agree

to compromise by agreeing to sell at the same price at different locations therefore each would have a 50% share of the market. They would position themselves at the centre of the two market areas. If another seller entered the market a similar process would take place (Hotelling, 1929).

As with all models it made certain assumptions

- ➢ Buyers of commodities are uniformly distributed throughout the market
- ➢ Market served by two competing entrepreneurs, with equal production costs and capable of supplying the entire market, producing two identical products.
- ➢ Infinitely Elastic demand
- ➢ Costs of production are the same everywhere
- ➢ Transport costs are paid by the buyer to avoid discrimination by the seller
- ➢ Transport costs are independent of quantity
- ➢ Entrepreneurs capable of relocating without cost. The only factor affecting preference of one seller over another is price plus transport cost (Hotelling, 1929).

One problem with this theory was that the initial assumptions were seen as unrealistic and very rare in business.

Losch

According to this theory individual buyers and sellers are not atomistic. Individual sellers have the right to set prices, these prices have an influence over other sellers, and other sellers act and react with respect to prices and location. Losch (1954) states that the optimum factory location depends upon the firms' costs of production at different sites and the corresponding market area, which it can control from each site (Greenhut, 1952). Each producer maximises gains. All areas are served by at least one firm. All extraordinary profits must disappear under the competitive free-entry assumption, new rivals will

eliminate them. The area served by each seller must be as small as possible. Consumers on boundary lines are indifferent to suppliers at minimum cost. Losch (1954) portrays the hexagonal as the best market area shape; this is determined by a system of equations (Greenhut, 1952). Losch (1954) theory concludes that the optimum plant location is the site at which profits are maximised.

Some attempts have been made to build on the Loschian framework to derive general rules that characterise optimal location in a general equilibrium system. The main obstacles facing this type of investigation are the non-convexities that enter when economies of scale are introduced on the production side. Therefore one is left with a relatively abstract framework that is of limited usefulness in the analysis of industrial location behaviour.

4.2.2 Economic Geography

<u>Isard</u>

Isard (1969)theory was based on the theorists who went before him namely Weber (1909), Von Thunen (1826) and Launhardt (1882). He attempted to develop a general theory. According to Isard, attention should be paid to the geographic distribution of inputs and outputs and the geographical variations in prices and costs. He went on to conclude that firms substitute between inputs (e.g., labour for capital) based on the relative price of the inputs. Isard treated transportation cost as an input. His theory examined the interdependence of industries as suppliers and buyers of each other's inputs and outputs (Isard, 2003).

Outcomes of theory:
  - ➢ Same locational outcome as Weber
  - ➢ More general analysis
  - ➢ Based on accepted theory of input substitution (Isard, 2003)

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4.2.3 New Economic Geography

<u>Krugman</u>

His model is based on the interaction of three factors: increasing returns of scale, transportation costs and demand. Given sufficiently strong economies of scale, each manufacturer wants to serve the national market from a single location. To minimise transportation costs, he chooses a location with large local demand. However, demand will usually be bigger in places where there are more industries. Therefore, there is a circular relation between production and demand, implying that regions that are industrialised first as a result of a historical accident will attract industries from other regions that have less favourable initial attractions (Krugman, 1991).

Features of Krugman's theory:

➢ utility maximising consumers

➢ profit maximizing producers

➢ constant and increasing returns to scale

➢ perfect competition and monopolistic competition

➢ two sectors and two regions

4.2.4 Porter's Cluster theory

Porter (1998) has proposed that today's economic map of the world is dominated by what he refers to as clusters: a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalties and complementarities. Clusters are viewed as encompassing an array of linked industries and other entities important to competition, that include, for example, suppliers of inputs such as components, machinery, and services. Clusters also extend downstream to channels and customers and laterally to manufacturers of complementary products, and to companies in industries related by skills, technologies, or common inputs (Porter, 1998). According to

Porter an industry cluster helps companies to substantially improve their international competitiveness compared to organizations working in isolation. Porter explained that clusters affect competition in three broad ways by firstly, increasing the productivity of companies based in the area; second, by driving the direction and pace of innovation; and third, by stimulating the formation of new businesses within the cluster (Porter, 1998).

Productivity

Being part of a cluster allows companies to operate more productively by firstly increasing the productivity of companies based in the area through efficient access to specialized inputs, services, employees, information, institutions and training programs, secondly by allowing rapid diffusion of best practices amongst companies in the cluster and thirdly by facilitating on-going, visible performance comparisons and strong incentives to improve vs. local rivals (Porter, 1998).

Innovation

In addition to enhancing productivity, clusters play a key role in a company's continuing ability to innovate. In clusters there is a greater likelihood of perceiving innovation (unmet needs, sophisticated customers, combinations of services or technologies), the presence of multiple suppliers and institutions also assists in knowledge creation (Porter, 1998).

New Business Formation

Many new companies grow up within an existing cluster, rather than in isolated locations. This is not surprising because it is often easier to identify perceived gaps in the marketplace, there are lower barriers to entry than those outside the cluster, and there is a significant local market to which the new company can market their products (Porter 1998).

The vast majority of benefits proposed by Porter's cluster model are evident in the Irish processing sector and explain the behaviour of the key industry players over the last few years. Irish milk producers are world class; the industry has access to highly qualified workforce from universities throughout Ireland, the high concentration of processors in Ireland results in vigorous local competition. This competitive landscape has put pressure on dairy processors to improve and innovate.

4.3 Operation research and application of operation research techniques to location problems

Operation researchers have applied, adapted and improved theoretical location models to fulfil the field's specific needs. Location problems tend to be large scale and exhibit the following characteristics: inconsistent from one problem to the next, involve multiple time periods, have conflicting objectives. Operation researchers have used the following operation research techniques to solve practical problems: network algorithms, benders' decomposition, standard MIP packages, branch and bound, enumeration and heuristics (Lucas and Chhajed, 2004).

The following presents various applications of operations research techniques to location decision problems.

4.3.1 Olson model to determine the optimal size of milk-processing plants and optimal distances between plants in a cooperative dairy

In the 1960's in Minnesota the dairy industry was in a period of transition. Small creameries were been replaced with fewer and larger milk processing plants. Management of dairy firms were eager to develop a long run planning program that would help them make decisions on the optimum number and location of future plants (Olson, 1959).

The problem: Minimise total assembly and processing costs of Minnesota dairy firms

Questions: What was the optimum size of the Minnesota dairy plants?

How far apart should they be from each other?

Assumptions:

- Raw material was evenly and adequately distributed over a wide plain

- Volume of milk supply was given

- Milk assembly costs were uniform throughout the area

- Milk was processed into cheese, butter and powder

- Milk powder, butter and cheese received the same price at all locations

- Perfectly competitive market

- Business in question had a co-operative structure (Olson, 1959)

To determine the lowest total cost, milk assembly and processing costs were analysed. Assembly costs were broken into two, fixed and variable. Variable cost included transport driving; according to Olson this was the only component of assembly costs that varied with volume. This variable part of the milk collection cost varied linearly with the weight and the volume of milk collected. Processing costs were calculated for several proposed plant numbers and capacities. Processing cost was assumed to be a polynomial function of the volume processed. The sizes and the interplant distances were calculated using both circular and hexagonal market areas for each plant (Olson, 1959).

Olson modelled the impact of the density of milk production, transportation costs and the ratio of fixed cost to volume on interplant distance (Lucas and Chhajed, 2004).Olson's analysis found that plants with capacity larger than 5,000,000 pounds per day may be optimal (Olson, 1959).

4.3.2 Stollsteimer's model to determine the number, size and location of plants that minimise the combined transportation and processing

In California, a study was carried out on the marketing efficiency of a major pear-producing region, Lake County. It was located in the secluded mountainous area of the northwestern section of California. The specific objective of the work was to determine the number, size and location of pear packing facilities, which would minimise the combined cost of assembly and packing the pear crop produced in 1970 (Stollsteimer, 1963).

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The problem: to determine the number, size and location of plants that minimised the combined transportation and processing costs involved in assembly and processing any given quantity of raw material produced in varying amounts at scattered production points.

Questions: How many plants should we have?

Where should our plants be located?

How large should each plant be?

Where should the raw material processed in each plant be obtained?

What customers should be serviced by each plant?

He formulated this problem mathematically as follows:

Minimise $\quad TC = \sum\limits_{j=1}^{J} P_j X_j \big| L_k + \sum\limits_{i=1}^{I} \sum\limits_{j=1}^{J} X_{ij} C_{ij} \big| L_k{}^5$

With respect to plant numbers (J $\diagup$ L) and location patterns $L_k = 1 \ldots ({}^L_J)^5$

$\sum\limits_{j=1}^{J} X_{ij} = X_{i=}$ quantity of raw material available at origin i per production period

$\sum\limits_{i=1}^{I} X_{ij} = X_{j=}$ quantity of material processed at plant j per production period

$\sum\limits_{i=1}^{I} \sum\limits_{j=1}^{J} X_{ij=} X_{=}$ total quantity of raw material produced and processed

In the above

TC= total processing and assembly costs

P_j= unit processing costs in plant j (j= 1…..J ⁻ L) located at L_j

$X_{ij=}$ quantity of raw material shipped from origin i to plant j located at L_j

C_{ij}=unit cost of shipping material from origin I to plant j located with respect to L_j

L_k= one location pattern for J plants anpng the (${}^J_L$) possible combinations of locations for J plants given L possible locations

L_j= a specific location for an individual plant (j= 1,2….J) (Stollsteimer, 1963).

However, before attempting to solve the equation, Stollsteimer noted that one must determine if economies of scale are present or not. With respect to economies of scale he identified four situations (Stollsteimer, 1963):

- Economies of scale present, plant costs independent of plant location. This is the most applicable in many plant operations. In this situation unit costs are a function of plant size. This was the case in the pear factory example.

- Economies of scale present, plant costs vary with location. In this situation unit plant costs are assumed to be a function of plant location

- No economies of scale present, plant costs independent of plant location

- No economies of scale present, plant costs dependent on plant location

Four categories of data are required when using the above model:

- Estimated or actual amount of raw material to be assembled from each origin

- A transportation cost matrix which specifies the cost of transporting a unit of material between each point of origin and each potential plant site

- A plant cost function, which permits the determination of the cost of processing any fixed total quantity of material in a varying number of plants.
  This was developed by means of economic-engineering procedures.

- Specification of potential plant locations

Not all potential plant sites can be considered as this number would be infinite; one must narrow down the number of sites considered. In the pear example only sites located adjacent to the road network were considered (Stollsteimer, 1963).

Total costs were achieved by the addition of assembly costs and processing costs with respect to plant location and varying numbers of plants. The optimum number of plants was at the point where assembly costs and production costs intersect i.e. total costs are at a minimum. The procedures used are an extension of the basic linear programming transportation model (Stollsteimer, 1963).

It was found in the pear example that one plant with sufficient capacity to handle the entire forecasted production located at site named K would minimise total costs.

The unique factors here are the inclusion of plant numbers and locations as variables and the acceptance of economies of scale in plant costs. By relaxing assumptions associated with plant numbers and locations, changes in the entire system can be analysed (Stollsteimer, 1963).

4.3.3 King and Logan's model to determine the optimal location and size of California cattle slaughtering plants

King and Logan looked at the problem of location and number of processing plants when consideration was given to shipment patterns of raw materials and finished goods. Thirty-two supply and demand regions in California plus two regions each for out of state animals were considered. There were twelve slaughtering plants of varying scale available (King and Logan, 1964).

The problem: The objective was to minimise the combined cost of assembly of live animals and the shipment of meat to consuming regions

Questions:

Where should processing plants be located?

What is the optimum number and size of plants be to move the animals through plants and to consumers at least aggregate cost?

The problem was presented mathematically as follows:

$$\textbf{Minimise}_{i\ j} \qquad \sum_i\sum_j T_{ij}X_{ij} + \sum_i H_i S^i + \sum_i\sum_j t_{ij}L_{ij}$$

X_{ij} = meatshipment from region i to region j

L_{ij} =Live animal shipment from region i to region j

S^i =slaughter of cattle in region i

T_{ij} = meat transfer cost from region i to region j

t_{ij} = animal transfer cost from region i to region j

H_i = slaughter cost per head in region i

$S^{i=}$ supply of cattle into region i

Assumptions:

- Single product firm

- No need to consider present locations of plants

- Demand and supply functions are inelastic

- Transportation costs per unit for live animal and meat do not vary with volume shipped (also the rate for shipping live animals was adjusted to a dressed weight equivalent)

- Slaughtering cost; vary with size of the plant and with location (different wage rates, property taxes and utility rates etc.)

- Benefits derived from economies of scale were based on quantities shipped

In this problem there were 34 points of origin and 32 demand centres. The problem was formulated as a transhipment model. Each production and consumption area became a possible shipment or transhipment point. King and Logan did four runs of the model as they ran into difficulties with representing economies of scale. Twelve slaughtering plants in the 32 regions were found as the optimum number of plants i.e. where costs were minimised (King and Logan, 1964).

This procedure is useful in that it illustrates the impact of processing costs and transport costs on plant numbers and locations. Processing costs alone favours centralised, large scale slaughtering. However transportation costs of raw material and finished goods are of such importance in remote areas that the establishment of small scale plants is more economical in this situation (King and Logan, 1964).

4.3.4 Polopolus model for determining the optimum plant numbers and locations for multiple product processing

Polopulus sought to develop a model for multiple product processing. Processing of sweet potatoes, okra and tomatoes in Louisiana was examined. There were 25 production regions and 10 processing locations. In Louisiana okra and tomatoes are produced simultaneously and sweet potatoes are produced at a different time of the year when it is out of season to process the other two products (Polopolus, 1965).

Information required:

- Raw material areas and volume produced in each area

- Quantity of raw materials

- Potential processing locations

- Number of processing plants

The model was presented mathematically as follows:

Minimise $\underset{(J,L_k)}{TC} = \sum\sum_{m=1}^{} C_{mj}Q_{mj} \mid L_k + \sum_{m=1}^{}\sum_{i=1}^{}\sum_{j=1}^{} Q_{mij}T_{mij} \mid T_{mij}$

With respect to plant numbers (J≤L) and locational pattern $L_{k = ...(L_J)}{}^2$

C_{mj}= unit processing cost of product m in plant j (j=1….J $\leq$ L) located at L_j

Q_{mij}= quantity of raw material m shipped from origin ito plant j located at L_j

T_{mij}= unit cost of shipping raw material m from origin I to plant j located at L_j

$L_{j =}$ a specific location for an individual plant (j= 1……J)

L_k = one locational pattern for J plants among the $_{(L_J)}$ possible combinations of locations

for J plants given L possible locations

Constraints included the following:

- volume of raw material in each production region

- quantity of raw material processed at each plant per production period

- total quantity of raw material produced and processed per production period

Estimates of the supply of the three products were forecasted. Then 10 potential locations were selected; these locations were all situated in the major geographic areas in Louisiana. In the next step assembly cost matrices were developed (assembly costs from supply areas to factories). Assembly unit costs were composed of loading and unloading costs and fixed and variable transport costs (variable costs are costs which vary with mileage). Assembly costs were expressed in linear equation form for three different truck sizes. This is shown below for sweet potatoes. Assembly of each product is done separately; therefore equations are also needed for okra and tomatoes (Polopolus, 1965).

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Small-sized truck <2 tonne load: TAC= 3.75+ .142M

Medium-sized truck between 2 and 7 tonne load: TAC=3.18+.825M

Large-sized truck > 7 tonne load: TAC= 2.385+0.334M

Processing cost equations were calculated for each product through economic engineering methods.

Canned sweet potatoes: TPC_{sp}= 108840+2.97Q_{sp}

Canned okra: TPC_o= 68078+2.38Q_o

Canned tomatoes: TPC_t= 40895+2.86Q_t

Processing costs are made up of fixed and variable. The variable costs varied with the number of cases produced. Total processing costs for the three products are equal to the sum of the fixed costs for each (intercept values) which totalled $213,813 minus joint processing costs which in this case were estimated at $43,618. (Polopolus, 1965).

This problem which minimised total costs with respect to plant numbers was solved with the aid of a computer program written at Louisiana State University for IBM 7040. In this example one plant was more economical than any other numbers of plants. Total costs of processing each product in separate plants was $39,000 higher than processing them all at 1 plant (Polopolus, 1965).

4.3.5 O' Dwyer's model for determining of the optimum number, location, and size of dairy manufacturing plants

In the early 1960's the Minister for Agriculture in Ireland formed a "Dairy Products Survey Team" to examine the industry. It was found that operating costs varied

considerably from co-operative to co-operative. Knapp was then asked to conduct an appraisal of the industry; he recommended that greater consolidation was required in the industry. Also at the same time creameries in competing regions such as Denmark, New Zealand and Holland were merging. In Ireland the numbers of plants were increasing rather than decreasing; there were 143 central creameries in Ireland in 1968. For his PhD research, O' Dwyer decided to determine the optimum number, location and size of manufacturing plants operating in Munster that would minimise total transportation and processing costs. This area comprised the traditional dairying region of Ireland. O' Dwyer's methodology was based on Stollsteimers' model for optimum plant numbers and locations. As discussed earlier there were two steps to this, firstly a transfer cost function must be developed with respect to varying plant numbers and locations and secondly a plant cost function was developed with respect to plant numbers (O' Dwyer, 1968).

Plant Assumptions:

- Only butter and skim milk power were produced

- Capacity was based on the quantity of peak day milk that the technology in the plant could handle in a specified time

- All branches required at least one manager and one man

- Mechanical intake did not take place at creameries

- Milk storage facilities were available on site for plants handling up to 8,000 gallons on peak days, beyond that a truck visits the larger branch

- The following were included in branch creamery costs: investment costs of buildings, equipment, land, labour and maintenance/repairs of equipment

- The costs of central management, branch management, cleaning, spares and milk testing facilities are manager), electricity, fuel and oil and maintenance and repairs of equipment (O' Dwyer, 1968).

Milk assembly assumptions

- A truck operates 9 hours a day, 300 days a year

- Maximum distance from origin to plant is 60 miles one way

- Truck visits the branch once a day

- The truck driver is employed for 9 hours a day

- Two types of trucks are considered (seven tonne truck with capacity of 2,100 gallons or a fifteen tonne articulated truck with capacity of 3,150 gallons)

- The seven tonne truck can travel 25 miles per hour and the fifteen tonne truck can travel 20 miles an hour (O' Dwyer, 1968).

Information required:

- Volume of raw material available in each origin

  In this example there were 143 origins, these were the branch creamery locations. The branch creamery locations were the points to where the farmers brought their milk; the milk was then assembled and transported in bulk to the factories.

- Transportation-cost matrix detailing the cost of transporting a unit of product between each source and potential site

  67 potential site locations were chosen as potential plant sites. Milk assembly costs were comprised of handling costs at central creamery and transport costs from central creamery to factories. A transfer cost function was then calculated from these costs. It was calculated with the help of a computer program, which was designed for the IBM 360-65.

- Plant cost function (specifying the cost of processing any fixed total quantity of product in varying plants. Branch creameries of the following peak day capacities were examined; 2,000, 4,000, 6,000, 8,000 and 10,000 gallons (these plants had annual intake of 400,000, 800,000, 1,200,000, 1,600,000 and 2,000,000 gallons respectively). O' Dwyer decided to use the economic engineering approach and

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present value analysis to estimate processing costs for hypothetical plants of various sizes in Ireland. Dairy experts in Ireland e.g. technologists, plant managers and dairy engineers were consulted in this task.

In this example only skim milk powder costs were relevant (O' Dwyer, 1968).

In this study total costs were calculated by the addition of assembly costs and processing costs. The optimum number, location and size of plants is the point where total costs are at a minimum. In this case it was found to be 23 plants; this represented a 12% reduction when compared with total costs for 67 plants (which was the number of potential sites examined in this example) (O' Dwyer, 1968).

4.3.6 Benseman production planning in the short/medium term in the New Zealand dairy industry

In 1985 the New Zealand Dairy Board (NZDB) was acquiring product by law from New Zealand processors. The NZDB was set up under special legislation to act as a commercial company, owned and governed by the processing co-operatives in proportion to their supply. The co-ops had no choice but to sell their produce to the New Zealand dairy board. This enabled the NZ dairy industry as a whole to adopt a cost leadership strategy. Cost leadership requires the construction of efficient scale facilities, the constant pursuit of cost reductions, tight costs and overhead control, and a focus on all activities that add cost (Sankaran 2003). The New Zealand industry's cost-driven payment system acted as a direct incentive for companies to achieve greater economies of scale by taking over other co-ops and securing larger milk flows. The rationale for the statutory power of the NZDB was that through a single desk seller, the dairy industry as a whole could compete more effectively with large industry players such as Nestle in international markets. Also it would ensure that New Zealand dairy processors would not undercut one another's prices in overseas markets and thus dilute return to New Zealand farmers. The role of the NZDB

was to match market demand with processing capabilities (Sankaran 2003). Co-operatives had to submit proposals (containing information on prices, quality and technical requirements) to the NZDB; co-operatives were chosen to produce certain products based on these. The NZDB developed cost models for every product. These models included all the costs associated with producing a particular product, collection of milk, administration and capital costs. The models were updated regularly to reflect technological advances and other changes to the industry with only one product produced at each site. By having to participate in the industry cost surveys, the individual co-ops were forced to better measure their own costs, which in turn facilitated better tracking and management (Sankaran 2003).

Production planning was planned manually, however due to the complexity of this task not all factors could be accounted for. Benseman in 1985 developed a linear programming model for the New Zealand Co-operative Dairy Company (NZCDC) that could include all of these factors. The NZCDC processed 35% of New Zealand milk production at that time. It owned a transport fleet consisting of 219 tankers and 97 trailers. The catchment areas for this co-op were grouped into 45 regions. 16 base products were considered. Two dummy factories were included (butter and milk powder factories) and their aim was to emphasize areas where more capacity was needed. Seasonality in milk production was acknowledged; peak months included June to October where production rises to 12 million litres a day. As a result of seasonality production plans need to be changed regularly due to variations in milk supply volumes and yields. To accommodate this the season was broken into 36 10-day periods. While 10 day periods were used for short term planning the model used months when planning on a yearly basis. In the early stages of model development each month was solved separately however the model was then able to simultaneously solve several months at a time. The following data was required in the formulation of the model:

- Freight costs
- Factory capacities and costs

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- Product prices and quotas

- Whole milk forecasting

- Product yields (Sankaran 2003)

The model was written mathematically as follows:

Maximise Profit = $\sum_{k}\sum_{p}\sum_{t}$ T_{kpt}*(Baseprice$_{pt}$ + Gradepremium$_{kp}$ - Productioncost$_{kp}$) - $\sum_{p}$ $\sum_{t}$ P_{pt}*Penalty$_{pt}$ - $\sum$ $\sum$ Z_{kt}*Fixedcosts - $\sum_{i}$ $\sum_{j}$ $\sum_{k}$ $\sum_{p}$ $\sum_{t}$ X_{ijkpt}*Freightcost$_{ijt}$

i= input type (whole, cream, buttermilk)

j= origin collection region or factory

k= destination factory

p= product type

t= time interval representing 10 days or a month

X_{ijkpt}= volumes of input I moved daily from j to k to make p in interval t

T_{kpt} = tonnes of product p made daily at factory k in interval t

P_{pt} = tonnes of product p sold at base prices in interval t

Z_{kt}= tonnes of product p sold at penalty prices in interval t

B_{pt} =1 when factory k is operating in interval t, 0 otherwise

In 1985 the problem consisted of 680 constraints and 2050 variables. OMNI matrix generator/report writer was used to generate mathematical models in MSPX data format. MPSX/370 which is an IBM program then read the LP problem from OMNI matrix generator/report writer and solved it in 7 minutes. The model was then passed back to OMNI matrix generator/report writer where the solution was converted into suitable form that managers could understand and read. The following reports were produced by the LP analyst for managers after solutions for all periods were found (Benseman, 1986):

- Allocation report

This reports illustrates how inputs should be used in factories

- Spare capacity report

  This report shows remaining capacity at plants.

  For plants that are capable of making multiple products capacity is measured in terms of whole milk.

- Production report

  This reports shows the tonnage of each product produced in a factory every month

- Reallocating whole milk report

  This report illustrates the difference in costs of optimal and second best supply areas and product mixes

It was claimed that the LP system saved NZCDC over $1 million a year in their processing operations. It coordinated production more successfully and it also highlighted the need for factory closure in some areas in off peak periods, as running costs made it uneconomical to keep all of the factories open (Benseman, 1986).

4.3.7 Mellalieu/Hall production planning in the long term in the New Zealand dairy industry

NZCDC used a model called NETPLAN, which was a network formulation to help managers with long term planning. This model was aimed at assisting managers with management decisions such as how to spend an investment of $200m in new plant operations/upgrading of present facilities, transportation policies and product risk strategies. Various scenarios regarding growth in milk supply and industry organisation was modelled over a 10-year time horizon (Sankaran, 2003). Network approach was used as it could produce a solution quickly and also for ease of representation i.e. when reformulation is required it was possible to extend the current formulation. The 4500 farms were grouped into 176 areas based on geographic factors and densities of factories. This

allowed the user to work with a more solvable network size. The network consisted of 806 arcs and 214 nodes which were made up of 176 supply areas, 14 factories, up to 5 processes at each factory and eight different products been produced (yields are allowed to vary from factory to factory). The following data was required for the model formulation:

- Transport costs

- Process net revenues

- Fixed production costs

NETPLAN with the exception of the out of kilter algorithm was written in I.B.M. PL/I, the algorithm was written in FORTRAN. NETPLAN enabled the travelling salesman problem to be solved simultaneously with product allocation decisions subject to capacity and product demand constraints, Mellalieu and Hall, 1983. NETPLAN's interactiveness and ability to perform sensitive analyses quickly proved very beneficial (Mellalieu and Hall, 1983).

However NETPLAN ran into the following complications:

- All butter factories were ignored

- All cream, whey and buttermilk by-products were ignored

- Multi-period quotas and two-tier prices were ignored

- Multi-input products e.g. baby food were ignored

- Back loading in milk assembly operations were ignored (Benseman, 1986).

4.3.8 Optimisation of Nutricia supply network in Hungary

Nutricia, a large international dairy company, purchased a number of dairy companies in Hungary between 1995 and 1998. Milk was supplied to these companies from 400 farms; the companies owned 9 processing plants in which they produced over 300 different products. The final products were then distributed to 17 distribution centres, which served

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17,000 retail stores. A proportion of products was also exported and sold to industry. Inefficiencies were evident in the whole supply chain therefore Nutricia was eager to minimise total production and transport costs. In order to achieve this they developed a mixed integer linear program model. The problem was defined as follows; "What should be the optimal number, location and size of the production plants and what product groups should each plant produce, given the market demand and the milk supply, such that the total costs (comprising the production and transportation costs) are minimised." Therefore their objective function was to minimise milk collection costs+ milk transportation costs from region to plant+ milk reception costs + production costs + transportation costs of inter-deliveries from plant to plant+ transportation costs of finished products from plant to sales region (Wouda *et al.* 2003).

The following costs were required:

- Milk collection costs (from farm to farm)
- Transport costs (driving from last farm to plant and from plant to first farm)
- Production costs

    Product costs were based on greenfield costs. A greenfield situation involves the following: define the capacity needed for a certain product group, invest in the newest and most advanced proven equipment available, arrange it into the most efficient layout of the plant.

- Inter-transportation costs
- Distribution costs for finished products
- Warehousing costs

Aggregation of data to make the model more solvable:

- milk supply is constant throughout the year, no variation in daily supply

- 400 farms grouped into 9 regions with 1 gravity point in each region, each region produced a certain milk volume

- 300 products grouped into 13 product groups based on preparation and packaging equipment

- Distribution centres and shops grouped into 20 geographical regions, each region is a county, and the gravity point is the capital of the county (Wouda *et al.* 2003).

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The problem was written mathematically as follows:

$$\text{Minimise} \quad smrc \sum_j Y\ MILK_j + \sum_i \sum_j (mcc_i + mrc + tcm_{ij})*X_{ij} + \sum_p spc_p * \sum_j YPROD_{jp} +$$

$$\sum_p pc_p * \sum_j PROD_{jp} + \sum_h \sum_i tci_{hj} * (CREAM_{hj} + WHEY_{hj} + PER_{hj} + BUT_{hj})$$

$$+ \sum_j \sum_k tcf_{jk} * \sum_p Z_{jkp}$$

Where:

mcc_i = milk collection costs in region i

mrc = variable costs milk reception

tcm_{ij} = milk transportation costs from region I to region j

X_{ij} = amount of milk transported from region I to location j

spc_p = set up costs production line p

pc_p = variable costs of production line p

tci_{hj} = transportation costs of semi=finished goods from location h to j

$cream_{hj}$ = amount of cream transported from region h to j

tcf_{jk} = transportation costs of finished product from from location j to depot k

Z_{jkp} = amount of product p transported from location j to depot k

The model was solved using Xpress-MP optimisation system from Dash Optimisation Ltd.

The following scenarios were examined:

- Scenario 0:current situation using greenfield production costs

- Scenario 1:running the model without any additional restrictions to calculate the optimal solution using the current 9 locations

- Scenario 2:running the model with an additional four locations, not all current locations need to be used, supply could travel to new locations

- Scenario 3: running the model with one of the optimal destinations left out

- Scenario 4: running the model with production of a certain product group forced into a certain location

- Scenario 5: Running the model with a fixed number of possible plants i.e. 1 or 2

- Scenario 6: Running the model after closing one plant in the current situation

The optimal solution was found to be 3 plant locations. Each product group was produced only at 1 location. There was still inter-transport but considerably less than the current situation. The model was found to be a very useful tool in the decision making process in Nutricia (Wouda *et al*. 2003).

4.3.9 Tursun model to optimise bio refinery locations and transportation network for the future biofuels industry in Illinois

Corn ethanol is the most widely used additive in renewable energy production in the US. U.S. ethanol production was 6.5 billion gallons in 2007, an increase of 4.9 billion gallons from 2000 (production was approx. 1.6 billion gallons in 2000). There is a drive in the US to increase the quantity of renewable fuels used in transportation fuels. The US Environmental Protection Agency has mandated that by 2012, at least 7.5 billion gallons of renewable fuel must be blended into motor-vehicle fuel and 36 billion gallons by 2022 (Tursun, 2008).

Problem: Determine the optimal transportation and processing of raw materials, delivery of the end product, selection of the bio refinery types, and capacity and location decisions to meet the mandated ethanol targets throughout the 2007-2022 in Illinois(Tursun, 2008).

Questions:

What type of processing facilities should be developed?

What should the capacities of these plants be?

 Where and when should they be built?

What quantity of raw material should be transported from production areas to processing facilities?

What quantity of ethanol should be transported to blending facilities?

What is the demand for end product?

The problem is formulated as a mixed integer linear program model. The objective of the model is to minimize the total costs including transportation costs (of raw material to bio fuel plants and of ethanol from plants to market), processing costs, and fixed investment costs associated with building refineries, minus by product credits(Tursun, 2008).

Data required:

- Supply of raw material each year from 102 counties in Illinois

- Demand for ethanol for each year in each of the 102 counties in Illinois (it is assumed to be 19% of the national ethanol target)

- Transportation costs between production regions and potential refinery locations

- Transportation costs between refineries and blenders

- Transportation costs between blenders' locations and markets for end products (in this situation end markets are counties, 1 point is picked in each county)

- Costs of bio refineries including fixed costs (cost of land, machinery and new facilities) , processing costs (dependent on volume processed) and operational expenses (labour and administration expenses)(Tursun, 2008).

According to the solution from the model the number of corn-based plants should grow from 11 plants in 2007 to 15 plants in 2022. A number of existing plants should be expanded by 50%, in particular in the northern and northeastern counties. In total 18 cellulosic ethanol refineries would be built by 2022 with an average size of 233 million gallons per year. The cellulosic plants should be located throughout southern and northeastern counties(Tursun, 2008).

4.3.10 Buschendorf, Boysen and Schroder models' to optimise the German dairy industry

The German dairy industry is the largest component of the German food industry. The number of dairy plants has been decreasing in recent years however the reduction is slower than its main competitors namely Denmark, Netherlands and New Zealand. Dairy companies are opting towards fewer and larger plants as they wish to take advantage of economies of scale in processing. However as the number of plants decrease, transport costs increase. Therefore, one needs to find the number of plants where total costs are at a minimum in order to optimise the structure.

Boysen and Schroder 2009 and Buschendorf 2008 both developed mixed integer models with the endeavour to optimise the German dairy industry. Boysen used an algorithm, which he wrote himself to solve the problem. Buschendorf (2008) used MOPS, an LP solver to solve the problem. The following gives an overview of both of their models.

Boysen and Schroder's model can be written mathematically as follows:

$$\text{Minimise} \sum_{d \in D | \varepsilon \, L_d} (f_d * \sum_{p \in P} Y_{dl} + k * \sum c_{pd} * z_{pd} + \sum s_l * q_{dl})$$

f_d = annual overhead costs of operating dairy plant d

Y_{dl} = 1 dairy d operates on production level l, 0 otherwise

c_{pd} = distance between region p and dairy d plus the radius r_p and back

z_{pd} = number of transports per collection cycle

s_l = processing cost per tonne on production level l

q_{dl} = output quantity of dairy d on production level l

d = 1,…,S dairies

From Boysen and Schroders' objective function it can be seen that the objective was to minimise assembly costs, production costs and overhead costs. In relation to milk assembly costs he looked at the number of tankers required, capacity of tankers and frequency of collection from farms. Boysen and Schroder (2009) did not include product distribution costs in his model as they are of lesser importance than milk assembly costs and also if included the model would expand exponentially. They looked at three scenarios a benchmark, a short run scenario and a long run scenario. Supply in all scenarios was the volume supplied in 2000/2001 which was 24,395,801 tonnes of milk, total capacity of all the factories was 33,196,800 tonnes (2000/2001 figures). Boysen and Schroder (2009) assumed a particular product mix which was the norm of the industry at the time the study was conducted. In the short term scenario all 360 plants (actual number of plants in 2001) stayed open; capacity utilisation was equal in all at 73.5%. In the short term scenario plants were allowed to operate at different capacities, however capacities were fixed and plants were also allowed to shut down. In the long term scenario capacity was not fixed and wasalso allowed to vary from plant to plant. The results show that in the benchmark scenario there were 360 plants open, in short run there were 156 and in the long term 65

plants (Table 4.1). When compared with the benchmark scenario costs decrease by 11% per tonne in the short term and 16% per tonne in the long term (next ten years) or 1.7 cent per kg of milk processed (Table 4.2) (Boysen and Schroder, 2009).

Table 4.1: Number of plants

Number of plants	Benchmark	Short-run	Long-run
Small	182	20	0
Medium	108	74	12
Large	70	63	53
Total	360	156	65

Source: Boysen and Schroder, 2009

Table 4.2: Scenarios explored and corresponding costs

Scenario	Cost per tonne (euro)	In index form
Benchmark	108.1	100
Short-run	96.1	89
Long-run	90.4	84

Source: Boysen and Schroder, 2009

Buschendorf's model can be written mathematically as follows:

$$\text{Minimise} \sum_{r=1}^{R} \sum_{b=1}^{B} \sum_{b=1}^{B} X_{TRMrb} * ZTK_{rb} + \sum_{b=1}^{B} x_{sb} * ZVK_{Sep} + \sum_{p=1}^{P} Y_{sb} * ZFK_{Sep} + \sum\sum x_{hbp} * ZVK_p$$

$$+ \sum_{b=1}^{B} \sum_{p=1}^{P} z_{HBp} * ZFK_p + \sum\sum_{b=1 \; b+1=1}^{B} (x_{TMMbb} + x_{TRAbb}) * ZTK_{bb} + \sum\sum_{b=1 \; m=1}^{M} X * ZTK_{bm} + \sum_{b=1}^{B} \sum_{p=1}^{P} \sum_{v=1}^{V}$$

$$x_{TMPbpv} * ZTK_{bpv}$$

Where:

R = raw materials centre with host locations r1 to r100

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B = dairy locations with sites b1 to b271

P = dairy production with products p1 to p8 (fresh milk, H-Milch, butter, cheese, soft cheese, yogurt, cheese and skimmed-milk powder)

M = whey processors with sites m1 to m11

V = consumption centre of dairy products with delivery locations v1 to v59

T = transport of raw milk (TRM) (TMM) of skimmed milk, cream (TRA), whey concentrate (TMOK) or dairyproduction with products p1 to p8 (fresh milk, H-Milch, butter, cheese, soft cheese, yogurt, cheese and skimmed-milk powder)

S = separation of raw milk fat and non fat (protein component)

H = production of dairy products

d = target function

x = continuous variable of activities T, S and H with size x

y = integer binary [0,1] variable of activity S scope y

z = integer [0,1,2,3,4,5,6,7] variable of activity H scope z

ZTK_{rb} = costs for transportation of raw milkfrom raw material centres R in dairy establishment premises B

ZTK_{bb} = costs for the transport of whey concentrate of dairy locations B to whey processors M

ZTK_{bm} = costs for the transport of skimmed milk and cream between dairy locations B

ZTK_{bpv} = costs for the transport of dairy products P from dairy location of B in V

ZVK_{Sep} = variable costs of separation or the general milk processing location and the administrative costs

ZFK_{Sep} = fixed costs of separation or the general milk processing

ZVK_{p} = variable cost production of product p

ZFK_{p} = fixed costs of products p

From Buschendorf's objective function it can be seen that his intention was to minimise milk transport costs, processing costs and product distribution costs as a means of optimising the industry. He did not go into as much detail in milk transport costs as Boysen. Another difference between the two was that Buschendorf (2008) included the cost of distribution of dairy products to EU, non EU countries and throughout Germany. Buschendorf estimated what milk supply volumes would be in Germany in 2013 using OECD, FAPRI and FAO forecasts. Acccording to Buschendorf supply will become more concentrated in fewer dairy farms. He also estimated demand for dairy products in 2013. He used these demand and supply estimates in his model. Eight products groups were considered, however niche products were not included in the model. Buschendorf used MOPS software to solve the problem. MOPS is a linear program solver. Buschendorf found that the optimum number of plants for the German dairy industry would be 90/100 plants (in 2007 there were 239 plants). 90/100 plants would lead to savings of 1.2 cent/kg of milk processed (Buschendorf, 2008).

Overall their results are not very different when one considers that Boysen was working with 2001 data and Buschendorf with 2007 data. They present two different ways of optimising the industry using different approaches in the costs they included and the software that they used.

4.4 Optimum location of the Irish dairy processing sector

The model that will be developed in subsequent chapters in this thesis is primarily concerned with Weberian theory. As will be indicated in more detail it is a least cost model and production costs are independent of location. The problem is formulated into a mathematical programming problem similar to that of Stollsteimer, O' Dwyer, Wouda *et al.,* Boysen and Buschendorf. The theory of the model is that the optimum organisation

structure of the Irish dairy processing sector involves a balancing of increasing transport costs against decreasing processing costs.

Milk Transport Costs

In reality resources are not evenly distributed across space. Ex-farm milk transport may be defined as the complete set of activities involved in transporting milk from farms to factories. While the term milk assembly is sometimes used, this is more commonly defined to include also the milk storage activity at the farm level, as well as milk transport. In economic terms milk transport is subject to several principles of transport economics, which primarily concern the relationship between cost and distance. The general relationship between length of haul and cost of transport may be called the transfer cost function. If one takes a central processing point (or market), surrounded by raw material (or product supplies), scattered over a uniform, flat geographic area where travel in every direction is equally feasible, the transfer cost function normally has a characteristic shape. This involves cost increasing with distance but at a decreasing rate. This was illustrated in both plain and cross sectional forms by Bressler (1976). Where cost increases with distance at a decreasing rate, the resulting isocost contours are concentric circles with radii that increase at an increasing rate, (Figure 4.4). The isocost contours are drawn to represent equal increments to transfer cost from one contour to the next. Thus in the cross sectional view the distance between D1 and D2, D2 and D3, etc. becomes greater and greater, reflecting the increase in cost at a decreasing rate.

Figure 4. 4: Length of haul to market centre

Plan View

Isocost contours

Cross-sectional view

Transfer cost function

Length of haul to market centre
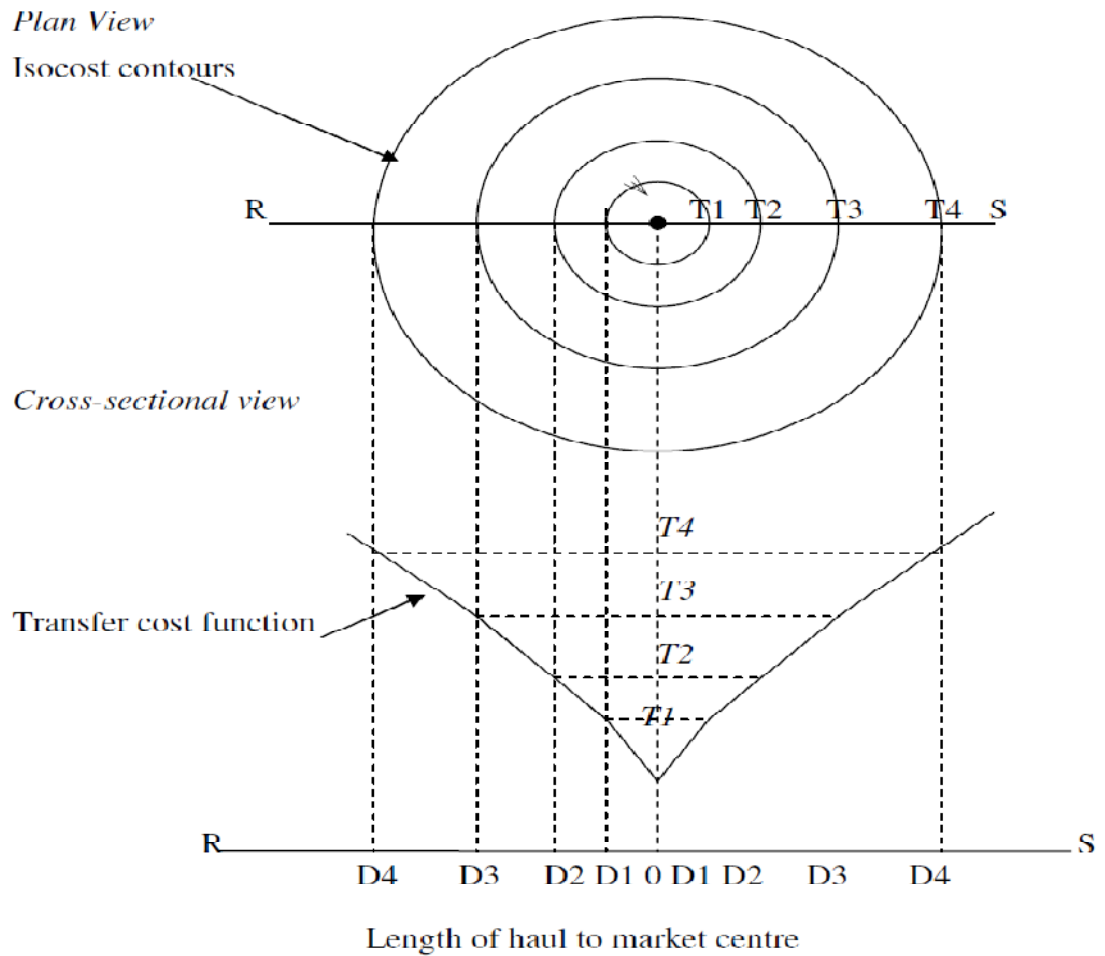
Source: Bressler 1976

With regard to milk transport specifically, there are six separate activities normally involved as follows:

a) Transport Driving; this involves the time spent in driving from plant to first farm and from last farm to plant (see figure 4.5).

b) Assembly Driving; this involves time spent driving between farms on the route (see figure 4.6).

c) On-Farm Routine Activities; this includes time spent attaching hose, agitating milk, sampling, rinsing tank, paperwork etc. on farms.

d) On-Farm Pumping; this depends on pumping rates

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e) Plant Non-Pumping; this includes tanker washing, waiting time, office, lunch, etc.

f) Plant Pumping; this depends on plant pumping rate

The effect of changes in supplier volume or distance from processing plant on these six activities provides some valuable insights into the factors that affect milk transport costs (Keane, 1986). The effect of volume can be dealt with by considering the effect of a doubling of supply per supplier. Then transport driving costs would double approximately, as twice as many trips between the plant and the collection area would be required. Likewise farm pumping, plant pumping and plant non-pumping costs would double due to the doubling of loads. Thus these four components are volume related and increase in proportion with increases in volume (Keane, 1986). Assembly driving, however, will not vary significantly even if volume doubles, as only one trip is required from farm to farm. Likewise, on-farm routine costs will remain unchanged regardless of volume. These two cost components arise due to the servicing of suppliers and are unrelated to volume or size of supplier as such. This form of breakdown forms the theoretical basis underpinning the division of transport charges on a stop or volume related basis (Keane, 1986).

The effect of distance from the plant may be similarly considered by assuming a doubling of the distance between the catchment area and the processing plant. In this case the transport driving component will double but the other five components will remain unchanged. This approach has formed the basis for zonal charges for milk transport in some countries (Lee *et al*., 1985).

Figure 4. 5: Assembly driving: 2 routes
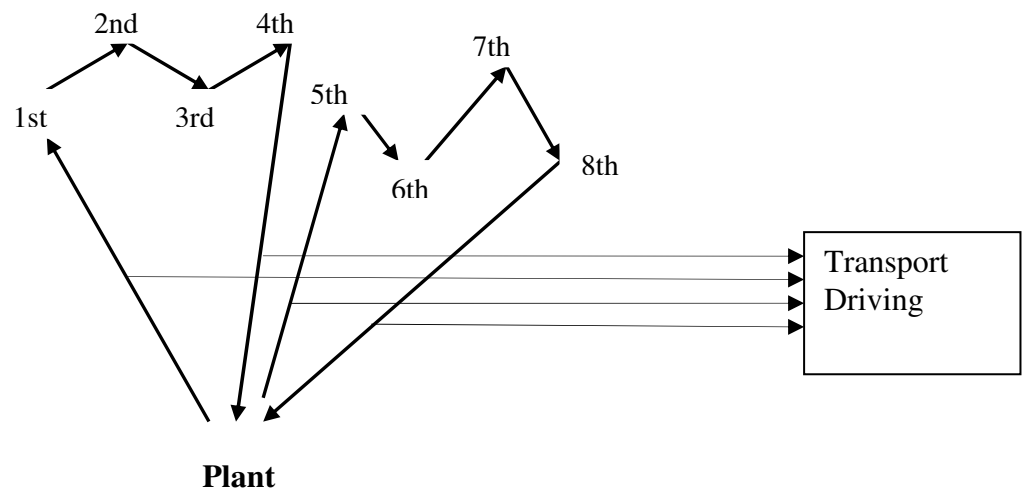
Figure 4. 6: Assembly driving: 1 route
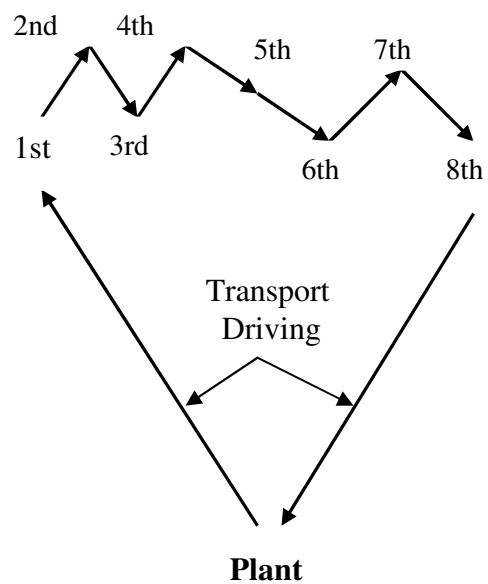
Processing Costs and Economic Principles

Production costs include labour, capital, and technical and managerial skills (De Souza, 1990). Economies of scale are features of a firm's technology that lead to falling long-run average cost as output increases (Parkin, 1999). Scale refers to the size of the firm as measured by its output (Begg *et al*., 2000). Scale is important as producers are concerned with the unit cost of production and adjustments in scale can produce considerable variations in unit cost (De Souza, 1990) (Figure 4.7).

Figure 4. 7: Optimum scale of output
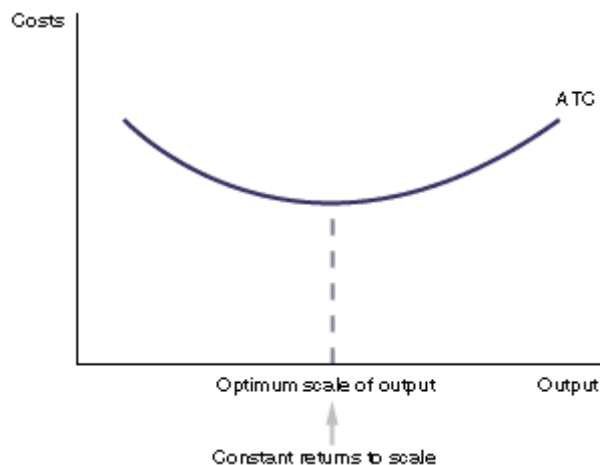
Source: De Souza, 1990

Many reasons may be cited for lower long term average costs are greater output, Hay and Morris, (1991);

➤ Technical economies made in the actual production of the good. For example, large firms can use expensive machinery intensively.

➤ Managerial economies made in the administration of a large firm by splitting up management jobs and employing specialist accountants, salesmen, etc.

➤ Financial economies made by borrowing money at lower rates of interest than smaller firms.

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- ➢ Marketing economies made by spreading the high cost of advertising on television and in national newspapers, across a large level of output.

- ➢ Commercial economies made when buying supplies in bulk and therefore gaining a larger discount.

- ➢ Research and development economies made when developing new and better products (Hay and Morris, 1991)

Additional economies of scale at the level of the firm involve such factors as research and development, management, advertising, computer services, and centralised accounting, Hay and Morris (1991). Further economies of scale are realised when costs are reduced by producing two or more products jointly, rather than in separate specialised plants. Also, large diversified firms can make there purchasing power felt in dealing with specialised suppliers. Diseconomies of scale may also exist beyond a certain size, connected with such factors as increasing problems of information and co-ordination, and problems of budgetary control (De Jong, 1993).

4.5 Conclusion

Laundhart, Von Thunen, and Weber were among the first to contribute to the field of location economics. Their work, along with Hotelling and Losch, work became known as classical location theory. Their work was primarily concerned with forces governing the use of land and the locations of plants and industries. One of the limitations of this theory is that it focused on the input side of the problem and took demand as given. Isard developed the theory grouped under regional science. Regional science refers to developments in location theory and spatial economics that occurred from the 1950's. Regional science focused on explaining why one production centre is more attractive to another in relation to production and demand for final products. This theory contributed to the explanation of forces governing international trade. Location theory was then neglected

until Krugman's work generated renewed interest. New economic geography aims to explain processes of concentration and deconcentration of manufacturing in a two-sector economy. Economists now acknowledge that location theory can provide powerful analogies that can be applied to a wide variety of microeconomic problems. As a result research in the area is ongoing.

Along with location economists, operational researchers have spent significant time and effort in examining location problems (Figure 4.8). There has been an increasing focus on supply chains in the last decade. Therefore this has increased interest in operation research techniques and their application to real life business problems.

Chapter 5 examines the methodology techniques used in this thesis

Figure 4. 8: Review of applications of theory of optimal locations

Olson (1959)
Considered the problem of determining the optimal size of milk-processing plants and optimal distances between plants in a cooperative dairy in Minnesota, USA
↓

Stollsteimer (1963)
Considered the problem of simultaneously determining the number, size and location of plants that minimise the combined transportation and processing costs involved in milk assembly and processing in pear plants in California, USA
↓

King and Logan (1964)
Determination of optimal location and size of California cattle slaughtering plants, when the location and quantity of slaughtered animals as well as the final product demand were known
↓

Popolus (1965)
Considered the problem of optimum plant numbers and locations for multiple product processing in Louisiana, USA
↓

O' Dwyer (1968)
Determination of the optimum number, location, and size of dairy manufacturing plants in Ireland
↓

Mellalieu/Hall (1983) and Benseman (1986)
Production planning in the New Zealand dairy industry
↓

Wouda, Van Beek, Van Der Vorst and Tacke (2003)
Optimisation of Nutricia supply network in Hungary
↓

Tursun (2008)
Optimal Bio refinery Locations and Transportation Network for the Future Biofuels Industry in Illinois, USA
↓

Buschendorf (2008) and Boysen and Schroder (2009)
Optimisation of the German dairy industry

Source: Own diagram

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Chapter 5

Methodology

5.1 Introduction

This chapter presents the research design and methodologies employed in this study. The objective of this chapter is to describe and discuss the research method and methodology that has been applied for this research. The overall research question that guided this study was: *What is the least cost industry configuration for the Irish dairy industry post milk quota abolition in 2020*? The main research question was broken down into the following research sub-questions:

Sub-question 1: *What are the effects of various efficiency factors on milk transport costs in Ireland? What are the effects of different milk production patterns on milk transport costs in Ireland?*

Sub-question 2: *Will milk production increase post milk quota abolition, if so where will it increase? How many processing plants should Ireland have post milk quota abolition? Where should the plants be located? How large should each plant be? Where should the milk to be processed at each plant should be sourced? How should milk be collected?*

Sub-question 3: *What will the total processing and transport costs be post milk quota abolition? What is the capital requirement for the Irish milk processing sector post milk quota abolition?*

The objectives of this study were: (i) to develop, validate and describe a national milk transport model for simulating milk transport activities in Ireland and (ii) to develop a model to determine the least cost dairy processing sector configuration in 2020 taking cognisance of regional milk supply, processing and milk transport costs.

In this chapter, firstly, the methods of data collection are discussed and the various research techniques used in the study are investigated.

<u>Research</u>

The word research is composed of two syllables, re and search. The dictionary defines the former as a prefix meaning again, anew or over again and the latter as a verb meaning to examine closely and carefully, to test and try, or to probe. Together they form a noun describing a careful, systematic, patient study and investigation in some field of knowledge, undertaken to establish facts or principles (Grinnell 1993: 4).

Grinnell further adds: 'research is a structured inquiry that utilises acceptable scientific methodology to solve problems and creates new knowledge that is generally applicable.'(1993:4)

> Burns (1994:2) defines research as 'a systematic investigation to find answers to a problem.'
>
> According to Kerlinger (1986: 10), 'scientific research is a systematic, controlled empirical and critical investigation of propositions about the presumed relationships about various phenomena.'

From these definitions it is clear that research is a process for collecting, analysing and interpreting information to answer questions. But to qualify as research, the process must have certain characteristics: it must, as far as possible, be controlled, rigorous, systematic, valid and verifiable, empirical, and critical. A general model of the marketing research

process is presented here, which can be applied to a wide range of real situations with minor adaptations (Figure 5.1) (Kumar, 1999).

Figure 5. 1: Model of marketing research process

Problem definition

⇓

Research objectives

⇓

Planning the research

- Prepare the research brief
- Agree the research plan

⇓

Data Collection

⇓

Conduct the research

⇓

Analyse and interpret the information

⇓

Prepare and present the report

⇓

Research evaluation
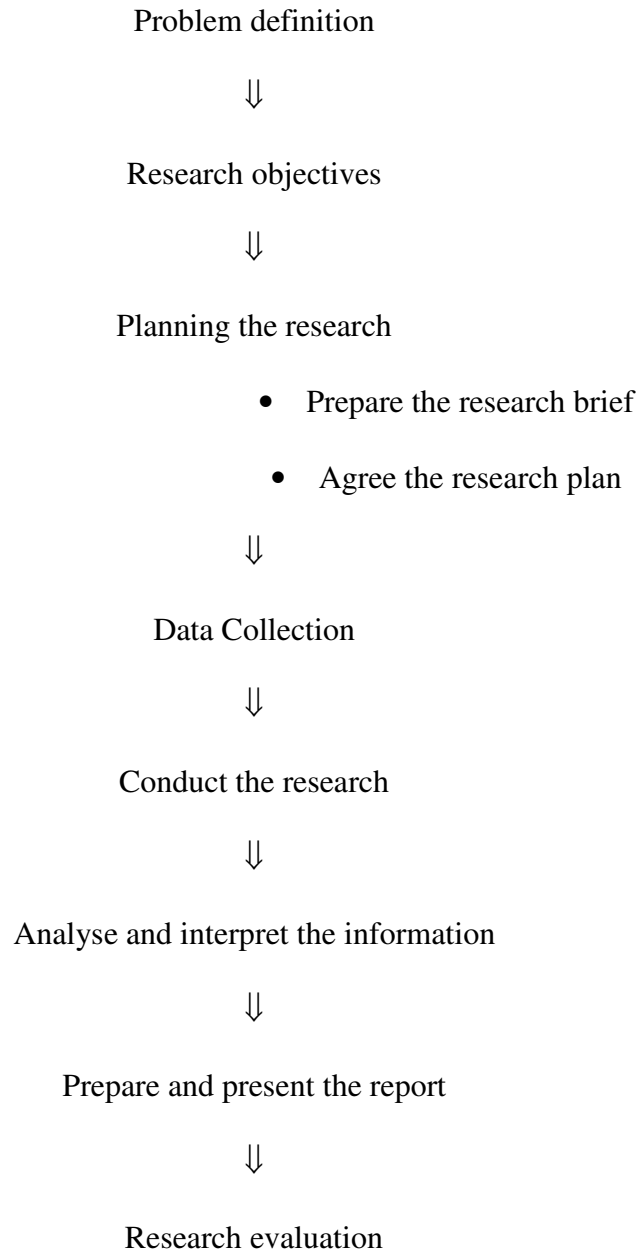
Source: Brassington (1997)

5.2 Data Collection

The data required for the first objective in this study was collected through desk research and consultation with industry experts[1]. The following basic data was required:

> ➢ Capital costs
>
> ➢ Labour costs
>
> ➢ Running costs
>
> ➢ Geographical location of milk producers and quantity of milk produced in each location (milk supply)
>
> ➢ Location of factories and the milk demand/capacity of each
>
> ➢ The distances between each supplier location and destination.

The transport costs included in the model are representative of the 2005 values taken from a survey conducted by Quinlan *et al.* (2005) on milk transport costs in Ireland. This survey was carried out across the dairy industry in Ireland with representatives from all of the major processors completing the survey. These costs were updated with 2010 values with the aid of published literature, processors annual reports, the Central Statistics office of Ireland or were assumed based on consultation with industry experts. The 2010 costs were then verified using the Delphi method with industry experts. The Delphi method is a forecasting method based on the results of questionnaires sent to a panel of experts. Several rounds of questionnaires are sent out, and the anonymous responses are aggregated and shared with the group after each round. The experts are allowed to adjust their answers in subsequent rounds. Because multiple rounds of questions are asked and because each member of the panel is told what the group thinks as a whole, the Delphi Method seeks to reach the "correct" response through consensus.

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[1]Industry experts represent processors in the Irish dairy industry, names cannot be disclosed for confidential reasons

Annual costs, which relate to capital expenditure including truck depreciation, tanker depreciation, interest and capital costs per tanker. The lifespan of the truck is depreciated based on the truck running; for 220,000 miles and the trailer or milk tanker was based on the trailer running for 660,000 miles (consultation with industry experts[2]). In the analysis it was assumed that all capital is borrowed over a 7-year period with an interest rate of5% per annum. Capital costs include provisions for 10% spare tankers and trucks as extra tankers are required to accommodate fluctuations in milk production, transportation schedules and normal glitches that can occur in transportation systems.

Labour cost was assumed to be €20 per hour based on industry guidelines and includes PRSI contributions (Quinlan *et. al* 2010), which is similar to costs of workers in the transportable goods services for 2007 where the most up to date information is available for Ireland (Central Statistics Office 2009).

Running costs include insurance, tax, tyre replacement, service/maintenance and fuel costs.

The Department of Agriculture, Food and Fisheries supplied information on dairy cow numbers at district electoral division (D.E.D.) level. Typical seasonal milk supply patterns were applied based on data from the Central Statistics Office (CSO, 2011). In this way an estimate of milk availability throughout the year by rural district was derived. The DED's were then aggregated up into 156 rural districts. Information about the location of destinations (Processors) was mainly obtained from a detailed map of the locations of dairy factories, which had been published, Irish Dairy Board (2009). Based on information on annual milk intake by factory, it was estimated that 19 Dairy Processing locations exist; this captured the vast bulk of milk processing capacity in the country.

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[2]Industry experts represent processors in the Irish dairy industry, names cannot be disclosed for confidential reasons

An estimate of road distance from a central or appropriate point from each source (rural district) to each destination was obtained from a computerised road-mapping source.

The data required for the second objective in this study was also collected through desk research and through consultation with industry experts[3]. For this part of the study the following basic data was required:

➢ Milk output in 2020

➢ Milk transport costs

➢ Milk Intake and other utility costs

➢ Processing costs

The regional milk output in 2020 was projected using the FAPRI-Ireland farm level model (Hennessy, 2007). The model utilized Irish National Farm Survey (NFS) data along with projected changes in prices and costs from the FAPRI-Ireland aggregate level model to simulate the response of farmers to policy changes. The country was divided into four regions: the Border Midlands and western region (BMW), the south-west (SW), the south (S) and the east region (E) and farms were categorized into three further groups based on herd size i.e. small, medium and large. A projected percent expansion capacity was forecasted for each group (Laepple and Hennessy 2010). The 2,627 DED's were assigned one of the four regions as stipulated by the FAPRI model (BMW, SW, S and E). The size of the herd (small, medium, large) for each DED was then determined (predetermined by the FAPRI model). The projected percentage expansion was then applied to each DED. These data were then converted to milk equivalent terms using average milk yields (stipulated by the FAPRI model). The DED's were then aggregated up into 156 rural

[3]Industry experts represent processors in the Irish dairy industry, names cannot be disclosed for confidential reasons

districts. Typical seasonal milk supply patterns were applied based on data from the Central Statistics Office (CSO, 2011). In this way an estimate of milk availability throughout the year post milk quota abolition by rural district was derived, which could be fed into the transportation model.

The model that was developed for the first objective of this study was used to estimate the milk transport costs. The results from the milk transport model were then fed into the GAMS model.

Milk intake and other utility were obtained using the economic engineering approach for intake levels of 24,000 l/hr., 40,000 l/hr., 60,000 l/hr., 120,000 l/hr. and 240,000 l/hr. (leading consultancy firm). These costs were provided by Global Engineering Alliance (GEA) technology. Milk intake costs included in the model include costs for milk intake, tanker emptying, tanker cleaning in place (CIP), milk storage, batch tracking, and milk pasteurisation and milk separation. Other utility costs include costs for construction of all building bases and plants, construction of all site development work (roads, weighbridge, landscaping, drainage and yards), water treatment (surface, waste water, fire water), utilities (refrigeration, labs, ventilation, electrical, steam boilers, compressed air) and financial contributions and fees. These costs were obtained from a leading consultancy firm and were depreciated over 15 years with a 5% interest rate applied. From these costs a linear relationship is assumed and the following regression line was fitted to total annual intake and other utility costs:

Total Intake and Other Utility Costs = €0.005x + €748,138

R^2= 0.996,

where x= million litres of milk processed annually.

Fixed and variable processing costs were also obtained for butter plus SMP, WMP and cheese using the economic engineering approach. For butter plus SMP plants, costs were

obtained for plants with capacity to produce 1.78 tonnes of butter and 3 tonnes of SMP per hour, 2.68 tonnes of butter and 5 tonnes of SMP per hour, 5.35 tonnes of butter 7.5 tonnes of SMP per hour and 10 tonnes of butter and 15 tonnes of SMP per hour. For cheese plants costs were obtained for plants with capacity of 0.85t/hr., 1.92t/hr., 3.2t/hr., 5.12t/hr. and 10t/hr. For WMP plants costs were obtained for plants with capacity of 3t/hr., 5t/hr., 7.5t/hr. and 15t/hr. Variable processing costs were obtained from a number of sources. Irish costs were available from Geary *et al.* (2010). The effect of various scales of operation of cheese and butter plants on variable costs was based on findings from Kieler milchwirtschaftliche forschungsberichte studies (Hargens *et al.,* 2003 and Krell, 1993) and scaled to 2009 values using the industrial price index, wholesale price index, or services producer price index as appropriate. Variable costs for different scales of WMP and SMP plants were sourced from a leading consultancy company. Variable costs included labour costs, energy, supplies, packaging costs, storage costs, effluent costs and provision for working capital.

The fixed construction cost was based on consultation among the service providers within the Irish dairy industry (leading consultancy firm; Tetra Pak, GEA Technology and Westfalia). All equipment was depreciated over a 15 years and 5% interest rate was applied to cost of equipment. The greenfield site costs were related to the most advanced and proven equipment currently available, arranged into the most efficient layout with the required utilities.

As processing cost and scale relationships seemed approximately linear, linear regression estimates were fitted to litres of milk per annum and total costs per annum for each product for each factory size. A good fit as measured by Pearsons correlation coefficient $R2$ for all products' was found.

Butter_SMP TPC = €0.034x + €3,116,300 R^2=0.9979

WMP TPC= €0.045x + €1,983,526 R^2=0.9993

Cheese TPC = €0.037x + €555,907 R^2=0.9991

Where TPC = total processing cost, and x = million litres of milk processed annually.

5.3 Research Methodology

A simulation model was used to solve the first objective in this thesis. Simulations of agricultural systems are developed to accurately describe the evolution of the systems (Shalloo *et al.,* 2004). Simulation models provide the opportunity to explore difficult relationships that cannot be explained in any other way. They allow examination with a far greater range of variables over a much wider range of conditions that is feasible in practice (Shalloo *et al.* 2004). Simulation is a powerful and important tool because it provides a way in which alternative designs, plans and/or policies can be evaluated without having to experiment on a real system, which may be prohibitively costly, time-consuming, or simply impractical to do. The strength of simulation is that it enables precisely this "what if" analysis, i.e., it allows to "look into the future" under certain assumptions (Rozinat *et al.* 2007).

The simulation model developed simulated the six components of milk transport namely; transport driving, assembly driving, on farm activities, on farm pumping, plant non-pumping and plant pumping.

Transport driving involves the time spent driving from the plant to the first farm and from last farm to the plant. This was calculated using a sub model developed by Quinlan *et al.*, 2006, it was then linked to the simulation model. The average driving speed for transport driving was estimated to be 35 miles per hour. Assembly driving involves time spent driving between farms on the route. The model simulated the quantity of milk available

from each farm every 3rd day. The average driving speed for assembly driving was estimated to be 20 miles per hour (Twomey 2010). On-farm routine activities includes time spent attaching the hose, agitating the milk, sampling, rinsing the tank, paperwork etc. on farms. It was estimated that on average on-farm routine activities took 5 minutes per supplier. Pumping rate at the farm was estimated to be 386 litres per minute. This includes tanker washing, waiting time, office, meals, etc., this activity takes 30 minutes per route. Pumping rate at the plant was estimated to be 1136 litres per minute.

Limitations of Simulations models

It can be argued that simulation models lack the credibility of field experiments (McCall, 1999), also simulation is not an analytical method and its application does not lead automatically to an optimal solution of the problems studied. It allows us to make a statement like, "If X is increased, Y will require extra input. But it does not provide answers like, "Cost is minimised if you take action X" (Bratley *et al.,* 1987).

A mixed integer linear program model was used to solve the second objective in this thesis. Mathematical modelling is a tool commonly used in the study of agricultural systems. System models provide a simplified description of system components and their interactions. Thornley (2001) provided four possible reasons for building a model; to provide a convenient summary of a set of data, to reduce the requirement for ad hoc experimentation, to make predictions and to provide an understanding of the system's operation. Optimisation models seek to optimise some criterion or set of criterion subject to a set of constraints (King *et al*., 1993).

The objective function of the problem in this study was written as follows:
Minimise:

$$\sum_{v}\sum_{a} X_{va} * (T_f + T_{km} * C_m) + \sum_{t}\sum_{a} Y_{ta} * FC_{ta} + \sum_{t}\sum_{a} Y_{ta} * VC_{ta} + \sum_{d}\sum_{p} Z_{dp} * VC_{dp} + \sum_{d}\sum_{p} Z_{dp} * FC_{dp}$$

Where:

r = rural districts (1-156)

s = sites (6-27)

t = Milk intake (6-27)

p = plants (6-27)

d = dairy products (Butter, Cheese, WMP, SMP)

X = *Quantity of milk transported*

Y = Integer binary (0, 1) variable of activity t at site (s)

Z = Integer binary (0, 1) variable of activity d at plant (p)

T_f= Transport cost fixed element

T_{tm}= Transport mileage

C_m= Cost of transport per mile

FC_{ts}= Fixed costs of Milk Intake &Other Utilities (t) at site (s)

VC_{ts}=Variable Costs of Milk Intake &Other Utilities (t) at site (s)

VC_{dp}= Variable processing costs of dairy products (d) at plant (p)

FC_{dp}= Fixed processing costs of dairy products (d) at plant (p)

mav_r= milk available at rural district (r)

Model constraints

> (i)   The quantity of milk transported from rural district (r) to the sites (s) must be equal to the amount of milk available at rural district (r)

$$\sum_{r=1}^{R} X = mav_r$$

> (ii)   The quantity of milk at milk intake (t) must be less than or equal to Capacity of Milk Intake (t) for each site

$$\sum_{s=1}^{S} t \leq \sum_{s=1}^{S} ICAP_y$$, with (ICAP) as fixed capacity of integer variable y

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(iii) The quantity of products (Qd) produced at plant (p) must be less than or equal to the capacity of plant (p) to produce the product (d)

$$\sum_{p=1}^{P}\sum_{d=1}^{D}PQ_d \leq \sum_{p=1}^{P}PCCAP_{dz}$$, with (PCCAP) as fixed capacity of integer variable z

The General Algebraic Modeling System (GAMS) was used to solve the problem poised by the second objective in this study. GAMS is specifically designed for modeling linear, nonlinear and mixed integer optimization problems. The system is especially useful with large, complex problems. GAMS is available for use on personal computers, workstations, mainframes and supercomputers. Optimisation

Limitations of mixed integer linear program models

Optimisation models are generally developed for a specific situation and are, therefore, less suited to study the consequences of a wide range of management strategies (Jalvingh *et al.,* 1992). Linear program models are based on the hypothesis of linear relations between inputs and outputs. This means that inputs and outputs can be added, multiplied and divided. But the relations between inputs and outputs are not always clear. In real life, most of the relations are non-linear.

5.4 Summary of steps in the methodology process

2 Objectives

1. To develop, validate and describe
a national milk transport model for
simulating milk transport activities in Ireland

2. To determine the least cost dairy
processing sector configuration in
2020 taking cognisance of regional
milk supply, processing and milk
costs

Data Collection

1st objective

2nd objective

Quinlan *et al*., 2005 survey, published
literature, processors annual reports, the
Central Statistics office of Ireland ,
industry consultation

Quinlan *et al.,* 2011, Laepple and
Hennessy, 2011, leading consultancy firm,
Global Engineering Alliance (GEA)
technology, consultancy firm, Geary *et
al*., 2010, Hargens et al., 2003 and Krell,
1993).

Research Methodology

1st objective

2nd objective

Quinlan *et al*., 2006 sub model
Simulation model developed in
Excel.

Transport costs taken from simulation
model developed for first objective
of this study. GAMS used to solve
the mixed integer linear program
problem.

5.7 Conclusion

This chapter presented the methodology utilised in this research to determine the least cost industry configuration for the Irish dairy industry post milk abolition in 2020. The research centered around two central objectives firstly; to develop a transport model for simulating milk transport activities in Ireland and secondly to determine the least cost dairy configuration post milk quota abolition. For the first objective of this study a simulation model was utilised. This technique was considered the most appropriate as it allowed for the examination of a wide range of efficiency factors in milk transport that would not be feasible in practice. The minimisation problem in the second objective was formulated as a mixed integer linear programming problem. GAMS was considered an appropriate tool in solving this problem as it involved large models; therefore the efficiency of computer solution procedures became relevant.

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Chapter 6: The Transport Implications for Ireland of the Elimination of the Milk Quota Regime in 2015

THE TRANSORT IMPLICATIONS FOR IRELAND OF THE ELIMINATION OF THE MILK QUOTA REGIME IN 2015

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ABSTRACT

Increasing competition and globalisation of markets is leading to on-going rationalisation in the global dairy industry. In Ireland the number of milk producers is declining and dairy companies are consolidating their operations in terms of the numbers and sizes of dairy processing plants. EU dairy policy is also undergoing some changes. The milk quota system which is currently implemented through the CAP (Common Agricultural Policy) regime and which limits the milk production of individual farms in Ireland will be fully dismantled by 2015. Reports have suggested that Ireland has the potential to substantially increase its milk supply; predictions of increases in supply centre around 40-50% by 2020 (ICOS, 2010).

Transportation costs are especially important where perishable products from farms are being transported and specialised handling is required. In 2005 milk transport costs were estimated to be in excess of €57 million per annum in Ireland (Quinlan 2005). Therefore milk transport (which involves the transportation of a bulky, perishable liquid collected from many spatially separated farms to centralized processing plants) plays a central role in planning for the future of the Irish dairy industry.

A simulation/optimization model of milk transport was developed to allow for the examination of a wide range of efficiency factors in milk transport including pumping rates, tanker sizes, size of suppliers, density of milk supply and frequency of collection. The model also facilitated the investigation of the effect of alternative industry development scenarios on milk transport costs. The model integrates capital costs, labour utilisation and running costs. As transportation is a significant contributor to carbon emissions and Ireland has committed itself to reducing its emissions by 20% by 2020, the model also estimated carbon emissions.

A key output of the model is the estimated total milk transport costs and associated carbon emission levels.

6.1 Introduction

The dairy industry is important to the Irish economy (IBEC 2010). Currently the Irish dairy sector is comprised of 22 Co-operatives/PLCs with about 7,000 direct employees (IBEC 2010) and approximately 19,000 dairy farmers (Prospectus 2009). The total milk output in 2009 amounted to 4,801 million litres from 1.107 million dairy cows (CSO 2009). Ireland's dairy industry is heavily export orientated with 80% of production destined for international markets (Promar and Prospectus 2009). Total dairy exports are worth an estimated €2.2bn per year, with the UK and other EU countries accounting for 32% and 48% of exports in 2008 respectively (Promar and Prospectus 2009).

Many recent reports on the Irish dairy industry (Promar and Prospectus 2009 and 2003, Bord Bia 2010) have commented that the industry is in urgent need of consolidation. Less fragmentation and greater consolidation can result in significant efficiency gains. In attempting to streamline the dairy industry, all components of costs must be examined. Milk transport is a component of these costs, which requires investigation with clear saving highlighted in previous studies (Quinlan 2005).

Milk transport involves the collection of milk by tanker from farm, the transport of milk to the factory and the unloading of the tanker at the factory. Major factors influencing milk transport costs are the spatial relationship of the farms and the processing plants, truck and tanker size, frequency of collection, seasonality of milk production, labour costs, route management, fuel costs, interest rates etc.

Studies carried out on milk transport in Ireland include Quinlan 2006; this study divided milk transport into six components; transport driving, assembly driving, on-farm routine

activities, plant non-pumping, farm pumping and plant pumping. It found that the only component affected by fewer processing plants was transport driving, therefore this component was investigated in detail. The study then looked at the implications of reducing the current dairy industry structure of 23 plants firstly to 12 plants, then 9 plants and finally 6 plants. In aggregate terms the results showed that milk transport costs would increase by €3, €5, €7 and €13 million per annum if processing plants were reduced from 23 to 12 to 9 to 6 (good location) and 6 (poor location) respectively. Detailed results of a comprehensive survey on milk transport costs in Ireland showed that the weighted average milk transport cost in the Republic of Ireland was estimated to be 1.15 cent per litre (Quinlan *et al.* 2005). The study concluded that milk transport costs vary due to many factors, including milk supplier size and location, processing plant size and location, tanker capacity and seasonality. A previous survey on milk transport was completed in 1996 (Shanahan, 1996). Comparing the two survey results it is estimated that weighted average milk transport costs increased by just 7% over 8 years. Butler *et al.* examined the milk routing in 2003. Their paper illustrates how a geographic information system (GIS) based DSS allows a scheduler interact with optimisation algorithms to co-ordinate milk collection routes. In their study the authors conclude that although operational research has produced useful techniques, implementing them in the real world has not been successful. In the milk collection sector a decision support system (DSS) that complements rather than replaces the scheduler is more successful. The effect of efficiency factors including tanker size, frequency of collection, transport mileage and supplier size on milk transport costs in Ireland was also examined in past decades (Keane 1986).

Overall there is limited research on milk transport in Ireland; it is an area where inefficiency is apparent at present due to the overlap of milk processors catchment areas

and where reorganisation could result in sizeable cost reductions (Quinlan 2005). Therefore, it was clear that there was a need to develop an up-to-date comprehensive model that could examine strategic questions in relation to milk transport.

Simulation models of agricultural systems are developed to accurately describe the evolution of the systems (Shalloo *et al.,* 2004). It can be argued that simulation models lack the creditability of field experiments (McCall, 1993), but that they provide the opportunity to explore difficult relationships that cannot be explored in any other way. Simulation models provide the opportunity to explore difficult relationships that cannot be explained in any other way. They allow examination with a far greater range of variables over a much wider range of conditions that is feasible in practice (Shalloo *et al* 2004). Simulation is a powerful and important tool because it provides a way in which alternative designs, plans and/or policies can be evaluated without having to experiment on a real system, which may be prohibitively costly, time-consuming, or simply impractical to do. The strength of simulation is that it enables precisely this "what if" analysis, i.e., it allows to "look into the future" under certain assumptions (Rozinat *et al*. 2007).

 Successfully development of a simulation model primarily depends on obtaining appropriate and sufficient supporting data (Rozinat *et al*. 2007). The information for the simulation model developed in this paper was secured through consultation with dairy industry experts.

The simulation model developed was constructed to allow the investigation of the effects of a wide range of efficiency factors including pumping rates, tanker sizes, the size of

suppliers, density of milk supply and the frequency of collection on milk transport costs and on carbon emissions.

The objectives of this paper are firstly, to describe the milk transport model and the unique aspects of the model and secondly, to demonstrate an application of the model using various scenarios. Scenarios explored include the examination of the effect on transport costs of increases in milk supply post milk quota and also the impact of using different milk tanker sizes on milk transport costs. The model can be used to inform the decision making process and ultimately minimise total milk transport costs and associated environmental impacts.

6.2 Materials and Methods

6.2.1 Dairy Industry

6.2.1.1. Dairy Farmers

Irish dairy farmers are considered to be both technically competent and commercially focused (Promar and Prospectus 2003). Dairy farm numbers are consolidating faster than any other system of farming in Ireland. There are less than 19,000 dairy farmers in Ireland at present, which is approximately 50% of the total 15 years ago. Average dairy output has increased from 115,000 litres to 250,000 litres in the last 15 years (Promar and Prospectus 2009).

As milk is a perishable product frequency of milk collection from farmers is a very important factor; practical alternatives include twice a day, once a day, every 2nd day and every 3rd day.

6.2.1.2 Milk Processors

At present the dairy processing industry in Ireland is dominated by six large processors located adjacent to each other in a band running through mid-Munster and south Leinster that is the heartland of dairy farming in Ireland. Many of the larger processors have more than one processing site in this region, with liquid milk plants also located in the main urban centres outside the region. The six largest companies process about 80% of the 4,801 million litres of milk produced, with this number rising to eight companies processing about 90% (Promar and Prospectus 2003).

6.2.1.3. Seasonality of Milk Production

Milk production in Ireland is primarily grass based; therefore it varies widely on a seasonal basis throughout the year. With the exception of liquid milk producers, Irish dairy farmers have continually adjusted the date of calving so that, through compact calving, the total herd calves around a time that facilitates lowest milk production cost. Supplies of milk are highest during the months of mid-April to August and lowest during the months of December and January; the peak to trough month ratio in Ireland is 6:1 Ireland (Promar and Prospectus 2009) (Figure 6.1). The model incorporates this seasonal nature of milk production.

The seasonal pattern of milk production has consequences for milk transport operations because a sufficient number of milk tankers must be provided to accommodate peak summer supplies, with consequent spare capacity during the periods of low milk volumes (Quinlan 2005). Through consultation with industry experts it was found that approximately 350 milk tankers of 22,500 litres capacity are required to collect the national milk supply.

The survey conducted by Quinlan 2005 found that the most frequently used tanker size in Ireland was 22,500 litres. Through consultation with the industry it became evident that although the tankers have this capacity, they do not run at full capacity and at off-peak times run at even less.

6.2.2 Milk Transport Model

6.2.3 Description of Milk Transport Model

A simulation model of milk transport for the Irish dairy industry was developed. The simulation of milk transport was based on dairy factories collecting milk on a least cost basis from dairy farms.

Transport conditions and costs vary from milk processors to milk processor due to factors such as total volume of milk assembled, the density of supplies within the area, the average size of producer and the efficiency of route structure.

The costs in the simulation model developed in this paper are based on estimates for a model route, which is considered to be typical of Irish conditions (based on personal communication with milk transport managers). There is a schematic diagram of the milk transport model presented in Figure 6.2.

The model was simulated over a 12-month period. The model displays the following information for each month; capital cost, labour cost, running cost, cost of spare capacity

and diesel emissions. Details of the simulation model will be described in detail subsequently.

A key and important part of the development of the milk transport model was the inclusion of the transportation model developed by Quinlan in 2006. This model used a transportation algorithm to minimise the transportation mileage from rural districts to processors.

This transportation model allocates milk supplies from rural districts to factories based on a least cost basis (Figure 6.3) . In this model, transportation costs are treated as a direct linear function of the number of units shipped. The result from this analysis was linked to the simulation model .

6.2.3.1 Capital Costs

Approximately 350 tankers collect the total milk supply in Ireland. Capital costs incurred by each tanker included truck replacement, tanker replacement, tax, insurance and interest. Tanker replacement costs €120,000 per tanker which is typically written off over 15 years which equates to a cost of €8,000 per annum. Truck replacement costs €85,000 per truck which is typically written off over 5 years which equates to a cost of €17,000 per annum. Insurance was estimated at €6,000 per year per tanker. Motor tax was estimated to be €2,600 per annum per tanker. Interest on tanker and truck replacement is assumed to be 5% per annum which is equal to €5,501 per annum. Cost of tankers and trucks were estimated through consultation with industry experts.

The availability of spare tankers and trucks is vital in the dairy industry. Milk is a bulky, perishable product so spare tankers and trucks must be available in the case of a breakdown. It was found that in Ireland, processors have about 10% spare tankers and trucks. Cost of spare capacity includes cost of tanker, cost of truck, insurance and tax

6.2.3.2 Labour Costs

Labour requirement per month was dependent on the number of loads per day, which is influenced by the volume of milk production, tanker size and frequency of milk collection. Labour requirement per month was calculated by breaking the transport activity down into its components as follows:

❖ Transport Driving; this involves the time spent driving from plant to first farm and from last farm to plant (see Figure 6.4). This figure is derived by dividing the transport mileage per month by the average driving speed for transport driving. The average driving speed for transport driving was estimated to be 35 miles per hour.

❖ Assembly Driving; this involves time spent driving between farms on the route (see Figure 6.4). This figure is arrived by dividing the assembly driving mileage per month by the average driving speed for assembly driving. The average driving speed for assembly driving was estimated to be 20 miles per hour.

❖ On-Farm Routine Activities; this includes time spent attaching hose, agitating milk, sampling, rinsing tank, paperwork etc. on farms. On average on-farm routine activities takes 5 minutes per supplier. The total time taken on on-farm routine activities each month is calculated by multiplying the number of loads per month by the number of suppliers on a typical route by 5 minutes.

❖ On-Farm Pumping; the time spent on this activity is calculated by dividing the quantity of milk collected by pumping rate on the farm.

❖ Plant Non-Pumping; this includes tanker washing, waiting time, office, meals, etc., this activity takes 30 minutes per route.

❖ Plant Pumping; it is calculated by dividing the quantity of milk collected per month by pumping rate at the plant.

Labour cost per hour was assumed to be €20, this includes PRSI and P.A.Y.E.

6.2.3.3 Running Costs

Running costs include tyre replacement, service/maintenance and fuel from assembly mileage, transport mileage and milk pumping on the farm and at the plant. Tyre replacement was estimated to be €2,950 per truck per annum and €2,700 per tanker per annum. Service/maintenance costs were estimated to be €9,000 per truck/tanker per annum. Insurance, tax and tyre replacement, service/maintenance costs were estimated based on advice from industry experts. Assembly mileage as previously discussed is the distance travelled from farm to farm on a typical milk collection route. It was assumed that the distance between each farm within each route was 1.5 miles. Total fuel required for the number of loads per month by the corresponding number of suppliers visited per load multiplied by 1.5 miles. Transport mileage as previously discussed is the distance travelled from the plant to the first farm and from last farm to plant. Transport mileage was calculated using the model developed by Quinlan 2006. The total cost of fuel required for transport mileage each month was derived by multiplying the number of loads per month by transport driving mileage by the price of the fuel/mile. Each milk tanker load burns fuel while pumping milk on the farm and at the plant as the engine remains running while the milk is being collected. This is necessary as the milk suction pump is operated off the lorry hydraulics. On average 2.73 litres of fuel is used per route to pump milk into milk tankers

on the farm and 0.91 litres of fuel is utilised to pump milk out of milk tankers at the plant. Therefore, the fuel cost for pumping on the farm and at plant is calculated by multiplying the average number of routes per month by the two factors discussed by the price of the fuel.

6.2.3.4 Carbon Emissions

During milk transport carbon dioxide is emitted when milk is pumped into the tanker at the farm, during assembly driving and transport driving and also at the plant when the milk is pumped from the tanker into the silo. The assembly driving and transport driving greenhouse gas emissions were calculated using emission factors from the Environmental Protection Agency (EPA). The EPA provided a table detailing fuel consumption and CO_2 emissions for different truck sizes/technologies (Table 6.1). Industry experts confirmed that the truck size and technology most frequently used was the artic 42 tonneHD Euro IV - 2005 Standards. This truck burns 0.576 litres of diesel per mile travelled and also emits 1521.32g/CO_2 per mile travelled. Therefore, total emissions per month from transport driving and assembly driving were calculated by multiplying total mileage each month by this factor. CO_2 is also emitted from pumping on the farm and at the plant. 2,640g of carbon dioxide is emitted from every litre of diesel utilised while pumping on the farm and at the plant. Therefore, total emissions from this activity are calculated by multiplying the total diesel utilised while pumping by 2,640g/per litre.

6.2.3.5 Outputs

The outputs from the model include physical indicators (number of loads per day, number of suppliers per route) financial indicators (total milk transport costs) and environmental impacts (carbon emissions). Capital costs, costs of spares, labour costs and running cost are summarised for each month of the year. Total milk transport costs, which include total

capital costs, total labour costs, and total running costs, are calculated in million euro, cents and cents per litre transported. Carbon emissions emitted from driving mileage and pumping of the milk on the farm and at the plant are calculated in tonnes of CO_2.

6.2.3.6 Assumptions

- ❖ Pumping rate at the farm was estimated to be 386 litres per minute (Quinlan 2005)
- ❖ Pumping rate at the plant was estimated to be 1136 litres per minute (Quinlan 2005)
- ❖ It was assumed that milk was collected every three days.
- ❖ The distance between farms on each route was assumed to be 1.5 miles (consultation with industry experts)
- ❖ Milk supply from each farm was equal
- ❖ The cost of fuel was assumed to be €1 per litre excluding VAT

6.2.4 Milk Transport Scenarios

In the 1984 reform of the CAP milk quotas were introduced as a means to restrict milk production and overall EU expenditures on agriculture. Recently it was announced that the EU milk quota system will be dismantled by 2015 following a number of small yearly expansions of one percent every year between 2009/10 and 2013/14 (Europa 2008). This will have a significant impact on the Irish dairy industry as milk production will no longer be restricted.

Three milk transport scenarios were explored; they correspond to different milk production and technology scenarios.

The benchmark scenario or S1 resembles the current milk production and milk transport situation in Ireland (Table 6.2). In 2009 milk production was exceptionally low due to poor market conditions and global recession; therefore, 2008 was used as the baseline year for

milk production volumes in the benchmark scenario. In 2008 total yearly milk production was 4,958 million litres. In this scenario there were 19,000 dairy farmers as this is the current number of dairy farmers in Ireland. The transport fleet consisted of 350 milk tankers; the capacity of each milk tanker was 22,800 litres (5000 gallons).

As milk production will no longer be restricted in Ireland post 2015; in S2 and S3 an alternative milk production scenario was explored. Through consultation with dairy industry experts it was estimated that milk production will increase by 30% by 2020. In S2 and S3 milk production was estimated to be 6,446.61 million litres (this figure represents the 30% increase on 2008 milk production volumes). In these scenarios it was estimated that there will be 15,500 dairy farmers in Ireland in 2020 (Teagasc, 2010).

Two scenarios were investigated in relation to the expanded dairy industry and compared to S1;

❖ Milk tanker capacity remaining as they were 22,800 litres (S2)
❖ Milk tanker capacity increased to 27,360 litres (S3)

The financial and environmental impacts of the three scenarios are presented.

6.3 Results

6.3.1 Physical Outputs

Litres of milk supplied per month in S1, S2 and S3 are shown in Table 6.3. Also the quantity of milk supplied every third day from each farm in S1, S2 and S3is shown in Table 6.3.

The average working hours per day are shown in Table 6.4. During the peak month of May in S1, S2 and S3 the average working hours were 12 hours a day. In order to accommodate peak supplies, 435 tankers were required in S2 and 378 tankers were required in S3.

In S1 the average number of loads per day were 226, 402, 550, 860, 989, 957, 880, 788, 660, 663, 412 and 268 from January through to December respectively. In S2 the average number of loads per day were 294, 522, 715, 1,119, 1,286, 1,244, 1,144, 1,024, 858, 861, 536 and 349 from January through to December respectively. In S3 the average numbers of loads per day were 294, 522, 594, 929, 1068, 1033, 950, 850, 712, 861, 536 and 349 from January through to December respectively.

6.3.1.1 Mileage from sub model

The model developed by Quinlan (2006) was used to allocate tanker loads from rural districts to factories on a least cost basis. Transport driving mileage was 49.12 miles, 49.89 miles and 49.79 miles per return trip per route for S1, S2 and S3 respectively.

6.3.1.2 Total mileage

Total mileage for S1, S2 and S3 was 14.87 million, 18.09 million and 16.12 million respectively.

6.3.2 Financial outputs

6.3.2.1 Capital costs

Annual capital costs were €15,124,380 €18,797,445 and €18,056,781 for S1, S2 and S3 respectively. Capital costs per litre were 0.035 cent, 0.029 cent and 0.028 cent for S1, S2 and S3 respectively.

6.3.2.2 Running costs

Annual running costs in S1, S2 and S3 were €13,484,966, €16,611,760 and €15,796,750. Running cost per litre was 0.028 cent for S1 and 0.027 cent for S2 and 0.025 cent for S3.

6.3.2.3 Labour costs

Annual labour costs were €21,820,096 €25,389,620 and €23,827,500 for S1, S2 and S3 respectively. Labour costs per litre of milk were 0.044 cent, 0.039 cent and 0.037 cent for S1, S2 and S3.

6.3.2.4 Total transport cost

Total milk transport costs in S1, S2 and S3 were €50.43 million, €60.80 million and €57.68 million respectively. Total milk transport costs per litre were 1.02 cent, 0.94 cent and 0.89 cent for S1, S2 and S3 (Table 6.5).

6.3.3 Carbon Dioxide Emissions

Carbon dioxide emissions from travelling in S1 were 22,624 tonnes and 2,246 tonnes from pumping. Carbon dioxide emissions from travelling in S2 were 27,525 tonnes and 2,920 tonnes from pumping. Carbon dioxide emissions from travelling in S3 were 24,526 tonnes and 2,568 tonnes from pumping Total emissions were 24,870 tonnes 30,446 tonnes and 27,094 tonnes for S1, S2 and S3 respectively (Table 6.5).These are equivalent to 5.02g, 4.72g and 4.20g per litre of milk for S1, S2 and S3 respectively.

6.4 Discussion

6.4.1 Transport Costs

The tanker fleet in S1 consisted of 350 tankers/trucks with an average tanker capacity of 22,800 litres. The tanker fleet in S2 consisted of 435tankers/trucks with an average tanker

capacity of 22,800 litres. Additional tankers were required in S2 to accommodate peak summer milk supplies as milk production increased by 30%. The tanker fleet in S3 consisted of 378 tankers/trucks with an average tanker capacity of 27,360 litres. Again additional tankers were required in S3 to accommodate additional milk production; however fewer were required as the tankers utilised in S3 had a higher capacity than the tankers in S1 and S2.

When compared with the benchmark S1 scenario, capital costs per litre were lower in S2 and in S3. This was attributable to the higher milk production volume in S2 and S3 as the costs of the tankers and trucks were spread out over a larger volume of milk.

The trucks in S3 cost €95,000 each and the tankers cost €140,000 each compared with a cost per truck in S2 of €85,000 and a cost per tanker of €120,000. However, as mentioned previously, the trucks in S3 were higher capacity; therefore fewer were required; which resulted in lower capital costs per litre in S3 when compared to S2.

When compared to the benchmark scenario running costs per litre were lower for S2 and S3. This was attributable to the fact that as milk production increased on each farm by 30% in S2 and S3 the number of suppliers required to fill a tanker reduced. This resulted in lower assembly driving mileage in these scenarios. Running costs per litre were lower in S3 compared with S2. This was a consequence of the higher capacity tankers in S3. This resulted in fewer numbers of loads each day, particularly in the peak months of April to September.

Labour hours in all scenarios were approximately the same each day per tanker. When compared to the benchmark scenario S1 labour costs per litre were lower for S2 and S3. This was a result of higher milk production volumes in these scenarios, which allowed

costs to be spread out over a larger volume. Labour costs were lower in S3 compared with S2 as fewer tankers were required in S3 due to the higher tanker capacity this resulted in lower total labour hours.

In summary, total milk transport costs were 20% higher in S2 (€60.80million) and 14% higher in S3 (€57.68 million)when compared with S1 (€50.43 million). This was a result of the 30% higher milk production volume in S2 and S3. However, milk transport cost per litre was lower in S2 (0.94 cent) and S3 (0.89 cent) when compared to S1 (1.02 cent) as total milk transport costs are spread out over a higher volume of milk production. Therefore as milk production volumes increase post quota abolition it is estimated that milk transport costs per litre will fall.

Total milk transport costs and milk transport costs per litre were lower in S3 when compared to S2. This was as a result of the higher tanker capacity (27,360 litres) in S3. The higher tanker capacity resulted in lower capital costs, lower running costs and lower labour costs. This clearly illustrates that there are cost savings to be made in switching from tankers with a capacity of 22,800 litres to tankers with a capacity of 27,360 litres. In New Zealand, Fonterra are currently using milk tankers with 27,000 litres capacity (excluding trailer) (Fonterra, 2010). Therefore as the milk industry in Ireland expands; milk tankers with a capacity of 27,000 litres are clearly a better investment than the current milk tanker capacity.

As well as changing tanker sizes, savings in milk transport costs could also be achieved by the elimination of cross haulage, faster milk pumping speeds and new milk concentration technology.

In practice the sourcing of milk for delivery to processing plants deviates from the benchmark least cost pattern (Breathnach 2000).Presently in Ireland distances between farms or rural districts and processing plants are sometimes unnecessarily long, due for example to dairies assembling milk from areas closer to their neighbours' processing plants. This has arisen for many reasons, including in particular the pattern of merger and takeover activity within the industry over many years (Breathnach 2000). Quinlan (2005) estimated actual transport mileage in Ireland using the submodel used in this paper. It was estimated that there would be a 32% overall reduction in transport mileage in moving from the current pattern of milk collection to the benchmark ideal.

Increasing pumping rates at the farm and at the plant can also result in lower milk transport costs. In Ireland average pumping rates at the plant are 1,136 litres a minute this is compared to our major competitor countries Denmark and New Zealand where pumping rates are 1,500 litres minute and 2,000 litres a minute respectively (Irish Farmers Journal, 2009).

Fonterra in New Zealand have introduced milk concentration technology that can concentrate milk to approximately half its original volume before being transported to the factory. They have implemented this technology in the South Island area of New Zealand and it has resulted in 3,000 fewer tanker movements in that area (Fonterra 2010).

Therefore there is scope for further savings in milk transport costs in Ireland, which will benefit milk suppliers and processors. The milk transport model developed in this paper can be used to estimate the savings.

An often overlooked but very important issue in simulation is validation. Therefore, in the present study, actual data for the year 2005 was compared with the results from the model to determine the reliability of the key model outputs. In the milk transport model tanker loads are allocated to factories based on least cost, therefore, the cross haulage currently happening in Ireland is eliminated. Transport driving mileage based on optimum allocation of tankers from rural districts to factories is approximately 49 miles per return trip, however actual transport mileage in Ireland is approximately 75 miles[4] per return trip. If this figure is inputted, total transport costs are €56.93 million or 1.15 cent per litre. In 2005, Quinlan 2005 conducted a milk transport survey with all the dairies in Ireland; it was found that milk transport costs were €57 million or 1.15 cent per litre. The figures from the model are very close to the actual results in the survey; therefore, the simulated results match actual data.

6.4.2 Carbon Emissions

Under the Kyoto protocol, Ireland cannot allow national emissions to be more than 13% above 1990 levels between 2008 and 2012 (O' Brien *et al* 2009). In 2008, total GHG emissions in Ireland were 67.44 million tonnes carbon dioxide equivalent while the Kyoto agreement limit over the 5 years (2008-2012) is 62.84 million tonnes per year (EPA, 2010). Transport is the third highest contributor to national GHG emissions; in 2008 emissions from transport were 14.255 million tonnes (EPA, 2010). The transport sector is the fastest growing contributor to national GHG emission levels. Carbon emissions from milk transport were found to represent 0.17% of total emissions from transport in Ireland. Carbon emissions for milk transport in Ireland have not previously been calculated; therefore that was a novel element of the milk transport model. In the milk transport model total emissions were higher in S2 and S3 as the quantity of milk transported was higher in S2 and S3, resulting in higher mileage and more pumping on the farm and at the plant.

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[4] This figure was calculated in previous research

However, carbon dioxide emissions per litre of milk are lower for S2 and S3 when compared to S1. This is a result of the 30% increase in milk supply per supplier, which reduces assembly mileage and thus carbon dioxide emissions.

6.5 Conclusion

Milk Transport is central to the strategic plans for the future of the Irish dairy industry. In this analysis a simulation model was designed to support decision-makers to make decisions about milk transport activities. The milk transport model was developed to allow for the examination of a wide range of efficiency factors in milk transport including pumping rates, tanker sizes, size of suppliers, density of milk supply and frequency of collection. It integrates the capital costs, labour costs, and running costs incurred on a typical milk route. The model developed by Quinlan 2006 to facilitate the allocation of milk supplies from rural districts to factories on a least cost basis was included. When the results of the model were compared to a milk survey on milk transport costs carried out in 2005 the results were favourable. This showed that the model can be used in confidence to aid in decision making while analysing the milk transport activities. Ireland is committed to the Kyoto protocol, therefore it is essential that plans for the future of the industry take these commitments into consideration. The milk transport model calculated the carbon emissions for milk transport in Ireland. It is anticipated that the milk transport model will be used to investigate the influence of changes in future milk production on transport costs and on the environment. It is also anticipated that the model will be used in planning the optimum configuration of the Irish dairy industry post milk quota elimination.

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Figure 6. 1: Milk supply 2009
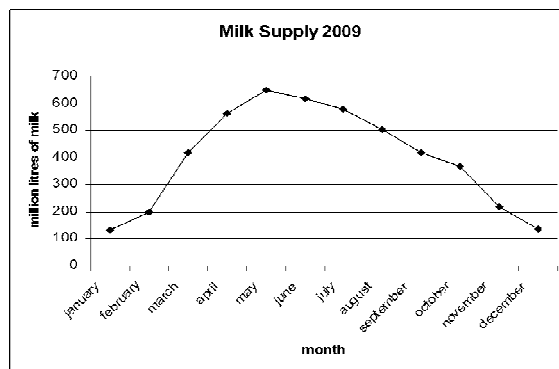
Source: Promar and Prospectus 2009

Figure 6. 2: Milk Transport Mode

Schematic Diagram of Milk Transport Model
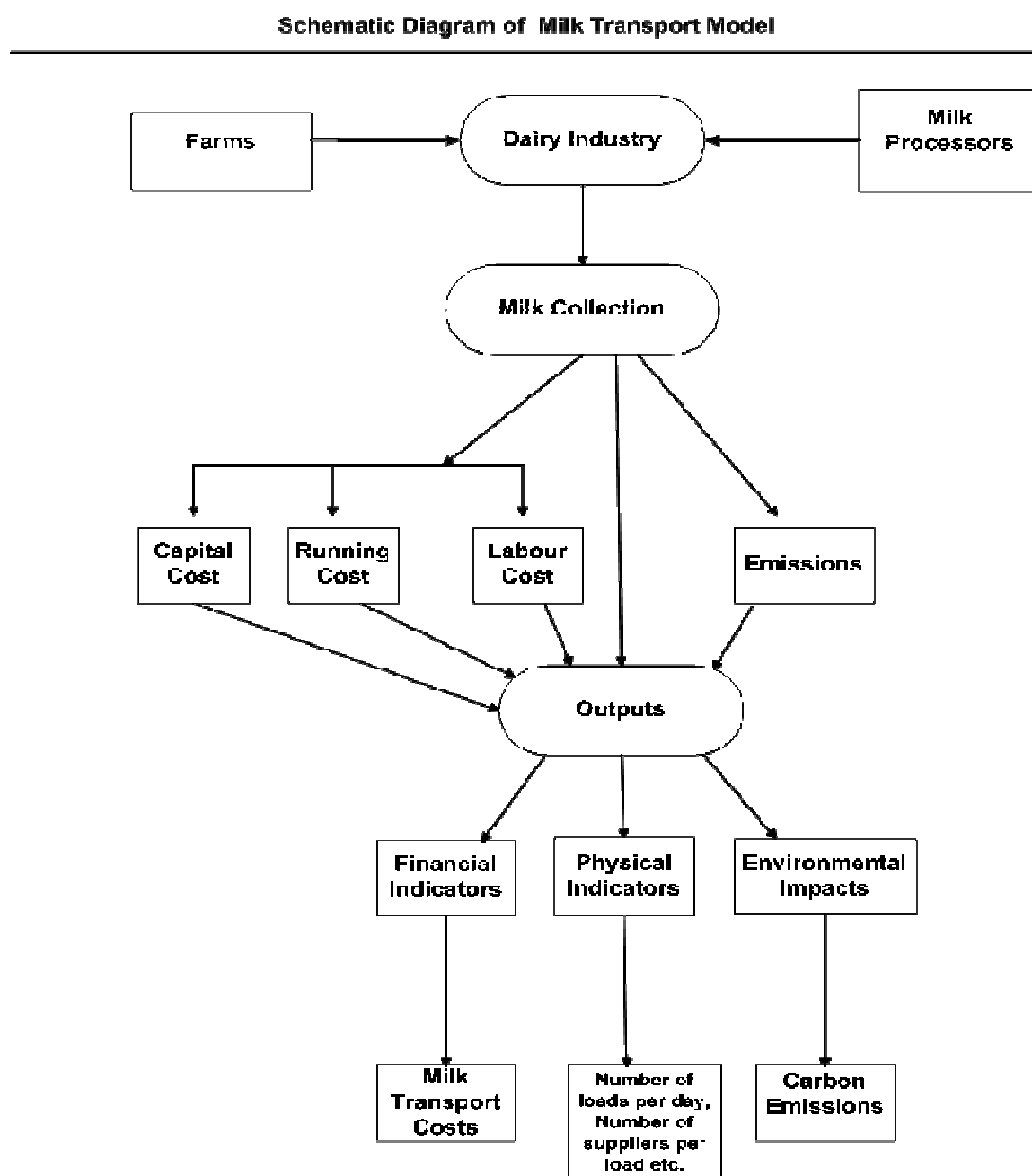
Source: Own diagram

Figure 6. 3: Rural districts in Ireland
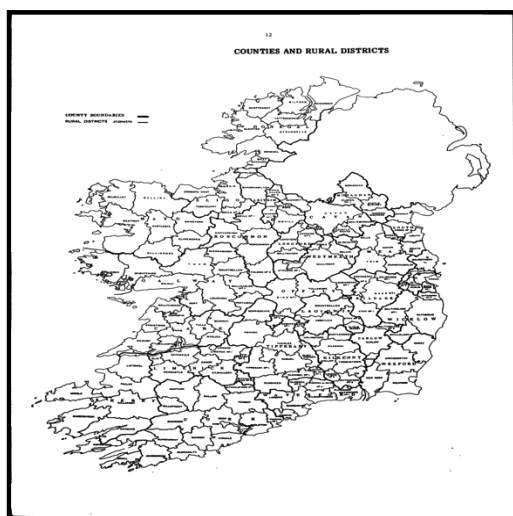
Source: Own diagram

Figure 6. 4: Illustration of Milk Transport
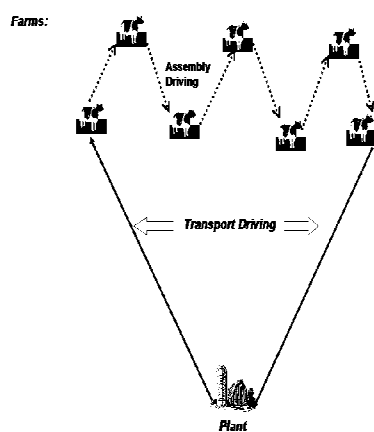
Source: Own diagram

Table 6. 1: Fuel Consumption and CO$_2$ Emissions from Different Truck Sizes/Technologies

Truck Size	Technology	Urban	Rural	Highway	Urban	Rural	Highway	Urban	Rural	Highway	Urban	Rural	Highway
		g diesel/km travelled			G CO2/km travelled			Litres diesel/km travelled			litres diesel/100 km travelled		
Articulated 40 - 50 t	Conventional	482.589	362.764	288.18	1532.027	1151.631	914.856	0.580	0.436	0.346	58.010	43.607	34.641
Articulated 40 - 50 t	HD Euro I - 91/542/EEC Stage I	423.236	321.104	254.732	1343.605	1019.377	808.672	0.509	0.386	0.306	50.876	38.599	30.621
Articulated 40 - 50 t	HD Euro II - 91/542/EEC Stage II	413.33	316.669	249.261	1312.157	1005.297	791.304	0.497	0.381	0.300	49.685	38.066	29.963
Articulated 40 - 50 t	HD Euro III - 2000 StandardsHD Euro	424.936	322.428	252.62	1349.002	1023.580	801.967	0.511	0.388	0.304	51.080	38.758	30.367
Articulated 40 – 50t	IV - 2005 Standards	395.229	299.511	233.676	1254.694	950.828	741.828	0.475	0.360	0.281	47.509	36.003	28.089

Source: EPA 2010

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Table 6. 2: Key Attributes of Scenarios

	S1	S2	S3
Yearly milk supply (million litres)	4,958	6,446	6,446
Number of farmers	20,000	15,500	15,500
Number of milk tankers	350	435	378
Milk tanker capacity at peak (litres)	22,344	22,344	26,904
Milk tanker capacity at off-peak (litres)	18,240	18,240	18,240
Frequency of milk collection	Every 3rd day	Every 3rd day	Every 3rd day
Distance between farms (miles)	1.5	1.5	1.5
Transport driving mileage	49.12	49.89	49.79
Diesel cost per litre (euro)	1	1	1
Labour cost per hour (euro)	20	20	20
Pumping rate at the farm	386 litres/minute	386 litres/minute	386 litres/minute
Pumping rate at the plant	1136 litres/minute	1136 litres /minute	1136 litres /minute
Capital costs (€'000)	13,749.44	17,088.59	16,415.26
Running costs (€'000)	13,484.97	16,611.76	15,796.75
Labour costs (€'000)	21,820.97	25,389.62	23,827.5

Source: Own calculations

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Table 6. 3: Industry Data

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Million Litres of milk supplied per month (CSO, 2008)												
S1	127.3	204.6	379.8	574.9	683.2	639.3	607.8	543.8	440.8	373.5	232.4	151.3
S2	165.49	265.98	493.74	747.37	888.16	831.09	790.14	706.94	573.04	485.55	302.12	196.69
S3	165.49	265.98	493.74	747.37	888.16	831.09	790.14	706.94	573.04	485.55	302.12	196.69
Every third day milk supply from each farm (litres)												
S1	650	1157	1940	3035	3490	3375	3105	2778	2327	1908	1187	773
S2	974	1733	2905	4544	5226	5053	4649	4160	3484	2857	1778	1157
S3	974	1733	2905	4544	5226	5053	4649	4160	3484	2857	1778	1157

Source: Own calculations

Table 6. 4: Number of Loads per day and Number of Working Hours per day

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Number of loads per day												
S1	226	402	550	860	989	957	880	788	660	663	412	268
S2	294	522	715	1119	1286	1244	1144	1024	858	861	536	349
S3	294	522	594	929	1068	1033	950	850	712	861	536	349
Number of working hours per day per tanker[5]												
S1	5	6	8	11	12	12	11	10	8	8	6	5
S2	4	6	7	10	12	11	10	10	8	8	6	4
S3	5	6	8	11	12	12	11	10	8	8	7	5

Source: Own calculations

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[5] This figure represents the number of hours required per day per tanker; it does not correspond to the number of working hours per person per day.

Table 6. 5: Milk Transport Costs and Tonnes CO^2 Emitted for each Scenario

Scenario	Milk Transport Costs Million €	Milk Transport Costs cents/litre	Tonnes CO^2
S1	50.43	1.02	24,870
S2	60.80	0.094	30,446
S3	57.68	0.089	27,094

Source: Own calculations

Chapter 7: Milk Transport Costs under differing seasonality assumptions for the Irish Dairy Industry

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Milk production in Ireland is seasonal in nature with the milk supply matching grass growth at farm level. The objective of this paper was to estimate the milk transport costs and carbon emissions from milk transport associated with alternative milk supply patterns and output levels in Ireland. A milk transport simulation model was used to simulate three alternative milk supply patterns with peak to trough month ratios of 5.37:1, 2.71:1 and 8:1. It was found that milk transport costs were not very sensitive to alternative milk supply patterns. Alternative milk supply pattern also had very little effect on carbon emissions from milk transport in Ireland.

Key Words: Seasonality, Milk transport, Simulation model, Carbon emissions.

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7.1 Introduction

The dairy sector is one of the most important sectors of Irish agriculture and accounts for 28% of agricultural output (Bord Bia 2009). The dairy industry also makes a significant contribution to sustaining rural communities, in 2010 there were approximately 18,294 dairy farmers (Department of Agriculture, Fisheries and Food 2011) and the dairy processing industry employs 7,000 people (Irish Business and Employers Confederation 2010). In 2009 total dairy exports were worth €2billion (Department of Agriculture, Fisheries and Food 2010a). Since the introduction of the EU milk quota regime in 1984, Ireland's milk deliveries have remained very close to milk quota at 5.1 billion litres per annum (Department of Agriculture, Fisheries and Food 2010b), however as the European milk quota increases annually by 1%, with its ultimate removals in 2015, the European dairy sector will soon face an opportunity, for the first time in a generation, to expand.

Milk producers in Ireland enjoy a comparative advantage over their competitors as the temperate climate favours grass growth and grazing conditions over a long period (Dillon *et al.,* 1995). Therefore milk production in Ireland is primarily grass-based, resulting in a low cost system where the objective of the system is to produce as much milk as possible from grazed grass (Dillon *et al*. 1995, Shalloo *et al*. 2004). Irish dairy farmers target the start of calving with the objective of matching grass supply with feed demand (Shalloo *et al*. 2004). Increased proportions of grass in the diet result in grass based systems having a competitive advantage over grain based systems, which are therefore less exposed to feed price volatility (Shalloo 2009). The pasture-based feeding system also has the advantage of being perceived to be more animal welfare and environmentally sustainable (Promar and Prospectus 2003). However, compact calving in the spring with the objective of matching feed supply

and demand results in a seasonal milk supply. Seasonality can be measured using a ratio of a peak month to a trough month in milk deliveries each year (Smyth *et al.* 2007). In Ireland the peak month is May and the trough month is January. The peak to trough month ratio in Ireland in 2010 was 5.9:1, in 2009 the peak to trough month ratio was 4.91:1 and in 2008 it was 5.4:1 (Central Statistics Office 2011).

Highly seasonal milk supplies have consequences for all aspects of the milk supply chain including milk transport. For milk transport operations a sufficient number of milk tankers must be provided to accommodate peak summer supplies, with consequent spare capacity during the periods of low milk supplies(Quinlan 2005). Seasonality also imposes additional costs at processor level in the form of additional processing capacity, increased seasonal labour, as well as increased financing and storage costs. Seasonal milk supply profiles may also restrict the types of products that can be produced as the opportunity for product diversification in the months where milk is at peak can be limited by the physical amount of processing capacity available, while there may be insufficient milk available in the low supply months to meet a required minimum market need.

Milk transport involves multi stop collection of a perishable food product ex farm using bulk milk tankers to dairy factories. Keane (1986) broke milk transport into six components; transport driving (driving from the plant to the first farm and from the last farm back to the plant), assembly driving (driving from farm to farm), pumping on the farm, pumping at the plant, non-pumping activities at plant and farm (non-pumping activities). Transport conditions and costs vary between processors due to factors such as total volume of milk assembled, the density of supplies within the area, the average size of producer and the efficiency of route structure.

Milk transport is a challenging logistical problem that has long been of interest to operational researchers for many years(Butler *et al*. 2004). Various milk transport planning models using simulation techniques have been developed around the world. Simulation allows examination with a far greater range of variables over a much wider range of conditions than is feasible in practice (Shalloo *et al.* 2004). Simulation is a powerful and important tool because it provides a way in which alternative designs, plans and/or policies can be evaluated without having to experiment on a real system, which may be prohibitively costly, time-consuming, or simply impractical (Rozinat *et al.* 2009). Simulation models are useful for communicating the results of alternative research strategies to stakeholders and decision makers (Gijsbers 2001).

Mellalieu and Hall (1983) developed a long-term planning model 'NETPLAN' which incorporated milk transport activities. The model was used for long term planning in relation to milk transport activities in the New Zealand Co-operative Dairy Company. The U.S. Dairy Sector Simulator Model (Cornell 1998) was developed to simulate milk transport costs in the US associated with different milk tanker sizes and different milk transport wage rates. The US Dairy Sector Simulator was seen as an important tool, which was able to provide useful policy guidance (Cornell 1998). Dooley *et al*. (2005) developed a milk transport simulation model to estimate transport costs in New Zealand associated with the introduction of milk segregation, which was subsequently used to evaluate alternative transport management strategies for the New Zealand dairy industry.

The objective of this paper was to estimate the milk transport costs and carbon emissions from milk transport associated with alternative milk supply patterns and output levels in Ireland.

7.2 Materials and Methods

Model description

The model used in this paper is a simulation model developed by Quinlan *et al.* (2010). The model simulated the six components of milk transport namely; transport driving, assembly driving, on farm activities, on farm pumping, plant non-pumping and plant pumping, each milk transport component is described subsequently. Key variables include monthly labour requirement, mileage travelled (as a result of assembly driving and transport driving) and the quantity of tankers required to transport peak milk supply. The model was simulated over a 12 month period. Key outputs include monthly capital costs, monthly running costs and monthly labour cost. Carbon emissions from milk transport activities are also simulated (Quinlan *et al.* 2010). Other outputs from the model include physical indicators (number of loads per day, number of suppliers per route).

The model permitted the examination of a wide range of efficiency factors in milk transport including pumping rates, tanker sizes, size of suppliers, and density of milk supply and frequency of collection and also facilitated the investigation of the effect of alternative industry development scenarios on milk transport costs (Quinlan *et al.* 2010). This approach was considered superior to the complex modelling approach as it provided immediate answers (Bjarnadóttir 2004). A unique feature of the model was that within the simulation model a transportation algorithm was used to allocate milk supplies from rural districts to factories based on a least cost basis and thus minimise the transportation mileage from rural districts to processors i.e. transport driving mileage (Quinlan et al. 2010). Quinlan et al. (2010) found that the model could be used in confidence to aid in decision making while analysing milk transport activities in Ireland.

7.2.1 Components of Milk Transport

Transport driving

Transport driving involves the time spent driving from the plant to the first farm and from last farm to the plant (Quinlan *et al.* 2010). This was calculated using a sub model, which was linked to the simulation model. In 2010 there were approximately 18,294 dairy farmers in the Irish Republic (Department of Agriculture, Fisheries and Food 2011). In order to calculate the transport mileage these farms were aggregated into one of 156 rural districts based on their location from data from the Central Statistics Office. Such an approach is similar to the U.S. Dairy Sector Simulator Model discussed earlier. A single town at the milk production centroid was then chosen to represent the entire supply of the aggregated area. Based on information on annual milk intake by factory, the 19 largest dairy factories were used as potential destinations, as this captured 95% of the milk processing capacity in the country. Using transportation algorithms, the model selects where to process milk such that the transportation costs are minimized(Quinlan *et al.* 2010).

Assembly driving

This involves time spent driving between farms on the route (Quinlan *et al.* 2010). The model simulated the quantity of milk available from each farm every 3rd day. The quantity of suppliers per load was calculated by dividing the capacity of the tanker by the quantity milk available from each supplier, which varied, based on the milk supply profile. The average driving speed for assembly driving was estimated to be 20 miles per hour (Twomey 2010). The number of farms visited in order to fill the tanker will change for each month of year as milk supplies change on farm.

On-Farm Routine Activities

This includes time spent attaching the hose, agitating the milk, sampling, rinsing the tank, paperwork etc. on farms. It was estimated that on average on-farm routine activities took 5 minutes per supplier (Quinlan *et al.* 2010).

On-Farm Pumping

Pumping rate at the farm was estimated to be 386 litres per minute (Quinlan *et al.* 2010)

Plant Non-Pumping

This includes tanker washing, waiting time, office, meals, etc., this activity takes 30 minutes per route (Quinlan *et al.* 2010).

Plant Pumping

Pumping rate at the plant was estimated to be 1136 litres per minute (Quinlan *et al.* 2010).

7.2.2 Cost data

The costs in the simulation model developed in this paper are based on estimates for a model route, which is considered to be typical of Irish conditions. Model route assumptions included the following; milk tankers had a capacity of 27,000 litres, milk collection was every 3rd day (Quinlan *et al*. 2010), all factories remained open all year round, pumping rate at the farm was estimated to be 386 litres per minute (Quinlan *et al.* 2005), pumping rate at the plant was estimated to be 1136 litres per minute (Quinlan *et al.* 2005), the distance between farms on each route was assumed

to be 1.5 miles (consultation with industry experts) and all tankers were assumed to work 12 hours each day during the peak month of May (Twomey 2010). In 2018 it is projected that there will be 15,500 dairy farmers (Teagasc, 2011).

The transport costs included in the model are representative of the 2005 values taken from a survey conducted by Quinlan (2005) on milk transport costs in Ireland. This survey was carried out across the dairy industry in Ireland with representatives from all of the major processors completing the survey. These costs were updated with 2010 values with the aid of published literature, processors annual reports, the Central Statistics office of Ireland or were assumed based on consultation with industry experts. The costs were then verified using the Delphi method with industry experts. Costs were found to be representative of 2010 industry cost values. Cost information was broken into capital costs, labour costs and running costs, detailed information on costs are described subsequently.

Capital costs

The number of tankers required within the dairy industry depends on the milk supply pattern and volume of milk supplied and the number of hours each tanker is in operation at peak. Annual costs, which relate to capital expenditure including truck depreciation, tanker depreciation, interest and capital costs per tanker are shown in Table 7.1 (Quinlan *et al.* 2010). The lifespan of the truck is depreciated based on the truck running; for 220,000 miles and the trailer or milk tanker was based on the trailer running for 660,000 miles (consultation with industry experts). In the analysis it was assumed that all capital is borrowed over a 7 year period with an interest rate of5% per annum. Capital costs include provisions for 10% spare tankers and trucks as extra tankers are required to accommodate fluctuations in milk production,

transportation schedules and normal glitches that can occur in transportation systems.

Labour costs

Labour requirement was based on the number of hours that tanker operative's were working per month. It was dependent on the daily volume of milk production, tanker size and frequency of milk collection. Labour cost was assumed to be €20 per hour based on industry guidelines and includes PRSI contributions (Quinlan *et. al* 2010), which is similar to costs of workers in the transportable goods services for 2007 where the most up to date information is available for Ireland (Central Statistics Office 2009).

Running costs

Running costs include insurance, tax, tyre replacement, service/maintenance and fuel, which are shown in Table 7. 2. Fuel was utilised in milk transport from assembly mileage, transport mileage and from milk pumping on the farm and at the plant (as the engine remains running while the milk is being collected to allow the milk suction pump to operate). Fuel costs which are the largest proportion of running costs were included at €1/L plus VAT (average value in 2010) (Pumps 2011).

7.2.3 Carbon emission

During milk transport carbon dioxide is emitted when milk is pumped into the tanker at the farm, during assembly driving and transport driving and also at the plant when the milk is pumped from the tanker into the silo. Details were included in the model based on CO_2 emissions (Environmental Protection Agency 2010) from differing

truck sizes/technologies (Table 7.3). Therefore projections associated with emissions and milk transport was included in the model outputs.

7.2.4 Scenarios explored

Three milk supply patterns were investigated (Figure 7.1); Scenario 1 (S1) was the milk supply pattern realised in Ireland in 2008. In 2009 milk production was exceptionally low due to poor market conditions and extremely poor weather conditions, therefore 2008 was used as the baseline year for milk production volumes with a peak to trough month ratio of 5.37 :1 (denoted as current) (May: January) (Central Statistics Office 2009).

Scenario 2 (S2) involved a moderate reduction in seasonality (denoted as moderate). Reports have concluded that the Irish dairy industry will need to alter their product mix and produce more high value products (Department of Agriculture, Fisheries and Food 2010c, Bord Bia 2010, Promar and Prospectus 2009), this would demand a reduction in seasonality. Taking this into consideration this scenario simulates a slight reduction in seasonality with a peak to trough month ratio of 2.71:1 (May: January).

It has been suggested that Irish farmers should aspire to a more compact calving pattern, thus reducing feed costs and improving competitiveness (Teagasc 2009), which would ultimately result in a more synchronised relation between grass growth and feed demand. Prior to milk quota introduction the peak to trough month ratio in Ireland was on average 8:1 (Central Statistics Office 2011). Therefore, scenario 3 (denoted as seasonal) simulated an increase in seasonality post milk quota abolition. The peak to trough month ratio was 8:1.

The abolition of EU milk quotas in 2015 presents a real opportunity for the Irish dairy sector with significant potential for increased milk production. The Food Harvest report 2020 forecasted a 50% increase in milk production by 2020 (Department of Agriculture, Fisheries and Food 2010c). Laepple and Hennessy (2010) forecasted an increase of 45% in milk output post milk quota abolition. Lips and Reider (2005) found that the potential for increased milk production post milk quotas was comparatively greater in Ireland, with a projected (38.6%) relative to the average of all EU member states. Donnellan and Hennessy (2007) also revealed that Ireland had capacity to increase milk supply by 20% using existing resources on dairy farms.

Therefore, four levels of milk output were examined; firstly the national milk output in 2008 denoted as (a) was explored (4,958 million litres). Secondly a 20% increase in milk output by 2020 denoted as (b) was examined (5,950 million litres) (Donnellan and Hennessy 2007, Teagasc 2010). Thirdly, a 38% increase in milk output by 2020 denoted as (c) was investigated (6,843 million litres) (Lips and Reider 2005). Finally a 45% increase in milk production by 2020 denoted as (d) was explored (7,190 million litres) (Laepple and Hennessy 2010, Department of Agriculture, Fisheries and Food 2010c). The scenarios explored are summarised in Table 7.4.

7.3 Results and Discussion

7.3.1 Physical outputs

The number of loads of milk per day for each month is shown in Table 7.5. In every scenario, the number of loads required to transport the milk is at its highest in May

(peak month) and at its lowest in January (trough month). The number of suppliers visited each day and the amount of working hours per day per tanker are also shown in table 7.6. In all scenarios the number of suppliers per load is lowest in May as milk producers are producing their peak milk supply; therefore, fewer suppliers are required to fill a load. The number of suppliers is highest in January as milk producers are producing low volumes of milk and therefore more suppliers are required to fill a load.

For current milk production volumes 310 tankers, 290 tankers and 325 tankers were required to collect the milk supply in Ireland in S1a, S2a and S3a respectively (Table 7.6).

When milk volumes increased by 20%, 345 tankers, 320 tankers and 360 tankers were required to collect the milk in S1b, S2b and S3b respectively (Table 7.6).

When milk volumes increased by 38%, 385 tankers, 360 tankers and 405 tankers were required to collect the milk for S1c, S2c and S3c respectively (Table 7.6).

When milk volumes increased by 45%, 400 tankers, 370 tankers and 420 tankers were required to collect the milk in S1d, S2d and S3d respectively (Table 7.6).

In all scenarios as the milk production pattern becomes more even fewer tankers are required to transport the milk and as it become more seasonal more tankers are required to transport the milk at peak. As milk production increases the quantity of tankers required to transport the milk increases.

7.3.2 Seasonal pattern of milk transport costs

In scenario 1 for current and all increased milk production volumes the peak month accounts for approximately 10% of annual costs (annual costs consists of total capital costs, total running costs and total capital costs) and the trough month 6%,

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however the peak month accounts for approximately 14% of milk supply compared with the trough month accounting for 3% of milk supply (Figure 7.2). This illustrates that the seasonal pattern of milk transport costs has less variation than the milk supply pattern. This is primarily due to capital cost been spread evenly throughout the year

In scenario 2 for the current and all increased milk production volumes the peak month accounts for approximately 10% of annual costs and the trough month 7%, however the peak month accounts for approximately 13% of milk supply compared with the trough month accounting for 5% of milk supply (Figure 7.3). Again milk transport costs have less variation than the milk supply pattern due to capital costs.

In scenario 3 for the current milk production volume and all increased milk production volumes the peak month accounts for approximately 10% of annual costs and the trough month 6%, however the peak month accounts for approximately 15% of milk supply compared with the trough month accounting for 2% of milk supply (Figure 7.4).

7.3.3 Impact of different milk supply patterns on milk transport costs

Capital costs, running costs, labour costs and total transport costs for each scenario are shown in Table 7.7. A reduction in seasonality for the scenarios denoted S2a (current total milk production) S2b (current output plus 20%), S2c (current output plus 38%) and S2d (current output plus 45%) resulted in a decrease in milk transport costs per litre of 3.06%, 3.41%, 3.53% and 3.57% when compared to S1. This represented a saving in transport costs at all output levels of 0.03 cent/l which equates to industry savings per annum of €1.49 million(current total milk production), €1.79 million (current output plus 20%), €2.05 million (current output

plus 38%) and €2.16 million(current output plus 45%). Capital costs decreased by 6-7% and running costs decreased by 3-4%. Little or no savings were achievable in labour costs as it was assumed that the labour was used on an hourly basis. However, when one combines the number of tankers and the labour requirement for each scenario total labour costs for each scenario are very similar.

When a more extreme milk supply curve was adopted (S3) milk supply costs in cent per litre increased by 1.02%, 1.14%, 2.35% and 2.38% for S3a (current milk output), S3b (current milk output plus 20%), S3c (current milk output plus 38%) and S3d (current milk output plus 45%) respectively when compared to S1. This equates to industry increases in milk transport costs of €0.5 million(current milk output), €0.6 millionS3b (current milk output plus 20%), €1.37 million (current milk output plus 38%) and €1.44 million (current milk output plus 45%) per annum. Capital costs increased by 4.5-5.5% and running increased by 2-2.5%. There was little or no increase in costs attributable to labour. This illustrates that when a more extreme milk supply curve was adopted and compared to S1, the change in milk transport costs in cent per litre were minimal.

Overall this study has shown that total milk transport costs are not very sensitive to seasonality. Nonetheless, there are a number of other components that need to be assessed before a final conclusion can be drawn on milk supply patterns. According to Keane (1980) consideration of alternative milk supply patterns involves a detailed cost benefit analysis including milk production cost differences associated with alternative calving dates, and cost differences due to differing supply patterns in milk transport, milk processing, and product storage and stock finance. Downey (2005) stated that analysis on milk supply patterns should embrace issues such as market requirements, product portfolio choice, milk transport costs, and manufacturing costs

and farm production costs. It is only when all of the components are answered can a clear conclusion be drawn about seasonality within the Irish dairy industry.

7.3.4 Effect of different milk supply output on transport costs

When milk output increased by 20% milk transport costs per litre decreased by approximately 10% across milk supply patterns. When milk output increased by 38% there was a saving of 12%-13% in milk transport costs per litre for all milk supply profiles and when milk output increased by 45% there was savings of between 13% and 15% in milk transport costs per litre for all milk supply profiles. As milk output increased total milk transport costs increased but unit costs decreased as there are changes in work practices. It can therefore be expected in the dairy industry that even though milk output will increase post quota that the unit costs of milk transport will decline once the potential efficiencies are adopted.

7.3.5 Environmental impacts

Under the Kyoto protocol, Ireland cannot allow national emissions to be more than 13% above 1990 levels between 2008 and 2012 (O' Brien *et al.* 2010). Furthermore, Ireland within the EU has also agreed to a 20% reduction in emissions by 2020 when compared to 2005.The future direction and plans for the dairy industry will to a large degree be shaped by these requirements.

   Total tonnes of carbon dioxide for each scenario investigated were calculated and shown in table 7.8. In all scenarios the frequency of milk collection was the same; consequently assembly mileage (driving from farm to farm) did not change. Transport driving mileage (driving from factory to the first farm and driving from last farm back to the factory) for each month of the year was different for each milk

supply pattern however total transport driving mileage for each scenario were similar. Therefore, there was very little difference in total tonnes of carbon dioxide emitted from each of the three alternative milk supply patterns investigated from a transport perspective.

The analysis reported here for the transport of the Irish milk supply suggests that carbon emissions from milk transport are unlikely to be reduced if milk supply profiles become more even. Likewise, carbon emissions did not increase as milk supply profile became more seasonal.

When milk output levels increased total carbon emissions from milk transport increased, this could result in issues for current and future legislation within the dairy industry. Some countries have attempted to reduce carbon emissions attributable to milk transport. In New Zealand they have endeavoured to reduce carbon emissions from milk transport by the introduction of milk concentration plants (reverse osmosis plants). In one region where it is practiced it is estimated there are 3000 fewer tanker trips and carbon emissions are reduced by 1350 tonnes (International Dairy Federation 2010) In Australia, Murray Goulburn has converted one third of its fleet to Liquefied Natural Gas (LNG); progressively, the whole fleet will be converted to LNG with an anticipated saving of 1,730 tonnes of CO2-e/year (International Dairy Federation 2010). Arla, a leading European dairy company, is also working to reduce fuel consumption and carbon emissions from milk transport. They are using bio-diesel blend to operate their milk transport fleet in the UK, they also use this fuel in Sweden and are testing it in Denmark (International Dairy Federation 2010).

7.4 Conclusions

This study revealed that total milk transport costs are not very sensitive to seasonality. Savings in total transport costs of 3-4% were obtained when switching to less seasonal milk supply pattern and increases in transport costs of 1%-2.5% were incurred when a more seasonal approach was followed. As milk output increased total milk transport cost savings increased from €1.5 to €2.2 million per annum when a more even milk supply was adopted and total milk transport costs increased from €0.5 million to €1.5 million per annum when a more seasonal milk supply pattern was simulated (volume effect). Carbon dioxide emissions from milk transport did not vary when milk supply profiles changed. Therefore, there were no environmental benefits/consequences of operating more even/seasonal milk supply patterns. This paper only examined the impact of even milk supply patterns on milk transport costs, supplementary studies on the impact of an even milk supply on production costs and processing costs are essential before any definitive decisions are made on the optimum milk supply for the Irish dairy industry.

ACKNOWLEDGEMENT

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Table 7.1: **Capital cost per truck/tanker**

Capital Costs	€
Truck replacement (Written off over 5 years)	95,000
Tanker replacement (Written off over 10 years)	140,000
Interest	5% per annum

Source: Quinlan et al 2010

Table 7.2: **Running cost per truck/tanker per annum**

Running cost	€
Insurance	6,000
Tax	2,600
Tyre replacement	2,950 per truck 2,700 per tanker
Service/maintenance	9,000

Source: Quinlan et al 2010

7.3: **Fuel Consumption and CO$_2$ Emissions from Different Truck Sizes**

Truck Size	Technology	Urban	Rural	Highway	Urban	Rural	Highway	Urban	Rural	Highway	Urban	Rural	Highway
		g diesel/km travelled			G CO2/km travelled			Litres diesel/km travelled			litres diesel/100 km travelled		
Articulated 40 - 50 t	Conventional	482.589	362.764	288.18	1532.027	1151.631	914.856	0.580	0.436	0.346	58.010	43.607	34.641
Articulated 40 - 50 t	HD Euro I - 91/542/EEC Stage I	423.236	321.104	254.732	1343.605	1019.377	808.672	0.509	0.386	0.306	50.876	38.599	30.621
Articulated 40 - 50 t	HD Euro II - 91/542/EEC Stage II	413.33	316.669	249.261	1312.157	1005.297	791.304	0.497	0.381	0.300	49.685	38.066	29.963
Articulated 40 - 50 t	HD Euro III - 2000 StandardsHD Euro	424.936	322.428	252.62	1349.002	1023.580	801.967	0.511	0.388	0.304	51.080	38.758	30.367
Articulated 40 – 50t	IV - 2005 Standards	395.229	299.511	233.676	1254.694	950.828	741.828	0.475	0.360	0.281	47.509	36.003	28.089

Source: EPA 2010

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Table 7.4: Summary of scenarios explored

Seasonality Ratio	Current milk production Output	Current milk production output plus 20%	Current milk production output plus 38%	Current milk production output plus 45%
5.37:1	S1a	S1b	S1c	S1d
2.71:1	S2a	S2b	S2c	S2d
8:1	S3a	S3b	S3c	S3d

Source: Own calculations

Table 7.5: Physical Outputs

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Number of loads per day												
S1a	226	402	457	715	822	795	731	654	548	449	412	268
S2a	408	420	460	616	751	721	612	549	515	458	406	415
S3a	161	319	399	729	871	796	746	675	596	481	401	240
S1b	184	327	548	857	986	954	877	785	657	539	335	218
S2b	332	503	552	739	901	865	734	658	618	550	487	338
S3b	131	259	479	875	1045	956	895	810	715	577	327	195
S1c	211	376	630	986	1134	1097	1009	903	756	620	386	251
S2c	382	579	635	850	1036	995	844	757	711	632	560	388
S3c	151	298	551	1006	1202	1099	1029	932	822	664	376	224
S1d	222	395	662	1036	1192	1152	1060	948	794	651	405	264
S2d	401	608	667	893	1088	1046	887	796	747	664	588	408
S3d	159	313	579	1057	1263	1155	1082	979	864	697	395	236
Number of suppliers per load												
S1a	28	16	14	9	8	8	9	10	12	14	15	24
S2a	16	15	14	10	8	9	10	12	12	14	16	15
S3a	39	20	16	9	7	8	8	9	11	13	16	26
S1b	30	17	10	6	6	6	6	7	8	10	16	25
S2b	17	11	10	7	6	6	7	8	9	10	11	16
S3b	39	20	11	6	5	5	6	6	7	9	16	26
S1c	26	15	9	6	5	5	5	6	7	9	14	22
S2c	14	9	9	6	5	6	7	7	8	9	10	14
S3c	36	18	10	5	5	5	5	6	7	8	15	25
S1d	23	13	8	5	4	4	5	5	7	8	13	20
S2d	13	8	8	6	5	5	6	6	7	8	9	13
S3d	33	16	9	5	4	4	5	5	6	7	13	22
Number working hours per day per tanker												
S1a	5	7	8	11	12	12	11	11	9	8	7	6
S2a	8	8	9	11	12	12	11	10	10	9	8	8
S3a	5	6	7	11	12	12	11	10	10	8	7	5
S1b	4	6	8	11	12	12	11	10	9	8	6	5
S2b	6	8	9	11	12	12	11	10	9	9	8	6
S3b	4	5	7	11	12	12	11	10	9	8	5	4
S1c	4	6	8	11	12	12	11	10	9	8	6	5
S2c	6	8	9	11	12	12	11	10	9	9	8	6
S3c	3	5	7	11	12	12	11	10	9	8	5	4
S1d	4	5	8	11	12	12	11	10	9	8	6	4
S2d	6	8	8	11	12	12	11	10	9	8	8	6
S3d	3	5	7	11	12	12	11	10	9	8	5	4

Source: Own calculations

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Table 7.6:Number of Tankers

Scenario	Number of Milk Tankers
S1a	310
S2a	290
S3a	325
S1b	345
S2b	320
S3b	360
S1c	385
S2c	360
S3c	405
S1d	400
S2d	370
S3d	420

Source: Own calculations

Table 7.7: **Milk Transport Costs**

|	S1a	S1b	S1c	S1d	S2a	S2b	S2c	S2d	S3a	S3b	S3c	S3d
Capital costs Million €	11.81	13.15	14.67	15.24	11.05	12.19	13.72	14.10	12.39	13.72	15.43	16.01
Running costs Million €	16.03	17.45	19.37	20.36	15.42	16.83	18.76	19.58	16.34	18.06	19.86	20.85
Labour costs Million €	20.63	21.75	24.06	24.63	20.46	21.74	24.05	24.58	20.56	21.42	24.07	24.63
Total Milk Transport Costs Million €	48.47	52.35	58.11	60.24	46.93	50.77	56.53	58.27	49.29	53.19	59.36	61.49
Milk Transport Costs cents/litre	0.98	0.88	0.85	0.84	0.95	0.85	0.83	0.81	**0.99**	**0.89**	0.87	**0.86**

Source: Own calculations

Table 7.8: **Carbon dioxide emissions for alternative milk supply patterns**

	Current Milk supply pattern Current volume (S1a)	Moderate reduction in Seasonality Current Volume (S2a)	Seasonal Milk Supply Current volume (S3a)	Current Milk supply pattern Current volume plus 20% (S1b)	Moderate reduction in Seasonality Current volume plus 20% (S2b)	Seasonal Milk Supply Current volume plus 20% (S3b)	Current Milk supply pattern Current volume plus 38% (S1c)	Moderate reduction in Seasonality Current volume plus 38% (S2c)	Seasonal Milk Supply Current volume plus 38% (S3c)	Current Milk supply Pattern Plus 45% (S1d)	Moderate reduction in Seasonality Current volume plus 45% (S2d)	Seasonal Milk Supply Current volume plus 45% (S3d)
Tonnes of CO_2	22,084	21,873	21,993	23,496	23,470	23,341	26,333	26,304	26,334	27,306	27,174	27,307

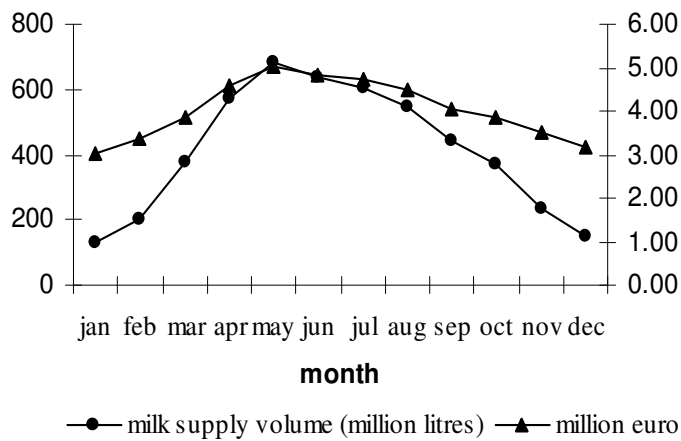**Source: Own calculations**

Figure 7. 1: Alternative milk supply pattern examined
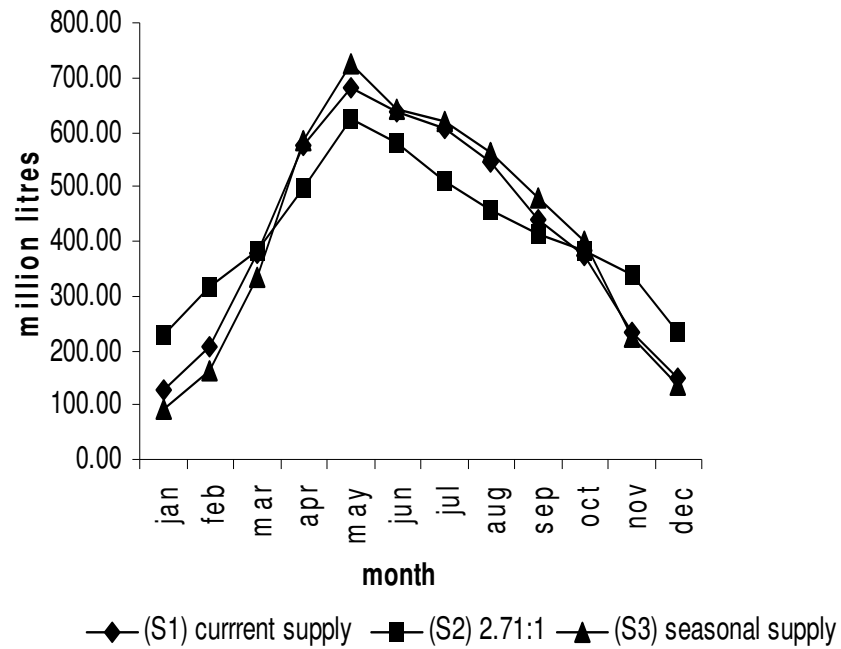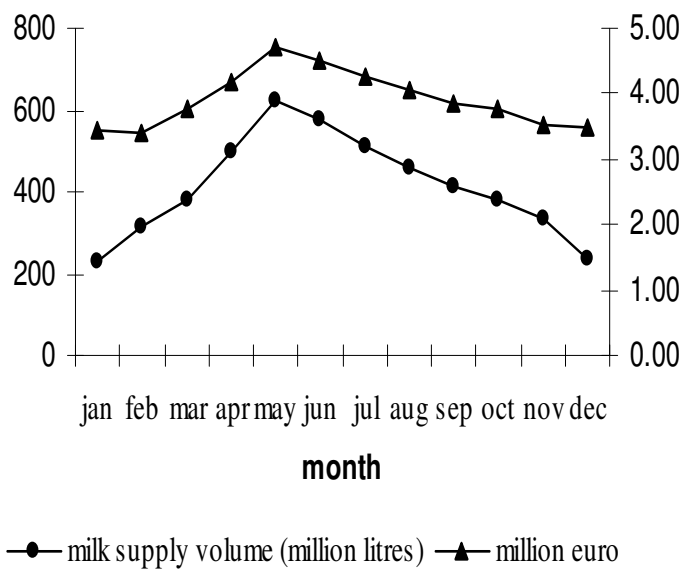

Source: Own diagram

Figure 7. 2: Current Milk Supply Pattern
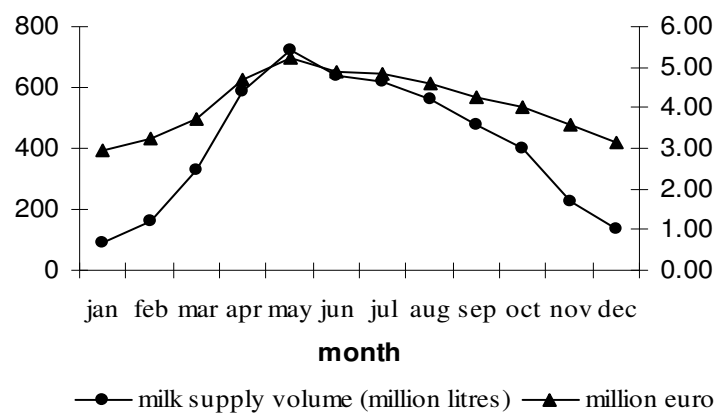

Source: Own diagram

Figure 7. 3: Moderate Reduction in Current Milk Supply

Source: Own diagram

Figure 7. 4: Seasonal Milk Supply Pattern

Source: Own diagram

Chapter 8: Expansion Strategies for the Irish Dairy Industry

Expansion Strategies for the Irish Dairy Industry

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ABSTRACT

Post 2015, the dairy sector in the European Union will face an opportunity, for the first time in a generation, to expand, unhindered. A number of studies have shown that milk production in Ireland will increase significantly post quotas. Current processing capacity will not be sufficient to process the subsequent peak milk supply. Additional processing capacity will be required, whether constructed on existing processing sites or on new sites. A transport optimisation model, which uses transportation algorithms, evaluated the effect on transport costs of routing additional milk supply to existing sites or Greenfield sites. The model works through seeking the optimum strategy, which results in the least cost solution around milk collection and assembly. Findings suggest that processors would achieve significant cost reductions by co-operating in milk transport activities This study could be used to help improve the decision making process around the inevitable changes n the milk processing sector in Ireland. [EconLit citations: C600, L000, L900]. © 2011 Wiley Periodicals, Inc.

8.1 Introduction

In the European Union under the Common Agricultural Policy (CAP), milk quotas have restricted milk production since 1984. However, due to recent changes in the Health Check (2008) of the Common Agricultural Policy (CAP), Irish milk quotas will increase by 9.3% between 2007 and 2013 (Shalloo, 2011) with their eventual abolishment in 2015. Therefore, the Irish dairy sector will soon face an opportunity, for the first time in a generation, to expand. Many reports have noted that the

abolition of EU milk quotas in 2015 presents a real opportunity for the Irish dairy sector with significant potential for increased milk production (Lips and Reider 2005; Donnellan and Hennessey 2007). Lips and Reider (2005) showed that the potential for increased milk production post milk quotas was comparatively greater in Ireland (38.6%) relative to the average of all EU member states. Donnellan and Hennessy (2007) also revealed that Ireland had capacity to increase milk supply by 20% using existing resources on dairy farms. A recently published Irish Department of Agriculture report (Department of Agriculture and Food) (DAFF). The DAFF "Food Harvest 2020 report" forecasted a 50% increase in milk production by 2020 (DAFF, 2010 (a)).

In Ireland the dairy industry is one of the most important indigenous industries and comprises a vital part of the agri-food sector accounting for 29% of agricultural output in 2010 (Bord Bia 2010). The dairy industry also makes a significant contribution to sustaining rural communities, currently there are approximately 18,294 dairy farmers (DAFF, 2010 (b)) and the dairy processing industry employs 7,000 people (IBEC 2010). In 2010, total dairy exports were worth €2.3 billion (Bord Bia 2010). The milk processing sector is divided between three key players, which are located adjacent to each other in a band running through mid-Munster and south Leinster that is the heartland of dairy farming in Ireland. The second tier of processing companies is divided between the north east, the west and the south (O'Connell, 1997). For many reasons, including in particular the pattern of merger and takeover activity within the industry over many years (Breathnach 2000) there tends to be an overlap of milk processors catchment areas (Figure 8.1).

The Irish dairy processing industry is also considered to be fragmented, as individual processors are of a considerably smaller scale than processors in competing countries such as Denmark, Holland and New Zealand. In these countries one processor processes 80% of the milk pool compared with six processors in Ireland (Promar and Prospectus, 2003).

Expansion in national milk output will present major new challenges for the Irish dairy sector. The potential for growth at farm level has implications for the processing sector. At present current processing facilities nationally are nearly at full capacity at peak supply. An increase in output with the current grass based system of production will increase the requirement for additional processing facilities. A model capable of identifying optimal locations for additional milk processing capacity would be instrumental in helping to improve the decision making process around changes in the milk processing sector in Ireland. Similar models have been developed around the world. The objective of these models was to identify the optimum location of processing facilities taking into consideration transport costs and other location factors. Examples include Wouda et al. (2002) who developed a mixed-integer linear program model to find the optimal number of plants and their locations when minimizing the sum of production and transportation costs in order to optimise the supply network of Nutricia (a leading international food processor) in Hungary. Hellmann and Verburg (2008) used an allocation algorithm to identify optimum locations in Europe for future bio fuel processing plants and to allocate bio fuel crops to plants based on transportation costs. Leduc et al. (2009) developed an optimisation model to identify the optimum location of a biomass based methanol

production plant from a transport and environmental perspective in Northern Sweden. The model was considered as a very useful tool for decision makers.

The objectives of this paper were to use regional and national milk supply change projections post milk quota abolition and current milk processing capacities to determine milk transport costs in the Irish Dairy Industry in 2020 if (a) Existing sites were expanded and processed the additional milk supply and (b) new Greenfield sites were constructed to process the additional milk supply. Finally the model was used to identify the effect on transport costs from using one site or a number of sites to process the additional milk.

8.2 Methodological Framework

A milk transport model (Quinlan et al., 2010) incorporating milk processor location was developed and adapted to reflect the current structure of the dairy sector in Ireland (processor configuration and farm layout and distribution).

The milk transport model was configured with 2008 data based on the configuration of the dairy industry and projections for 2020 dairy industry outputs based on the FAPRI Ireland farm level model(Laepple and Hennessy 2010). The transport model was used to assess the impact of the changes in the projected farm level production on milk transport costs under numerous different scenarios. The model compared current capacity of processors with expected potential expansion therefore determining the potential to absorb increased milk production within region. The

model then calculated the least cost (transport costs) options for expansion in 2020. There is a schematic diagram of the model presented in Figure 8.2.

8.2.1. Model Description

The aim of the transport simulation model was to calculate total transport costs by simulating the six components of milk transport i.e. transport driving, assembly driving, farm pumping, plant pumping, plant non-pumping activities and on-farm routine activities (Quinlan *et al*, 2010). Transport driving involves the time spent driving from the processing plant to 1st farm and return to plant from final farm. Assembly driving involves driving from farm to farm within the route. On-farm routine activities include time spent attaching hose, agitating milk, sampling, rinsing tank and recording information on farms. Farm pumping is the time spent pumping the milk into the tanker at the farm. Plant non-pumping activities include the tanker washing, waiting time and lunch. Plant pumping involves the time spent pumping milk from the tanker into the silo at the plant.

Transport driving is the only component directly affected by processor location; therefore this study focuses mainly around this component using a milk processor location model. Assumptions for the other 5 components of milk transport are listed in Table 8.1.

The milk processor location model that was developed in 2006 was also used in this study (Quinlan *et al.* 2006). A transportation algorithm was applied to a data set that included: (1) the geographic location and monthly milk production of each rural

district; (2) the geographic location and monthly physical capacity of each dairy processing site; (3) a transportation matrix containing the distance in miles from each source to each location. The transportation algorithm minimizes the total transportation mileage incurred in transporting goods from a number of origins to a number of destinations. The model works in two phases; The Phase I algorithm allocates supplies to demands using a minimal unit mileage approach to generate a feasible solution, which however is not necessarily optimal (taking the best immediate, or local, solution while finding an answer). Then an optimizing Phase II procedure follows which checks for optimality conditions, and makes mileage reducing improvements to the solution in case optimality conditions are violated. The Phase II iterations stop when the optimality conditions are finally met, at which time no further mileage reductions are possible. The advantages of this transportation algorithm are that the shortest path was quickly identified and it could be recalculated repeatedly (Fu *et al.* 2005).

In 2009 there were about 18,294 dairy farmers in the Irish Republic (DAFF, 2010). Identifying the location and size of each individual dairy farm as sources for the processor location model was beyond available resources. An alternative approach based on District Electoral Divisions (DED's) was adopted. In the Republic of Ireland, DEDs are the smallest legally defined administrative areas in the State for which Small Area Population Statistics (SAPS) and are published from the Census. There were 2,627 DED's in Ireland in 2008 and data for dairy cow numbers and number of herds by DED was supplied by DAFF. Typical seasonal milk supply patterns were applied based on data from the Central Statistics Office (CSO, 2011).

In this way an estimate of milk availability throughout the year by rural district was derived, which could be fed into the transportation model.

The regional supply of milk in 2020 was projected using the FAPRI-Ireland farm level model (Hennessy, 2007). The model utilized Irish National Farm Survey (NFS) data along with projected changes in prices and costs from the FAPRI-Ireland aggregate level model to simulate the response of farmers to policy changes. The country was divided into four regions: the Border Midlands and western region (BMW), the south-west (SW), the south (S) and the east region (E) and farms were categorized into three further groups based on herd size i.e. small, medium and large. A projected percent expansion capacity was forecasted for each group. Table 8.2, shows the expansion capacity in the BMW, SW, E and the S regions. (Laepple and Hennessy 2010).

The 2,627 DED's were assigned one of the four regions as stipulated by the FAPRI model (BMW, SW, S and E). The size of the herd (small, medium, large) for each DED was then determined (predetermined by the FAPRI model). The projected percentage expansion was then applied to each DED. These data were then converted to milk equivalent terms using average milk yields (stipulated by the FAPRI model). The DED's were then aggregated up into 156 rural districts. Typical seasonal milk supply patterns were applied based on data from the Central Statistics Office (CSO, 2011). In this way an estimate of milk availability throughout the year by rural district was derived, which could be fed into the transportation model.

Information about the location of destinations (Processors) was mainly obtained from a detailed map of the locations of dairy factories, which had been published, Irish Dairy Board (2009). Based on information on annual milk intake by factory, it was estimated that 19 Dairy Processing locations exist, this captured the vast bulk of milk processing capacity in the country. An estimate of road distance from a central or appropriate point from each source (rural district) to each destination was obtained from a computerised road mapping source. The program Quantitative Systems for Business was then used to solve the problem within the model. The model determined the national average transport driving mileage per route (i.e. the distance from the plant to the fist farm and the distance from the last farm back to the plant. This result (depending on processor location) was then inserted into the transport simulation model and total transport costs for each scenario were determined.

8.2.2: Scenarios

In Ireland due to the overlap of milk processors catchment areas milk tankers from the different processors regularly cut across the territories of the other processors on their way to their parent processing plants, this has led to inefficiencies in milk transport activities. This needs to be taken into consideration when identifying expansion strategies for increased milk output in 2020. Therefore, the optimal locations for expansion of existing facilities and development of Greenfield sites were found by the minimization of transport costs with respect to the mode in which milk is located (i.e. actual catchment areas and optimal catchment areas) and the location of milk supply and dairy factories. In all scenarios the milk transport costs

were compared to simulated milk transport costs based on the 2008 milk supplies and profiles. The following three scenarios were examined:

In Scenario 1: the milk transport model was used to estimate milk transport costs if milk was collected based on 2008 milk supply catchment areas and ;

(a) One existing site processes all the additional milk supply

(b) Two existing sites each process 50% of the additional milk supply

(c) Three existing sites each process 33.33% of the additional milk supply.

Scenario 2: in comparison to collecting milk by actual catchment areas in 2020 (as simulated in scenario 1) milk was assembled by optimum regional catchment areas in scenario 2. Optimum catchment areas refer to the milk being transported to the nearest plant for processing thus eliminating cross haulage. In these scenarios existing sites were examined to find the least cost location (from a transport cost perspective)if;

(a) One site processed all the additional milk supply

(b) Two sites each process 50% of the additional milk supply

(c) Three sites each process 33.33% of the additional milk supply.

Scenario 3: Taking cognisance of milk transport costs and changing circumstances at both farm and processor level 10 Greenfield site locations were chosen (locations chosen had access to the primary road network, clean water supply, seasonal labour force etc.) and analysed to find the least cost location (from a transport cost perspective) in 2020 if ;

(a) One site processed all the additional milk supply

(b) Two sites each process 50% of the additional milk supply

(c) Three sites each process 33.33% of the additional milk supply.

Existing milk output volumes were collected 2008 milk supply catchment areas and additional milk supply was collected based on optimum milk catchment areas.

8.3 Results

8.3.1 Regional Expansion Capacity

Figure 8.3 summarises the expansion capacity of farms by rural district to 2020. Expansion capacity ranged from 0% to76.92%. Nationally the average increase in milk supply was 45% in 2020. The South and the South East in particular Cork, Limerick, Waterford, Tipperary, Wexford, Kilkenny, Carlow and Wicklow had the highest expansion capacity (Laepple and Hennessy 2010).

8.3.2 Capacity of processors to absorb changes in milk production

With a 45% increase in national milk supply by 2020, current milk processing capacity in Ireland will need to be expanded. Based on the current processing capacities and the expected milk supply this study has estimated that that milk processing capacity would have to increase by 37% in order to be capable of processing an additional 45% of milk by 2020 without a change in the milk supply profile nationally.

8.3.3 Expansion of existing milk processing sites and collection by (2008 milk supply) catchment area – Scenario 1

Table 8.3 lists the total transport costs and transport costs in cent per litre in 2020 for seven different existing sites. From a milk transport perspective the seven least cost sites were ranked based on one, two, or three existing sites processing the additional milk that is produced. In this scenario (scenario 1) 2008 milk supply is assembled by actual catchment areas with the additional milk supplied to one, two or three sites in a least costs fashion based on milk expansion locations and location of processing sites. When 1 site processes the additional milk supply transport cost range from 1.02 cent per litre to 1.05 cent per litre, depending on the site locations. When two sites process the milk supply cost range from 0.97 cent per litre to 1.00 cent per litre (depending on location). When three sites process the additional milk supply costs range from 0.94 cent per litre to 0.97 cent per litre (depending on location). Table 8.4 summarises the total transport costs and transport cost in cent per litre for the least cost sites in this scenario.

When milk supply was assembled by actual catchment areas and existing sites were expanded in 2020 total transport costs were 7.58% higher and 3.46% higher when the additional milk supply was diverted to one or two sites respectively when compared with three sites when the sites were optimally located (Figure 8.5).

8.3.4 Expansion of existing milk processing sites and collection by optimum catchment area – Scenario 2

In contrast to scenario 1 where milk is assembled by 2008 milk supply catchment areas in scenario 2, milk is assembled by optimum catchment areas in 2020. Table 8.5 summarises the total transport costs and transport costs in cent per litre for the least cost existing sites (from a milk transport perspective). When 1 site processes the additional milk supply, transport cost range from 0.92 cent per litre to 0.97 cent per litre depending on location. When two sites process the milk supply cost range from 0.88 cent per litre to 0.91 cent per litre (depending on location). When three sites process the additional milk supply costs range from 0.85 cent per litre to 0.88 cent per litre (depending on location). Table 8.6 summarises the total transport costs and transport cost in cent per litre for the least cost sites in this scenario.

When milk supply was assembled by optimum catchment areas and existing sites were expanded in 2020 total transport costs were 3.76% higher and 7.86% higher when all the additional milk supply travelled to two sites and one site respectively compared with 3 sites (Figure 8.6).

When compared with scenario 1 it is clear that there are potential transport savings in milk transport costs from milk being assembled in an optimum fashion i.e. send milk to nearest processing site and avoid unnecessary transport mileage. Savings obtainable per annum were 9.65%, 9.65% and 9.92% or €6.6 million, €6.32 million and €6.28 for 1 site, 2 sites and 3 sites respectively in 2020 (Figure 8.4).

8.3.5 Greenfield sites process the additional milk supply – Scenario 3

In comparison to scenario 1 and 2 where existing sites process the additional milk supply, in scenario 3 new Greenfield sites process the additional milk supply in 2020. Milk was assembled based on 2008 milk supply catchment areas for 2008 milk supply volumes and based on optimum catchment areas for additional milk supply in 2020. Table 8.7 details the total transport costs and transport costs in cent per litre for ten Greenfield sites in 2020. When 1 site processes the additional milk supply transport cost range from 1.01 cent per litre to 1.19 cent per litre (depending on location). When two sites process the milk supply cost range from 0.98 cent per litre to 1.01 cent per litre (depending on location). When three sites process the additional milk supply costs range from 0.94 cent per litre to 0.99 cent per litre (depending on location). Table 8.8 summarises the total transport costs and transport cost in cent per litre for the least cost sites in this scenario

When milk supply was assembled by actual catchment areas and diverted to Greenfield sites in 2020 total milk transport costs were 3.90% higher and 8.1% higher when all the additional milk supply travelled to two sites and one site respectively compared with 3 sites (Figure 8.7).

8.3.6 Optimum number and location of additional processing facilities

It was found that the optimum expansion strategy for 2020 from a milk transport perspective was if milk was assembled by optimum catchment area and the additional milk supply was routed to three existing sites (Figure 8.8). In this situation transport costs were 0.85 cent per litre when the expansion was located correctly in

relation to the anticipated expansion at farm level. Transport cost rise to 0.92 cent per litre and 0.88 cent per litre if milk if the additional milk is diverted to one or two sites respectively, however these costs are still considerably lower than if milk was collected by actual catchment areas and diverted to existing or Greenfield sites. Overall, annual savings amount to €6.6 million, €6.32 million and €6.28 million for 1, 2 or 3 sites respectively when compared to existing sites and savings per annum of €6.4 million, €6.4 million and €6.1 million for 1 site, 2 sites and 3 sites when compared to Greenfield sites.

However, if milk is assembled by actual catchment areas, transport costs were similar when routing the additional milk supply in 2020 to Greenfield sites or routing it to existing expanded sites (Figure 8.9) (Figure 8.10). Transport costs per litre were 1.01 cent (€68.22 million), 0.98 cent (€65.57 million) and 0.94 cent (€63.11 million) for one to three Greenfield sites compared with 1.02 cent (€68.45 million) 0.97 cent (€65.53 million) and 0.94 (€63.26 million) cent for one to three existing sites, respectively.

In this study we did not examine green field sites and optimum catchment areas as it was felt that this was not likely to occur. If milk was collected by optimum catchment areas and sent to Greenfield sites there would be variation in transport costs when comparing existing sites and Greenfield sites.

8.3.7 Sensitivity analysis

Table 8.9, 8.10 and 8.11 contain the results of sensitivity analysis for fuel and labour costs as well as interest rates. Total milk transport costs increased and decreased by

4% in all scenarios when fuel costs increased or decreased by 20%. Total transport costs increased and decreased by 9% in all scenarios when labour increased or decreased by 20%. Total transport costs decreased by 0.5%-0. 7% in all scenarios when a 4% interest rate was applied, while total transport costs increased by 1%-1.2% in all scenarios when 7% interest rate was applied.

8.4 Discussion

The objective of this paper was to identify the effect of various expansion strategies at processor level in the Irish dairy industry based on an expected increased milk output by 2020. Projected milk output increases of 45% (Laepple and Hennessey, 2011) were included in the analysis with the highest expansion rates expected in the south of the country and the least in the northern half of the country. When the projections around milk supply increase by region were merged with existing processing capacities, it was found that milk processing capacity would have to increase by on average 37% nationally. However, there was not an even spread of the requirement for increased processing capacities across region, based on projected expansion and current processing capacities.

The transport model was then used to determine the effect on milk transport costs for different policies around building the additional capacities for processing the additional milk based on 2020 milk output projections. The transport model can determine the optimal location of the increased processing capacities by minimising transport costs using a transportation algorithm with respect to mode of collection

and distances between supplier regions and processing plants (Quinlan *et al* 2010). The advantage of using this approach is that the transportation algorithm can quickly identify the shortest path was quickly identified and it could be recalculated repeatedly (Fu *et al.* 2005) based any changes in particular components. Transportation costs play a major role in locational choices in the dairy sector because milk is a large bulky perishable product with its movement often resulting in high transport costs.

It was found in this study that the optimum expansion strategy from a milk transport perspective was if milk was collected by optimal catchment areas and milk was routed to three existing plants in 2020. In order for this to occur milk processors would need to route milk to the closest plants rather than the current situation where milk is routed by catchment region.

If milk was collected by optimal catchment areas there were only small overall differences in transport costs whether the milk was collected existing sites or Greenfield sites. However having three sites rather than one site to process the additional milk did reduce the total transport costs by 7-8% when compared to one site. In a situation where milk transport costs are identical, other cost factors such as economies of scale at processing level, distribution costs, existing site recourses, etc. would have to be taken into account in the final decision making process.

As well as finding the least cost site from a transport perspective, other factors also need to be considered when examining future locations of processing plants. Lopez

and Henderson (1989) found proximity to the raw material; infrastructure, availability and quality of water, availability of waste disposal and labour factors were all important factors in choosing where to locate a plant. Dobis *et al.* (2010) carried out a study on locational determinants of food processing in the United States and concluded that the attributes of a site that food manufacturers should use to make their location decision are access to input and product markets, agglomeration factors, labour attributes, infrastructure, fiscal characteristics and social capital.

Manufacturing productivity is influenced by labour quality (McNamara*et al*, 1988). Higher-quality workers are generally more productive, and increased productivity leads to lower costs and/or higher output. Therefore, access to high quality labour is important for the dairy processing industry. As the dairy industry in Ireland is seasonal in nature (the majority of processing occurs between April and September) access to seasonal workers would also be a key requirement.

Rainey and McNamara (1999) considered the effect of infrastructure on manufacturing location decisions and all found that infrastructure was a significant and positive determinant of plant location choice. Dairy processors require a reliable transport network to assembly milk from spatially separated farms to processing plants. Roads in Ireland are classified as national primary, national secondary, regional roads and local roads. The road structure and size will have a significant effect on tanker productivity.

Availability of a clean source of water is also an important factor to consider when deciding where to locate a milk processing plant. Water is required for general plant use, human use, for milk cooling and also during processing of the milk, therefore access is essential. The presence of a river also facilitates a situation where treated water may be discharges back into the water body and is part of the consideration process.

The efficient organisation of the industry must consider the volume-cost relationship of future plants as well as the location of milk supplies and other location factors. The presence of existing facilities at existing sites may also add to the computations around the optimal location of new processing facilities. The authors intend to carry out further studies on volume cost relationships of plants to add to the transport cost information, which ultimately lead to strong directions been provided for the Irish dairy industry.

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Table 8.1: Assumptions for components of milk transport

Assumptions for other components of milk transport

Tanker capacity : 6000 gallons
Average daily operating hours at peak: 20 hours
Assembly mileage: 1.76 miles
Costs increase between 9-11% in 2020 (depending on variable) (Binfield *et al.,* 2007)
Frequency of milk collection: Every third day at peak
Trucks value written off over 220,000 miles
Trailer value written off over 660,000 miles
Diesel cost: €1.1 per litre exclusive of VAT
Interest rate: 5%
Full list of costs available in Quinlan *et al*. 2011

Source: Own calculations

Table 8.2: Regional Expansion capacity

BMW region	Region	Overall	Small	Medium	Large
Milk Sales 2020 (in Mio litres)	BMW	1,297.315	157.107	419.47	720.738
	South-West	1,554.88	449.97	631.04	473.86
	East	1,050.93	134.32	390.64	525.97
	South	1,890.14	280.99	694.96	914.18
% Change in Milk Sales	BMW	25.5	10.6	53.9	16.4
	South-West	30.6	19.9	56.2	15.1
	East	29.9	18.4	54.8	18.7
	South	45.6	48.9	62.4	34.2
Farm numbers remaining	BMW	3,769	1,117	1,399	1,252
	South-West	4,897	1,663	1,694	1,539
	East	2,274	604	947	723
	South	4,097	1,119	1,548	1,431

Source: Laepple and Hennessy, 2010

Table 8.3: Transport Costs: Expansion of existing sites using actual catchment areas

Site	Million Euro	Cent /litre	Return transport mileage for average route
1 site			
Mitchelstown	68.45	1.02	64.38
Mallow	68.48	1.02	64.47
Charleville	69.47	1.03	67.44
Macroom	69.61	1.04	67.85
Newmarket	70.26	1.05	68.36
Tipperary	70.59	1.05	69.36
West Cork	70.68	1.05	69.63
2 sites			
Mitchelstown and Macroom	65.53	0.97	58.76
Mitchelstown and West Cork	65.75	0.98	59.39
Mitchelstown and Ballyragget	66.44	0.99	61.38
Mitchelstown and Mallow	66.48	0.99	61.48
Mitchelstown and Newmarket	67.17	1.00	62.09
Mitchelstown and Tipperary	67.17	1.00	62.10
3sites			
Mitchelstown, Macroom and Ballyragget	63.26	0.94	54.66
Mitchelstown, Macroom and Nenagh	63.99	0.95	55.39
Mitchelstown, Macroom and Wexford	64.38	0.96	56.58
Mitchelstown, Macroom and Tipperary	64.55	0.96	57.09
Mitchelstown, Macroom and Charleville	65.45	0.97	58.35

Source: Own calculations

Table 8.4: Summary milk transport costs for actual catchment areas (best sites)

	million	Cent/litre	transport mileage
2020 1 site			
Mitchelstown	68.45	1.02	64.38
2020 2 site			
Mitchelstown	65.53	0.97	58.76
Macroom			
2020 3 sites			
Mitchelstown	63.26	0.94	54.66
Macroom			
Ballyragget			

Source: Own calculations

Table 8.5: Transport Costs: Expansion of existing site using Ideal Catchment Areas

Site	Million Euro	Cent/litre	Return transport mileage for average route
1 site			
Mitchelstown	61.85	0.92	53.39
Mallow	62.55	0.93	54.04
Macroom	63.38	0.94	55.59
Tipperary	64.45	0.96	57.57
West Cork	64.48	0.96	57.64
Newmarket	64.71	0.96	58.06
Charleville	65.01	0.97	58.61
2 sites			
Mitchelstown and Macroom	59.21	0.88	48.49
Mitchelstown and West Cork	59.41	0.88	48.86
Mitchelstown and Mallow	60.64	0.90	51.15
Mitchelstown and Newmarket	60.82	0.90	51.48
Mitchelstown and Tipperary	61.02	0.91	51.85
Mitchelstown and Wexford	61.04	0.91	51.90
3 sites			
Mitchelstown, Macroom, Wexford	56.98	0.85	45.01
Mitchelstown, Macroom, Nenagh	58.08	0.86	46.71
Mitchelstown, Macroom, Tipperary	58.49	0.87	47.47
Mitchelstown, Macroom, Ballyragget	58.57	0.87	47.62
Mitchelstown, Macroom, Mallow	59.19	0.88	48.77

Source: Own calculations

Table 8.6: Summary table: Transport costs for ideal catchments areas (best sites)

	million	cent/litre	transport mileage
2020 1 site			
Mitchelstown	61.85	0.92	53.39
2020 2 site			
Mitchelstown, Macroom	59.21	0.88	48.49
2020 3 sites			
Mitchelstown, Macroom, Wexford	56.98	0.85	45.01

Source: Own calculations

Table 8.7: Transport Costs: Selection of Greenfield sites to process additional milk supply

Site	Million Euro	Cent/ Litre	Return transport mileage for average route
1 site			
Glenmore	68.22	1.01	63.70
Mogeely	69.10	1.03	66.33
Dungarvan	69.23	1.03	66.72
Croom	70.20	1.04	68.19
Kilmallock	70.21	1.04	68.21
Millstreet	70.35	1.05	68.65
Ashhill Horse and jockey	72.05	1.07	72.31
Nenagh	73.77	1.10	76.03
Belview Port	73.87	1.10	76.33
Rosslare	80.08	1.19	89.19
2 sites			
Glanmire and Dungarvan	65.57	0.98	57.53
Glanmire and Nenagh	65.67	0.98	57.80
Glanmire and Croom	65.83	0.98	58.27
Glanmire and Ashhill Horse and jockey	65.91	0.98	58.48
Glanmire and Belview Port	66.31	0.99	59.62
Glanmire and Kilmallock	66.59	0.99	60.44
Glanmire and Millstreet	67.08	1.00	61.83
Glanmire and Mogeely	67.32	1.00	62.50
Glanmire and Rosslare	67.62	1.01	63.37
3 sites			
Glanmire, Dungarvan and Nenagh	63.11	0.94	52.77
Glanmire, Dungarvan and Croom	63.35	0.94	53.47
Glanmire, Dungarvan and Kilmallock	63.94	0.95	55.24
Glanmire, Dungarvan and Millstreet	63.95	0.95	55.28
Glanmire, Dungarvan and Ashhill Horse and jockey	64.05	0.95	55.59
Glanmire, Dungarvan and Belview Port	65.58	0.98	58.73

Source: Own calculations

Table 8.8: Summary milk transport costs for least cost Greenfield sites

	million	Cent/litre	transport mileage
2020 1 site			
Glanmire	68.22	1.01	63.70
2020 2 site			
Glanmire	65.57	0.98	57.80
Dungarvan			
2020 3 sites			
Glanmire	63.11	0.94	52.77
Dungarvan			
Nenagh			

Source: Own calculations

Table 8.9: Transport costs (€ million) for 20% increase and 20% decrease in fuel costs

	Scenaro 1			Scenario 2			Scenario 3		
	current	20%	-20%	current	20%	-20%	current	20%	-20%
1 site	€68.45	€71.23	€65.67	€61.85	€64.26	€59.44	€68.22	€70.98	€65.47
2 sites	€65.53	€68.12	€62.94	€59.21	€61.46	€56.96	€65.57	€68.12	€63.02
3 sites	€63.26	€65.72	€60.81	€56.98	€59.11	€54.85	€63.11	€65.51	€60.73

Source: Own calculations

Table 8.10: Transport costs (€ million) for 20% increase and 20% decrease in labour costs

	Scenario 1			Scenario 2			Scenario 3		
	current	*20%*	*-20%*	*current*	*20%*	*-20%*	*current*	*20%*	*-20%*
1 site	€68.45	€74.36	€62.54	€61.85	€67.39	€56.30	€68.22	€74.11	€62.34
2 sites	€65.53	€71.25	€59.80	€59.21	€64.59	€53.83	€65.57	€71.25	€59.89
3 sites	€63.26	€68.85	€57.68	€56.98	€62.25	€51.72	€63.11	€68.64	€57.59

Source: Own calculations

Table 8.11: Transport costs (€ million) for 4% interest rate and 7% interest rate

|	Scenario 1			Scenario 2			Scenario 3		
	current	*4% interest rate*	*7% interest rate*	*current*	*4% interest rate*	*7% interest rate*	*current*	*4% interest rate*	*7% interest rate*
1 site	€68.45	€69.16	€68.02	€61.85	€62.50	€61.45	€68.22	€68.93	€67.79
2 sites	€65.53	€66.30	€65.20	€59.21	€59.86	€58.81	€65.57	€66.39	€65.26
3 sites	€63.26	€63.92	€62.86	€56.98	€57.61	€56.60	€63.11	€63.78	€62.71

Source: Own calculations

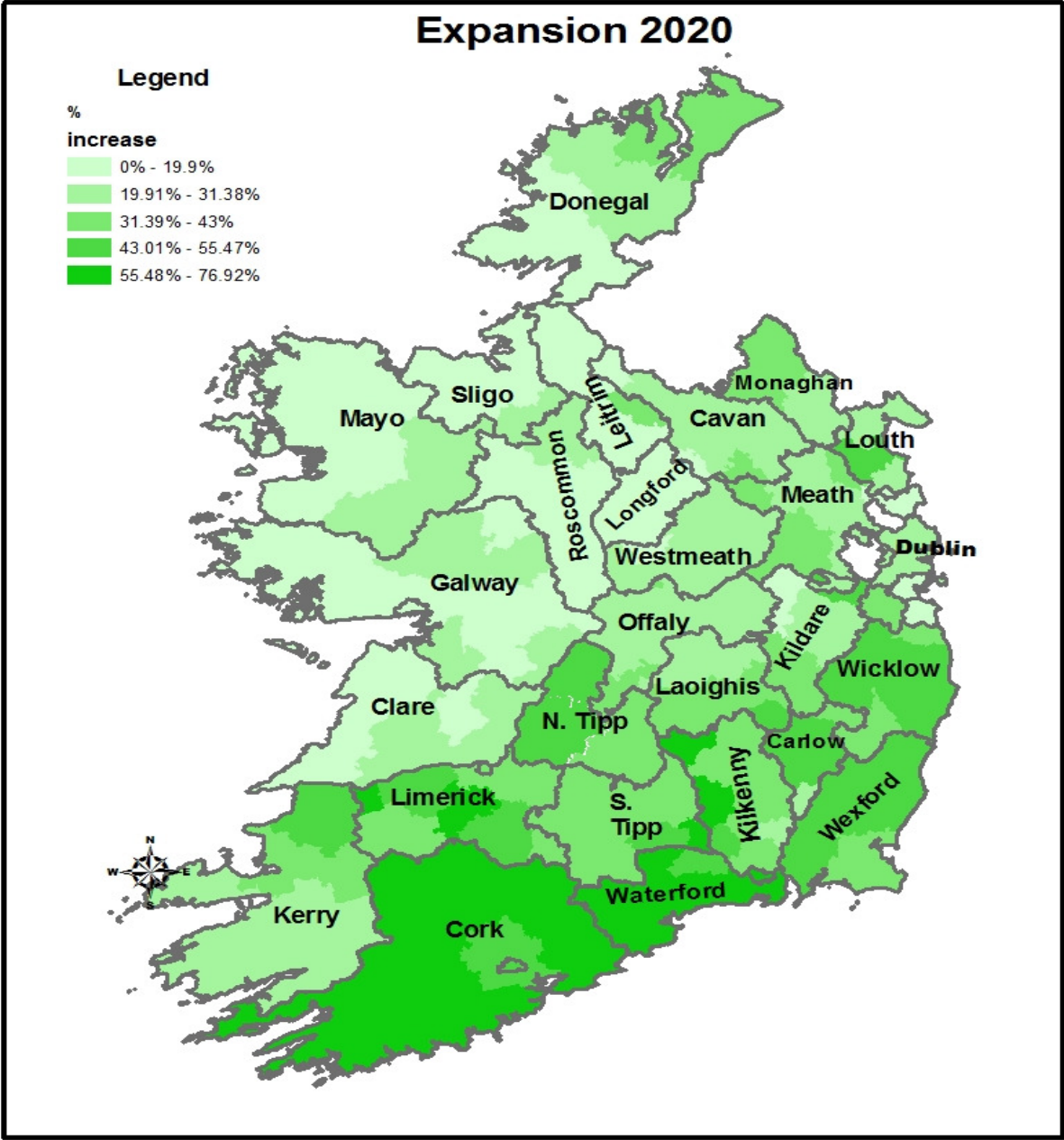**Figure 8.1: Actual catchment areas of milk processors in Ireland**
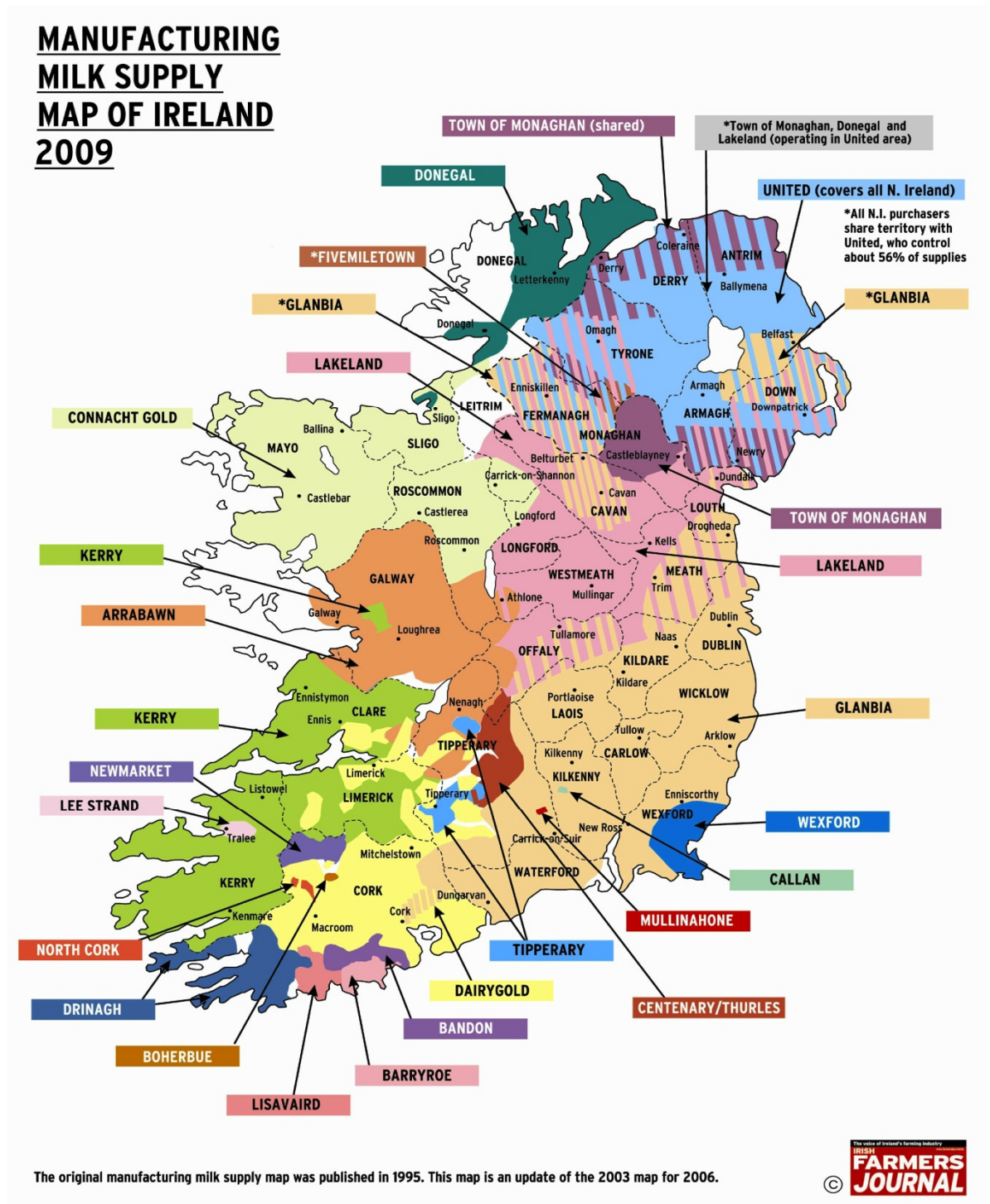
Source: Irish Farmers Journal, 2009
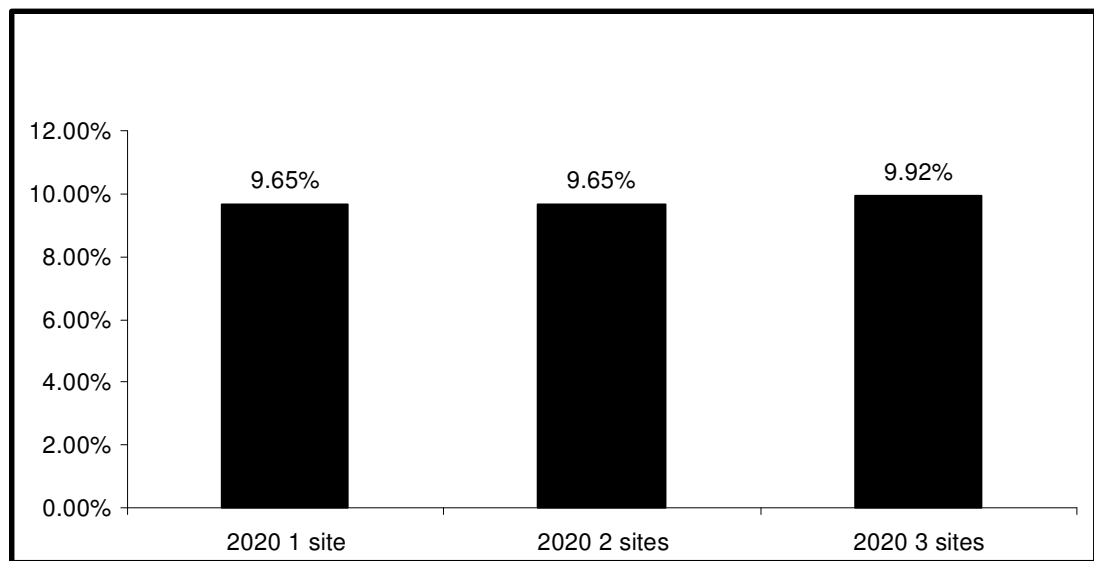
Figure 8.2: Schematic diagram of the model
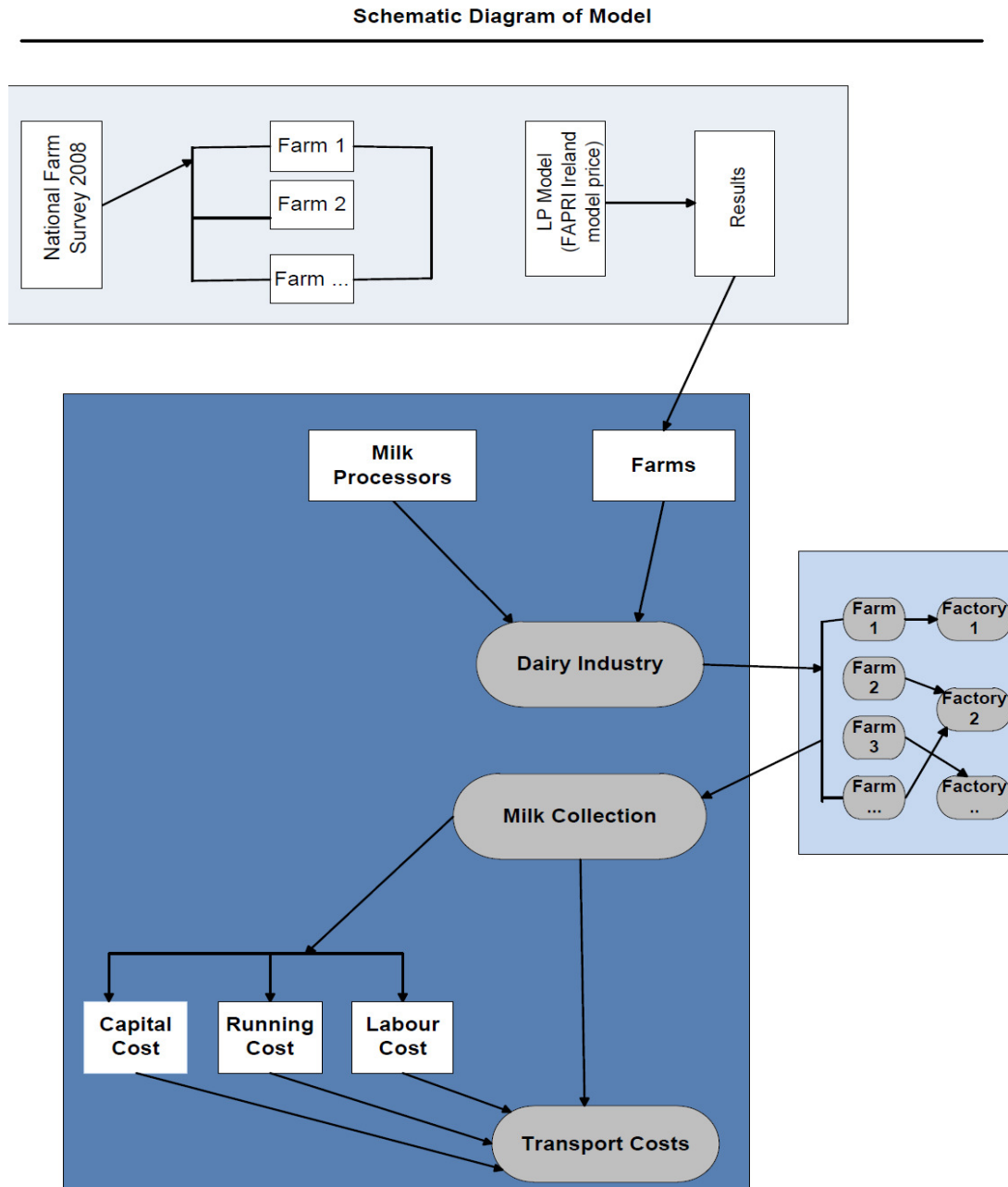
Source: Own diagram

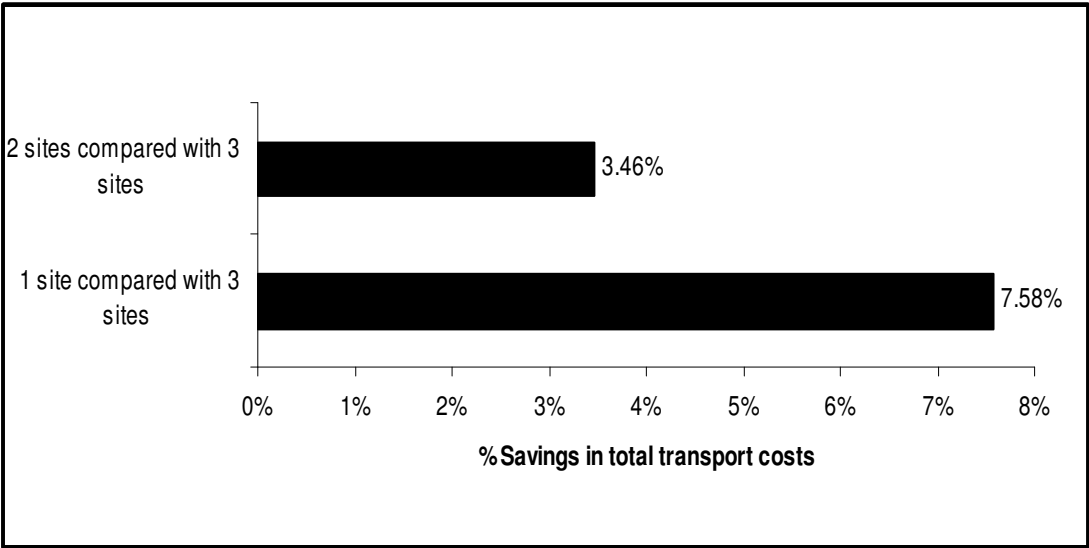**Figure 8.3: Expansion Capacity for Dairy Farms in Ireland in 2020**

Source: Own diagram

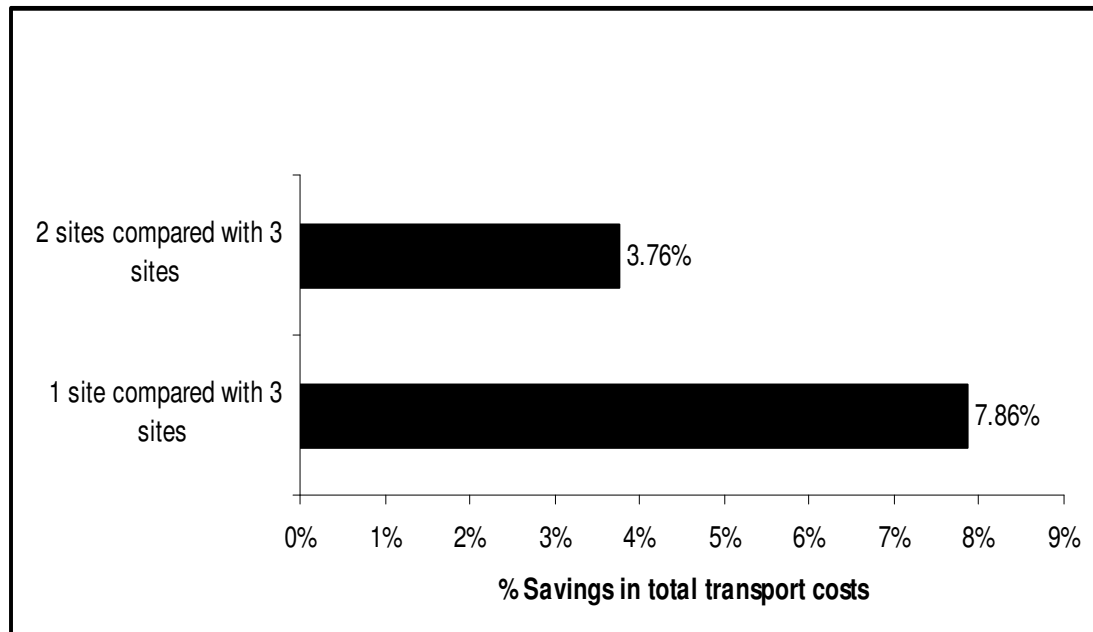**Figure 8.4: Optimum versus actual catchment areas % saving in transport costs**

Source: Own diagram

Figure 8.5: Additional milk supply: 3 sites versus 2 sites and 1 site (Actual catchment areas)
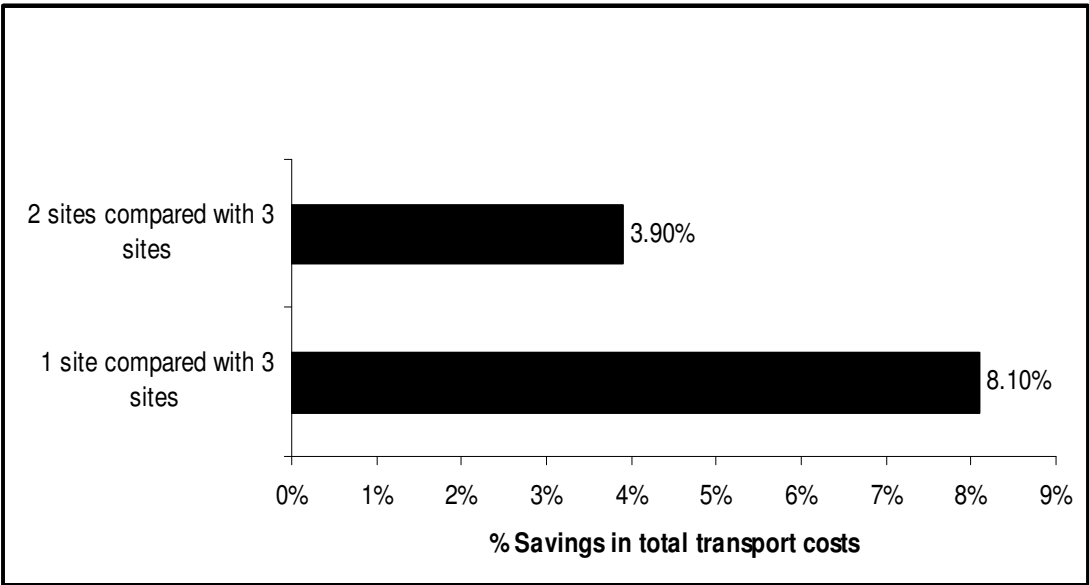
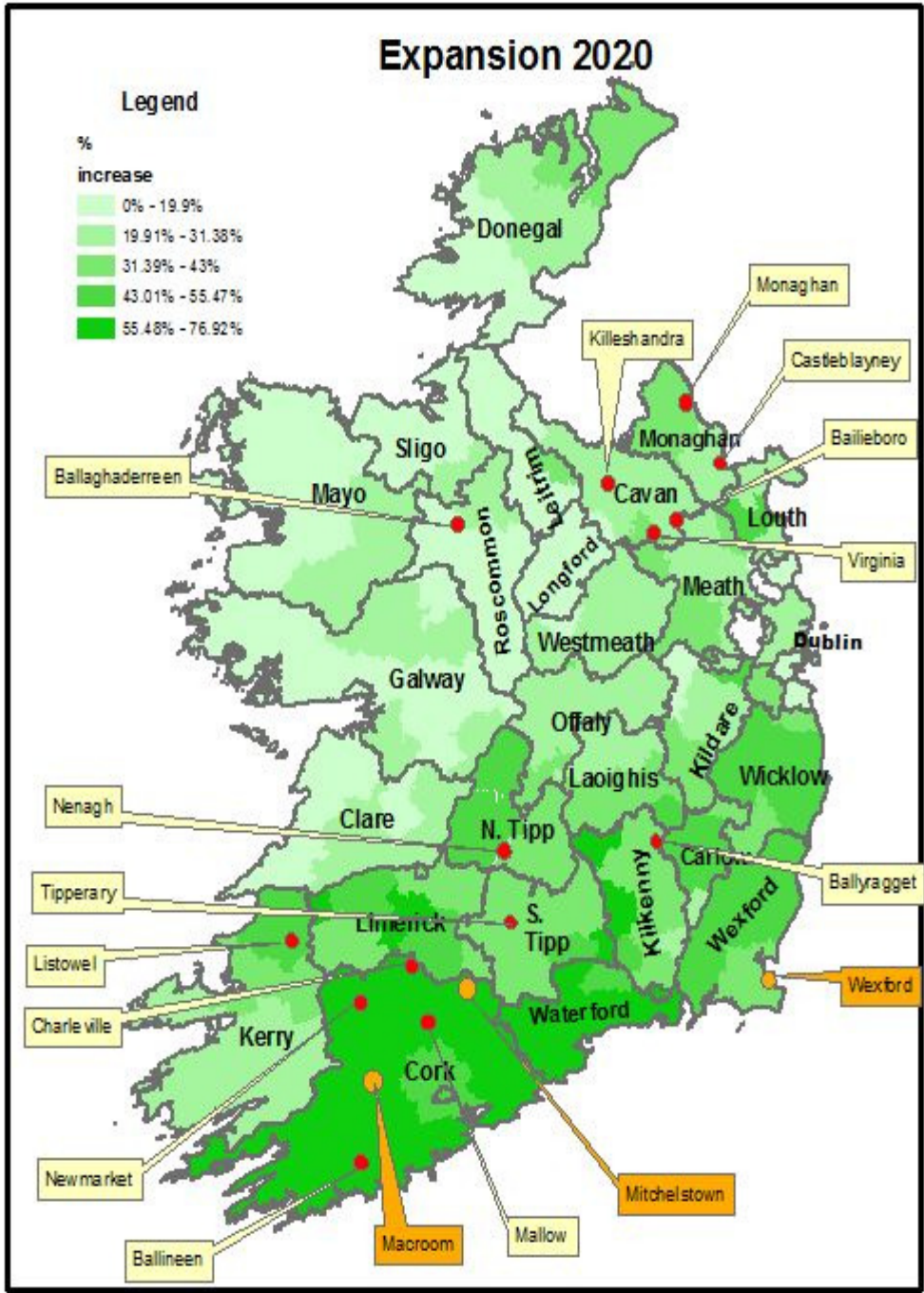**Figure 8.6: Additional milk supply: 3 sites versus 2 sites and 1 site (Optimum catchment areas)**

Figure 8.7: Additional milk supply: 3 sites versus 2 sites and 1 site (Greenfield sites)
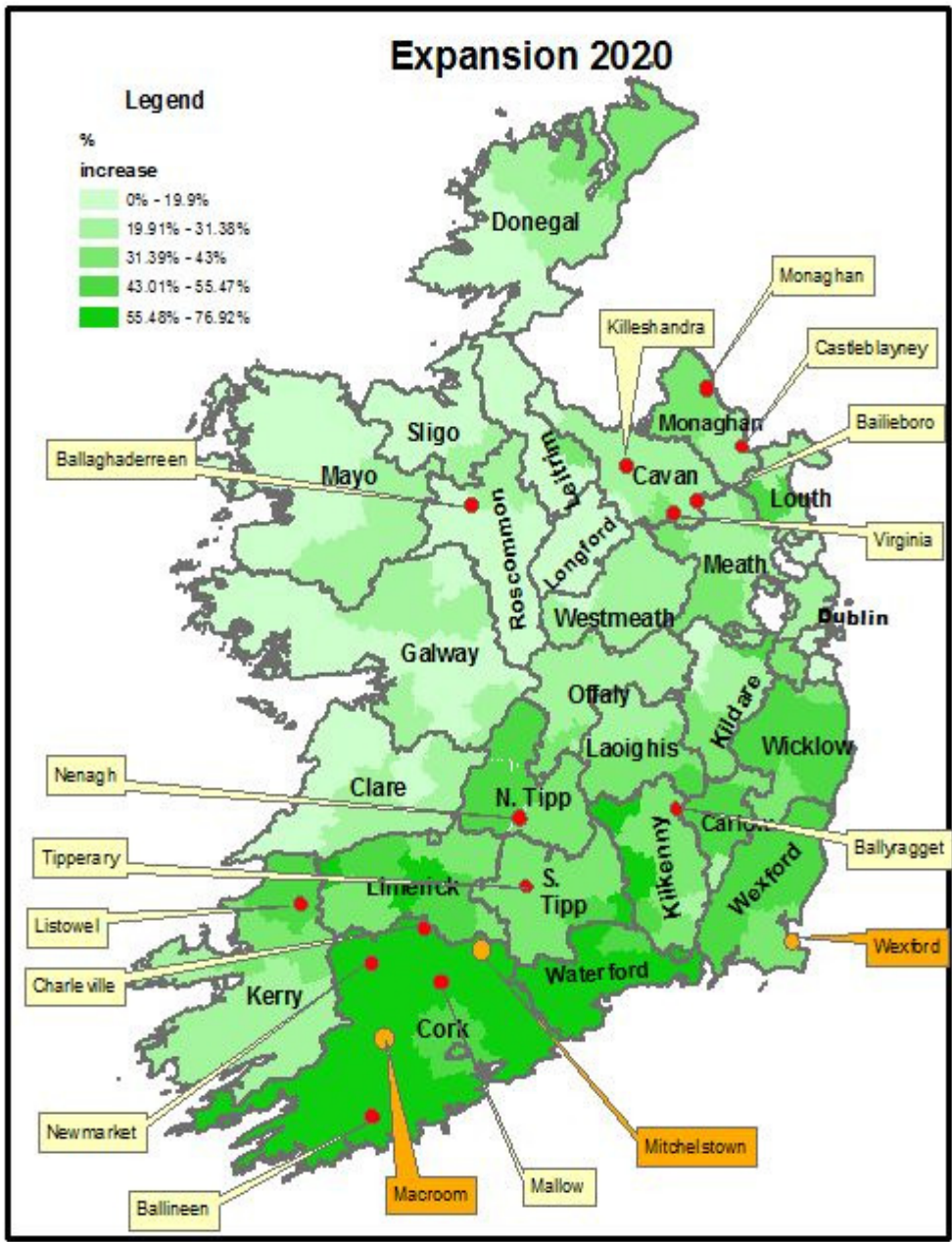

Source: Own diagram

Figure 8.8: Current processing sites/actual catchment areas: 3 best sites highlighted
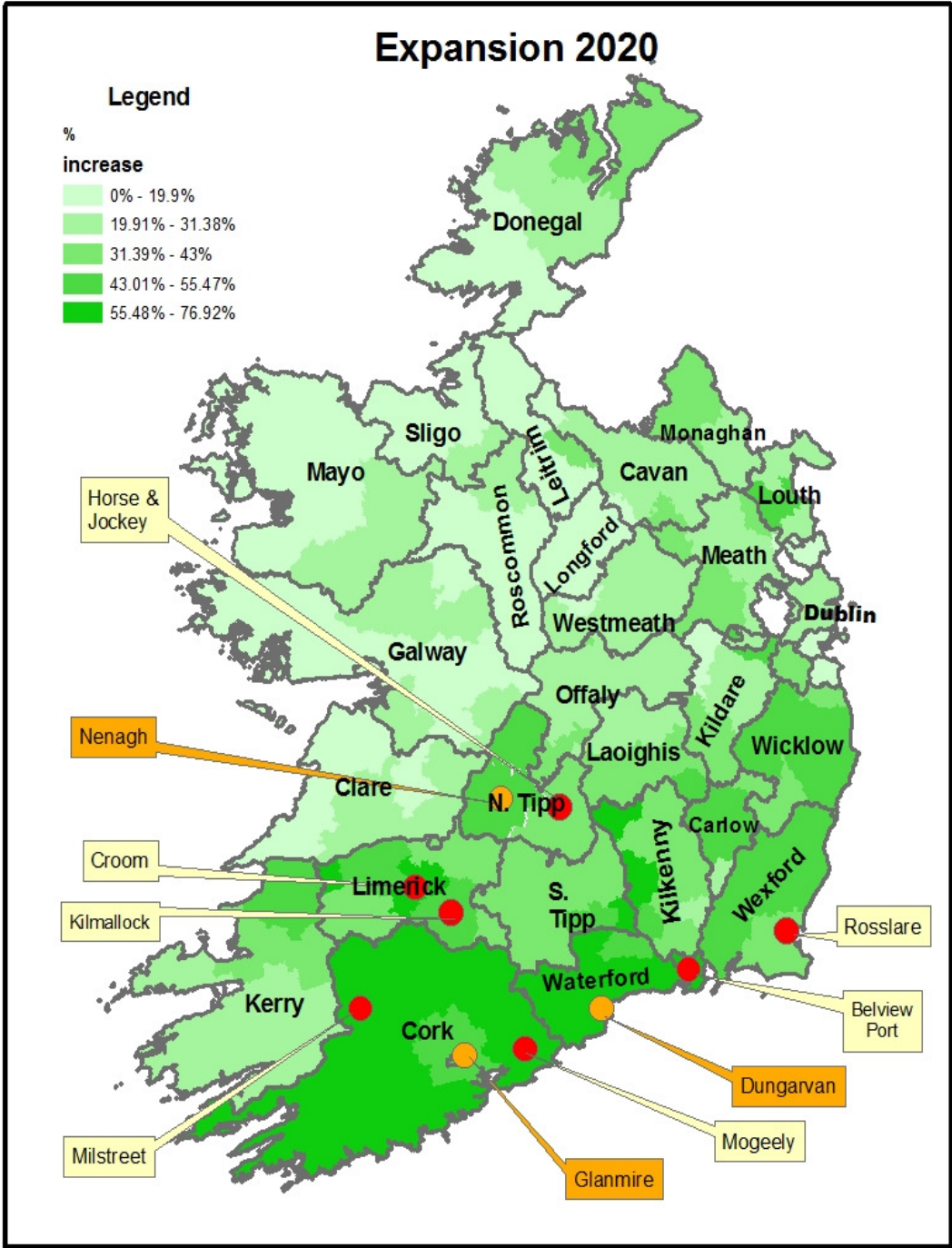

Source: Own diagram

Figure 8.9: Current processing sites/optimum catchment areas: 3 best sites highlighted

Source: Own diagram

Figure 8.10: Greenfield site locations

Source: Own diagram

Chapter 10: Conclusions

10.1 Introduction

This chapter presents the conclusions and recommendations of the research. The key conclusions derived are discussed together under a number of important headings. These include: national milk transport model which allows for the examination of a wide range of efficiency factors in milk transport, milk processing capacity and the location of milk processing capacity in 2020 and optimum dairy processing sector configuration in 2020 taking cognisance of regional milk supply, processing and milk transport costs. Finally in this chapter, recommendations to stakeholders in the Irish processing dairy sector are presented, and suggestions for further research are proposed based upon topics of interest that require further investigation.

10.2 Research Conclusions and Discussion

In Ireland the dairy industry is one of the most important indigenous industries and comprises a vital part of the agri-food sector accounting for 29% of agricultural output in 2010 (Bord Bia 2010). The dairy industry also makes a significant contribution to sustaining rural communities, currently there are approximately 18,294 dairy farmers (DAFF, 2010) and the dairy processing industry employs 7,000 people (IBEC 2010). In 2010 total dairy exports were worth €2.3 billion (Bord Bia 2010). Prospects for the dairy sector in the medium to long term are positive. Given projections for significantly increased demand, the abolition of EU milk quotas in 2015 presents a real opportunity for the Irish dairy sector, with a significant potential

for increased milk production. The sector also possesses a significant cost advantage in the form of an environmentally sustainable rain fed grass-based production system, which allows milk to be produced efficiently for much of the year. However, for the sector to flourish at optimum level, efficiency gains will be crucial at primary and processing level. Overall plant utilisation, product mix and market optimisation will need to be explored. In the following sub-sections, the research sub-questions are initially dealt with, and finally, the main research question guiding this study, which is an amalgam of the individual sub- questions, is addressed in Section 10.3.

Sub-question 1:*What are the effects of various efficiency factors on milk transport costs in Ireland? What are the effects of different milk production patterns on milk transport costs in Ireland?*

10.2.1. National milk transport model which allows for the examination of a wide range of efficiency factors in milk transport

There is limited literature on milk transport activities in Ireland; therefore it was decided to address this paucity in the literature by developing a national milk transport model detailed in Chapter 6. The purpose of this unique national milk transport model was to support decision-makers in relation to milk transport activities. The milk transport model was developed to allow for the examination of a wide range of efficiency factors in milk transport including pumping rates, tanker sizes, size of suppliers, density of milk supply and frequency of collection. It integrates capital costs, running cost and labour incurred on a typical route. The model simulates the six components of milk transport namely transport driving,

assembly driving, farm pumping, plant pumping, on farm routine activities, and plant non-pumping. The model developed is a simulation model, which includes the transportation model developed by Quinlan in 2006 (this model used a transportation algorithm to minimise the transportation mileage from rural districts to processors). The outputs of the model include environmental factors, physical factors and financial factors. Three scenarios were examined, firstly current milk transport costs were estimated, and secondly milk transport costs were estimated if milk production increased nationally by 30% in 2020. In the third scenario milk transport costs were estimated if milk production increased nationally by 30% in 2020 and larger tankers with capacity of 27,360 litres were used in milk transport activities. In summary total milk transport costs were 20% higher in the second scenario (€60.80million) and 14% higher in the third scenario (€57.68 million) when compared with the first scenario (€50.43 million). It was concluded that as milk output increases milk transport costs per litre decrease as transport costs can be spread out over a larger volume of milk. The higher capacity tankers were also found to be more economically efficient than what is currently being used in the industry

As the transport sector is the fastest growing contributor to national GHG emission levels, it was decided to calculate carbon emissions from milk transport activities in Ireland. Carbon emissions for milk transport in Ireland have not previously been calculated; therefore this is a novel element of the milk transport model. Total emissions from transporting the current milk output were found to be 24,870 tonnes or 5.02g per litre.

Comparing the results of a 2005 milk transport survey with the results from the model validated the model. The results were favourable indicating that the model can be used with confidence to aid in decision making when analysing milk transport activities.

The unique transport model was found to have a number of strengths and was the most suitable method of analysis for this study:

➢ It can produce a unique solution to a complex problem or situation. It is better equipped than other approaches to handle complex interrelationships that exist in the dairy sector.

➢ It is capable of handling the complex situations that may exist in the transport sector in an easy and effective manner.

➢ It allows one to examine scenarios that are outside the range of past experiences, for example milk quota abolition

➢ It is a relatively user-friendly approach and changes in model parameters could be easily incorporated into the model, which could then be resolved.

The novel milk transport model developed was then used to examine the effect of alternative milk production patterns on milk transport costs. Therefore, in Chapter 7 the model was used to examine the effect of a moderate reduction in seasonality (2.71:1, peak to trough month) on milk transport costs and an increase in seasonality (8:1, peak to trough month) on milk transport costs. Four different output levels were also examined; the current milk output level, a 20% increase, 38% increase and 45% increase in milk output levels in 2020. Savings in total transport costs of 3-4% were

attained when changing to a less seasonal milk supply pattern and increases in transport costs of 1%-2.5% were estimated when a more seasonal approach was pursued. As milk output increased total milk transport cost savings increased from €1.5 to €2.2 million per annum when a more even milk supply was followed and total milk transport costs increased from €0.5 million to €1.5 million per annum when a more seasonal milk supply pattern was adopted. Carbon dioxide emissions from milk transport did not fluctuate significantly when milk supply profiles altered. Therefore there were no environmental benefits/detriments of following more even/seasonal milk supply patterns. Other factors would need to be taken into consideration before any definitive decisions regarding milk supply patterns are made.

The effect of alternative milk supply patterns on milk transport costs had not previously been examined in Ireland. Therefore, the results of this study contribute to current literature on alternative milk supply patterns.

However, in order to draw conclusions on seasonality within the Irish dairy industry other issues such as market requirements, product portfolio choice, and manufacturing costs and farm production costs also need to be considered. It is only when all of the components are answered can a clear conclusion be drawn about seasonality within the Irish dairy industry.

Sub-question 2: *Will milk production increase post milk quota abolition, if so where will it increase? How many processing plants should Ireland have post milk quota*

abolition? Where should the plants be located? How large should each plant be? Where should the milk to be processed at each plant be sourced? How should milk be collected?

10.2.2 Milk processing capacity and the location of milk processing capacity in 2020

There is a debate around the future of the Irish dairy industry. Questions been asked include the following (i) is there a need for additional capacity to process milk supply post milk quota abolition and (ii) if so, where should it be located. In Chapter 8 of this thesis these questions were examined in detail and expansion strategies for the Irish dairy industry were explored. This novel study therefore informs the debate and contributes to existing literature. The FAPRI (Food and Agricultural Policy Research Institute) Ireland farm level model was used to estimate the regional increases in milk production post quota abolition (in association with Teagasc, Athenry). Current milk processing capacity was compared to future milk supply output. A milk transport model incorporating processor location was used to identify the optimum location for expansion of (a) existing sites and (b) greenfield sites. The model was also used to estimate the effect of different numbers of sites (to process the additional milk) and modes of milk transport (i.e. actual catchment areas and optimal catchment areas) on milk transport costs. Three scenarios were examined, in the first scenario the model was used to calculate transport costs if milk is collected from actual catchment areas and additional milk supply is transported to 1, 2 and 3 existing sites. In the second scenario the model was used to calculate transport costs if milk is collected from optimal catchment areas and additional milk supply is

transported to 1, 2 and 3 existing sites. In scenario 3 milk is collected by optimal catchment areas and additional milk supply is transported to 1, 2 and 3 greenfield sites.

It was found that expansion capacity in terms of milk output in Ireland in 2020 ranged from 0% to 76.92% by region, with a national average increase of 45% estimated for 2020. The South and the South East, in particular counties Cork, Limerick, Waterford, Tipperary, Wexford, Kilkenny, Carlow and Wicklow, had the highest milk expansion capacity. There was some spare processing plant capacity to process additional milk supply, however it was found that current milk processing capacity in Ireland would need to be expanded by 37% in 2020.

It is evident that there are potential transport savings in milk transport costs from milk being assembled in an optimum fashion i.e. sending milk to nearest processing site and avoiding unnecessary transport mileage. Savings obtainable if milk was collected from optimal catchment areas as opposed to actual catchment areas in 2020 were 9.65%, 9.65% and 9.92% for 1 site, 2 sites and 3 sites; however this would require co-operation among milk processors in milk transport activities.

If milk was collected by optimal catchment areas there were only small overall differences in transport costs in terms of whether the milk was transported to existing processing sites or new greenfield sites.

Having three additional sites rather than one site to process the additional milk reduced the total transport costs by 7-8% when compared to one site in all scenarios.

The optimum expansion strategy from a milk transport perspective was if milk was collected by optimal catchment areas and additional milk was routed to three existing processing plants (Mitchelstown, Macroom and Wexford) in 2020.

Potential economies of scale may outweigh savings in milk transport costs, the volume-cost relationship of future plants as well as the location of milk supplies and other location factors must also be considered before any decisions are made.

In this study the expansion capacity is based on a milk price of 28 cent per litre in 2020. Post milk quota elimination Ireland will be more susceptible to price volatility due to changes in world market prices. Expansion potential will be dependant on milk price.

Sub-question 3: *What will the total processing and transport costs be post milk quota abolition? What is the capital requirement for the Irish milk processing sector post milk quota abolition?*

10.2.3 Optimum dairy processing sector configuration in 2020 taking cognisance of regional milk supply, processing and milk transport costs

The determination of the optimum or least cost structure involves a balancing of decreasing average processing costs with increasing scale against increasing milk

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transcript costs. The objective of this component of the study examined in Chapter 9 was to establish the least cost configuration for the Irish dairy-processing sector taking into account the expected expansion in milk output by 2020. An optimisation model was developed with an objective function to minimise both transport and processing sector costs. Small processing sites were excluded from this study. This study concentrated solely on commodity products therefore liquid milk and niche products were not included in the study.

The model was solved using GAMS software. Inputs for the model included variable and fixed processing costs for bulk cheese, WMP, SMP and butter for a number of differing plant sizes, milk intake and other utilities costs for a number of differing plant sizes and transport costs for varying plant numbers. Five scenarios were examined, the first four scenarios assumed all 16 current plants in Ireland were working at full capacity and the 45% increase in milk supply was allowed to travel to the optimum location. In the first scenario the additional milk supply produced the 2007-2009 average product mix, in the second scenario the additional milk was used to produce cheese, in the third scenario it was used to produce WMP and in the fourth scenario all the additional milk was used for SMP plus butter. In the fifth scenario total milk supply (current and additional) was allowed to travel to the optimum location (27 possible site locations: 16 existing processing locations, 11 new greenfield processing locations).

Annual total costs overall were €404, €399, €420, €398 and €367 million for scenarios 1 to 5, respectively. Capital costs for additional plants and intake and

utilities in scenario 1, 2, 3, 4 and 5 were €291 million, €226 million, €341 million, €271 million and €830 million respectively. The product mix produced from the additional milk supply had a significant impact on the total costs and the capital required to fund expansion post milk quota abolition.

At a broader level, social, political, environmental and quality factors would also need to be examined before any decisions on the structure of the future of the industry are made.

The model could be used to help improve the decision making process with regard to changes in the milk processing sector in Ireland. The model is quite flexible and additional scenarios can be evaluated as required.

The model developed in this study is an extension of Stollsteimers model developed in 1963 and Dwyer's model in 1968. The model includes the seasonality problem associated with milk production in Ireland. It also caters for alternative product and additional milk supply post milk quota abolition. Boysen in 2008 and Buschendorf in 2009 developed similar models to that developed in this study for the German dairy industry. However, the model is unique in that prior to this research there was no literature available on combined milk transport and dairy processing models specifically designed for the Irish dairy processing industry.

10.3 Overall Conclusions

The overall research question that guided this study was: *What is the least cost industry configuration for the Irish dairy industry post milk abolition in 2020?*

In this study it was found that the optimum configuration in Ireland by 2020 assuming the current product mix, based on the scenarios examined, was 6 large integrated sites, with total annual savings of €37 million compared with a continuation of the current structure.

A substantial level of consolidation and product specialisation would take place in the least cost scenario. Processors would need to amalgamate or at a very minimum co-operate with each other and venture into joint processing facilities. The objective must be to achieve a new configuration at dairy processing level that matches the structures already in place in our key competing, exporting countries, such as Denmark, Holland and New Zealand.

There are also limitations with the product mix assumed in this study. This study assumed a product mix of 80% low margin commodity products. However, it is recognised that in order to achieve a sustainable Irish dairy processing sector investment must be made in research and development of high value dairy products. Food Harvest 2020 recommended increased focus on the development of health enhancing food products, gut health research, new dairy product development and the infant milk formula sector (Department of Agriculture Food and Fisheries, 2010).

10.4 Recommendations to Stakeholders in the Dairy Processing Sector

The results of this study have important implications for the Irish dairy-processing sector. As there is limited research on milk transport and processing costs in Ireland, this thesis fills this gap in the literature. Findings in this thesis could be used to help improve the decision making process around changes in the milk processing. Findings could also be used to encourage debate within the industry.

In relation to milk transport operations in Ireland, currently there are a lot of inefficiencies and considerable cost savings could be made if these inefficiencies were eliminated. For example it was found in this study that tankers with capacity of 27,360 litres were economically and environmentally more efficient than tankers with capacity of 22,800 litres. It was also more efficient to operate tankers 20 hours per day rather than 12 hours per day at peak. Savings were also available if processors co-operated with each other in milk transport operations and avoid the current overlap of milk transport activities that is currently taking place in the industry. From a milk transport point of view it was found that there were very little savings to be made in milk transport (3%-4%) if farmers adopt a more even milk supply throughout the year.

Milk quota abolition will provide significant opportunities for the Irish processing sector to expand. It was found in this study that current processing capacity will not be sufficient to process additional milk supply in 2020, therefore additional

processing facilities will be required. It is vital that this development is properly planned and scarce investment resources (especially in the context of the global financial crisis) are not wasted. Based on expansion estimates in 2020 (Teagasc, Athenry, 2011), it was found that the optimal solution from a milk transport perspective in 2020 was if 3 sites Mitchelstown, Macroom and Wexford were expanded and milk was collected by optimal catchment areas. However, Irish dairy processors are advised that processing costs must be taken into consideration as well as other location factors before any final decisions are made.

Processing costs and in particular economies of scale associated with processing costs were examined in this study and it was found that internationally competitors are operating at higher capacities and obtaining considerable economies of scale as a result. There was limited research available on processing costs in Ireland, this study therefore contributed to the literature available. It is highly recommended that dairy processors increase the scale of their processing operations as they can achieve substantial savings in costs if they do so. The industry must be particularly careful in deciding what products to produce as product mix has a considerable impact on the total costs and capital required to fund expansion post milk quota abolition.

10.5 Suggestions for Further Research

There are a number of potential research avenues that could be developed from this study. In relation to milk transport other efficiency factors that could be examined include increasing pump capacity at the processing plant and on the farm as well as

the frequency of milk collection. These factors may also result in additional savings in milk transport costs.

In relation to alternative milk supply patterns it would be useful to undertake a cost benefit analysis and to examine the effect of alternative milk supply patterns on milk production costs at farm level and on processing costs at processing sector level.

The Republic of Ireland was only included in this study as it was not possible to obtain data in relation to milk production quantities (at rural district level) and processing capacities at dairy processing sites for Northern Ireland. It is vital from a least cost perspective that processors in the North and South co-operate, therefore it would be very beneficial for Northern Ireland processors to supply this information and be included in subsequent studies.

This study concentrated solely on commodity products as the processing costs for niche, high value products are not publicly available. It is recognised that there is a need also for specialised, niche, high value products in the product mix. It would also be relevant to include these products in future studies. The liquid milk industry was also excluded and it would be very interesting to include this also.

It would be beneficial to examine carbon emissions for different plant sizes. This would also assist the dairy-processing sector in making informed decision regarding the future configuration of the Irish dairy-processing sector.

10.6 Summary

The dairy industry in Ireland is currently facing a period of change, with the impending removal of milk quotas in 2015. In this thesis milk transport and processing costs were examined in detail. Areas where substantial savings could be made were highlighted. Expansion strategies for the Irish processing sector post milk quota abolition were outlined. The novel models developed in this study are very flexible and can be used to model any scenario. The empirical studies presented in this thesis are timely and fill a gap in the literature of milk transport costs and dairy processing costs in Ireland. It is intended that the results from this thesis will contribute to the debate surrounding the future structure of the Irish dairy processing sector and aid in the subsequent decision making process. The Irish dairy industry has had a very successful past. It now must take action to secure a successful future.

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