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HAL Project Title:

Opportunities and challenges faced with emerging technologies in the Australian vegetable industry.

(Technology Platform 1: Supply Chain and Logistics)

Project VG08087

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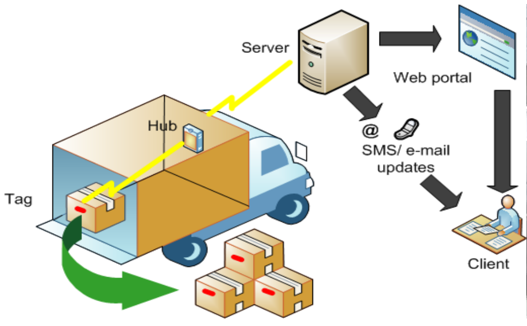

Opportunities and challenges faced with emerging technologies in the Australian vegetable industry.

(Technology Platform 1: Supply Chain and Logistics)

Horticulture Australia Project Number: VG08087

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Purpose of Project:

This report was prepared as an outcome of Milestone 102 of project VG08087,"Opportunities and challenges faced with emerging technologies in the Australian vegetable industry". The project aims to provide a broad review of technologies that are influencing the competitiveness of the industry. This is the 1st of five reports to be developed during 2009-2010 and reviews emerging technologies in Supply Chain and Logistics.

Funding acknowledgements:

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Media summary

The project “Opportunities and challenges faced with emerging technologies in the Australian vegetable industry” aims to provide a broad review of technologies that are influencing the competitiveness of the Australian vegetable industry. This is the 1st of five reports to be developed during 2009-2010 and reviews emerging technologies in Supply Chain and Logistics.

The following categories were investigated:

1. Emerging technologies for management of supply, demand and inventories, which included enterprise resource planning and digital pricing, among others.

2. Robotics and automation, with emphasis in mechanical harvesting.

3. Emerging packaging technologies, including active and intelligent packaging.

4. Cold chain logistics, including thermal packaging and refrigerated transport.

5. Emerging concepts in supply chain management, including the concepts of local supply chains and horticultural value chains.

Some key findings on this analysis were:

- A prerequisite for the exploitation of technologies to optimize supply, demand and inventory management is the adoption of computer and internet technologies. The low percentages of horticultural farms using a computer (62% in 2006) mean that there is little hope in achieving supply chain excellence if vegetable growers can’t access these basic requirements.

- Barriers to the adoption of active and intelligent packaging are costs and the fact that the benefits of improved product shelf-life do not necessarily flow back to growers. Although the value proposition from the adoption of new packaging technologies at farm level is not fully understood, growers have had to use these technologies to meet supermarket requirements. The investigation of costs and technical issues surrounding the adoption of new retail formats could enable HAL’s stakeholders to negotiate fairer terms of uptake with retailers.

- Increased urban population coupled with an increased awareness in the impact of food chains on the environment will lead to the development of new food chains. Fruit and vegetable growers can capitalize on these trends by re-developing farmers’ markets chains, direct grower-urban consumer chains and local /regional chains that appeal to ‘locavores’.

Further, historical patent trends were analysed to forecast the stage of these technologies (e.g. growth, maturity or decline) and the estimated time to full commercialization and R&D decline. From these observations, we propose a three-tiered strategy for project funding.

Technical summary

The objective of the project "Opportunities and challenges faced with emerging technologies in the Australian vegetable industry" is to provide a broad review of technologies that are influencing the competitiveness of the Australian vegetable industry.

This report is the first of five analyses to be developed in 2009-2010 and reviews emerging technologies in Supply Chain and Logistics.

A scanning of emerging SCL technologies revealed the following categories of interest:

1. Emerging technologies for management of supply, demand and inventories, which included enterprise resource planning, geospatial information and global positioning systems, remote sensing, electronic commerce, digital pricing and RFID track & trace.

2. Robotics and automation, with emphasis in mechanical harvesting.

3. Emerging packaging technologies, including active and intelligent packaging.

4. Cold chain logistics, including thermal packaging, mini-containers and refrigerated transport systems (sea, road and air).

5. Emerging concepts in supply chain management, including emerging distribution models (e.g. local supply chains, sharing of distribution networks and infrastructure, and supermarket initiatives in sustainable distribution) and horticultural value chains.

Key findings on this analysis were:

- A prerequisite for the exploitation of technologies to optimize supply, demand and inventory management is the adoption of computer and internet technologies. The low percentages of horticultural farms using a computer (62% in 2006) should be improved. This issue is particularly critical in small operations with revenues of less than $50,000. There is little hope in achieving supply chain excellence if vegetable growers can't access these basic requirements. Some strategies are suggested to increase computer and internet based technologies.

- The adoption of robotics in the Australian vegetable industry is low. Barriers include the need to adopt once-over harvest, mismatches of capacity with other supply chain operations and cost. However, it is expected that the integration of robotics with other emerging technologies (e.g. GPS, automatic machine guidance and computer-based vision systems) will significantly improve current performance. It is also expected that, as the costs of these technologies decline, commercial adoption of these new methods will increase.

- Barriers to the adoption of active and intelligent packaging are the cost and the fact that the benefits of improved product shelf-life do not necessarily flow back to growers. The same can be said about retail-ready presentations and the introduction of recyclable plastic crates. Although the value proposition from the adoption of these technologies at farm level is not fully understood, growers have had to adopt these technologies to respond to supermarket requirements. The quantification of costs and technical issues surrounding the adoption of new packaging systems could enable HAL's stakeholders to negotiate fairer terms of uptake with retailers.

- A major barrier to the use of modern (and old) cold chain technologies is the difficulty in proving a cost-benefit case. As with all the technologies investigated in this report, there is no average case study that can be representative of costs for all types of operations and products. Each case is unique and depends on a number of factors, including the size of the logistics operation, contractual arrangements with refrigerated transport providers and preferred service providers by buyers.

- Increased urban population coupled with an increased awareness in the impact of food chains on the environment will lead to the development of new food chains. Fruit and vegetable growers can capitalize on these trends by re-developing farmers' markets chains, direct grower-urban consumer chains and local /regional chains that appeal to 'locavores'.

- The major challenge for the implementation of value chain and co-innovation in horticultural chains is creating the level of trust and commitment required for these alternative business models. Implementation of value chain concepts could be pursued by placing retailers in the role of innovation leaders for the horticultural industry. The development of more balanced value chains with the foodservice, hospitality and Government procurement sectors could also be pursued.

Historical patent trends were analysed to forecast the stage of these technologies (e.g. growth, maturity or decline) and the estimated time to full commercialization and R&D decline. A summary of the status of each technology is presented, including stage of development, predictability and timeframe for commercialisation, among other parameters.

From these observations and in view of the forecasted decrease in HAL-funded supply chain projects by 2011, we propose that the supply chain platforms investigated in this report should continue to be supported, although with different funding strategies. A three-tiered strategy is proposed.

Project Background

The vegetable industry is a truly multi-disciplinary business, particularly in the context of modern global supply chains. The industry draws knowledge from a variety of fields such as plant breeding and production, greenhouse technologies, irrigation, climate control, information technologies, product processing, packaging, logistics and consumer science, among others. Therefore, the growth of the vegetable sector is intertwined with the development and application of innovative solutions in the fields mentioned above. The use of molecular biology to produce new enhanced (but still non-genetically modified organisms) cultivars that increase yields, the introduction of pre-packed fresh vegetables and the development of track-and-trace systems that can improve transparency in food supply chains are some examples of how emerging technological trends can influence the competitiveness of the Australian vegetable industry.

The objective of the project "Opportunities and challenges faced with emerging technologies in the Australian vegetable industry" is to provide a broad review of current and emerging technologies that are influencing the competitiveness of the Australian vegetable industry. This review, carried out through the use of competitive intelligence analyses, provides a technology roadmap that shows: (a) where the Australian vegetable industry lies in the use of technology that benefits the competitiveness of the sector; and (b) what specific technological trends can affect the industry's competitiveness in the years ahead.

The application of competitive intelligence (CI) techniques in this report was used to explain how the exploitation of emerging technologies (or lack of thereof) can influence the profitability of the Australian vegetable sector. In this project, the application of CI was based on a two-staged approach:

I) An analysis of the technological state-of-the-art in the Australian vegetable sector, *i.e.* what technologies are been applied commercially (as distinct from pilot trials) during the production, harvesting, processing and distribution of vegetables in Australia. This analysis includes hurdles faced by 'first-movers' in the implementation of new technologies and the benefits reaped from the uptake of new technologies.

II) An analysis of emerging and potentially disruptive technologies with potential impact on the vegetables industry. The analysis included potential impediments for commercial implementation in Australia and potential benefits arising from the uptake of such technologies.

This project delivers competitive intelligence analyses in five key technological platforms relevant to horticultural industries:

(1) Supply chain and logistics systems.
(2) Technology to adapt to climate change and environmental changes.
(3) Technology for food safety and quality assurance.

(4) Value addition processes (*e.g.* functional genomics, novel manufacturing processes).
(5) Technology for production and harvesting (including glasshouse production, robotics, mechanization and precision agriculture).

The present report specifically delivers to the first technical platform: supply chain and logistics.

Introduction: development of emerging technologies in horticultural supply chains

The Mack Center for Technological Innovation[1] defines "emerging technology" as '*a science-based innovation*[2] *with the potential to create a new industry or transform an existing industry'.* Although some authors differentiate between emerging and converging technologies[3], in the context of this report we will use emerging technology as a broad term that identifies any significant technological development with a potential for the transformation of an industry.

Figure 1 illustrates the behavior of technological performance as a function of time. An idea that is central to the analysis of technological trends is the application of logistic theory in R&D performance parameters (*e.g.* patent trends). This technique is one of several forecasting tools that aims to provide an insight on the direction and rate of technology changes in the future. There are four basic elements in this analysis:

a) A time horizon.
b) A specific technology.
c) A performance parameter for the estimation of the technology's advance.
d) A probability about the outcomes predicted.

Technology development is often constrained by limitations or technological barriers (*e.g.* environmental, social, economic or scientific).

An example of a limiting growth factor that may flatten R&D efforts is that the 'ceiling' of the theory needed to develop a technology has been reached. Or perhaps pilot trials show that the emerging technology can't compete in price or performance with current substitutes or does not yet present an attractive proposition for the industry.

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[1] The Wharton School, University of Pennsylvania.
[2] Innovation is a deliberative process undertaken *'by firms, governments and others that add value to the economy or society by generating or recognising potentially beneficial knowledge and using such knowledge to improve products, services, processes or organisational forms'* [17] Productivity Commission, "Public Support for Science and Innovation, chapter 1: Introduction. Draft Research Report.", 2006, pp. 9..
[3] Emerging technologies represent new and significant developments within a field of science; converging technologies represent previously distinct fields which are in some way moving towards stronger inter-connection and similar goals.

Further, in markets where several technologies compete, a technology's market share growth comes at the cost of growth for others. For example, nanotechnology can provide radical step changes in cooling, packaging, electronics and just about every emerging technology category that will be investigated in this report[4]. Growth in nanotechnology-derived products is likely to slow down development of products based on more traditional technologies.

Modern companies face tough decisions in the uptake of technology: those that are low risk takers and slow to adapt to new technologies will relinquish the "first mover" competitive advantage to others and will potentially lose market share to those businesses. However, companies that bet on technologies that fail in the marketplace can also fail. This is why tools that aid technology foresight are important.

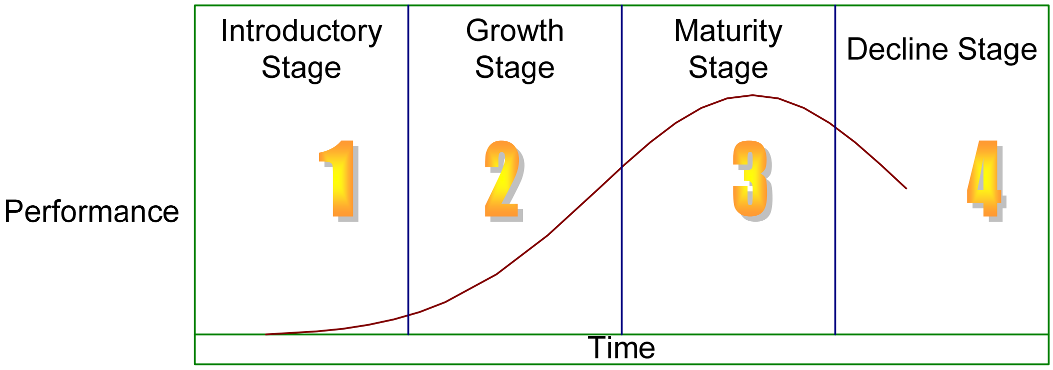


FIGURE 1. Generic growth curve for assessing technological development.

Why and how technological development happens in food chains are relatively unexplored questions. Some authors attribute this to the prevalent deterministic view of food production systems by economic theories, in that agriculture and food production are determined by nature and the biological cycles of crops and livestock (Morgan, 2000). Others view food-related innovation as a low capital, low risk activity, with low requirements of technological novelty or specialized skills when compared to other industrial sectors such as electronics or aircraft manufacturing. Furthermore, the number of patented inventions with direct application in the agri-food sector have been historically low [18]. Yet, food supply chains have successfully applied technologies developed in other sectors, such as the pharmaceutical industry, biotechnology and electronics [19].

Historically, technological development in agricultural chains has been fragmented. After the II World War food innovation focused into production, given that the need to improve yield and productivity in the farm were key drivers for technological invention. The political and economical environment encouraged farmers to invest in R&D, utilizing government subsidies and the available public research institutions oriented to agriculture. Farmers in the United States were particularly successful in capitalizing these opportunities. Agricultural technologies such as developments on seed production and agrochemical methods to

[4] Nanotechnology will be further explored in the report "Value addition processes".

combat weeds and pests in the 1950's significant aided the improvement of output and productivity of agricultural crops worldwide [20]. Concerns on the use of chemical control methods in turn led to the development of integrated pest management in later years [21].

Traditionally, manufacturing-led innovation rarely encompasses initiatives that involve food retailers and there is even less involvement of suppliers in primary industries. This partly explains why new product development (NPD) projects initiated by manufacturers have an extensive consumer research phase but often fail in engaging growers to ensure that the raw materials fulfill quality and grading expectations. Further, manufacturers may fail to ensure that characteristics such as shelf-life and proper storage conditions are understood by retailers so that the new product is adequately displayed in the shelves. As a result of this disengagement among supply chain partners, NPD remains a high risk activity in the food sector, where over 80% of NPD ventures fail [22].

From the three major organizational forces in food supply chains (*i.e.* farmers/growers, manufacturers and retailers) retail-led innovations have focused the most on improving supply chain and logistics through initiatives such as efficient consumer response (ECR), electronic data interchange (EDI) and traceability, among others. In fact, retail-end processes such as ECR, collaborative planning, forecasting and replenishment (CPFR) and category management rely on the joint development of strategic category plans and a collaborative framework between retailers and their suppliers [23].

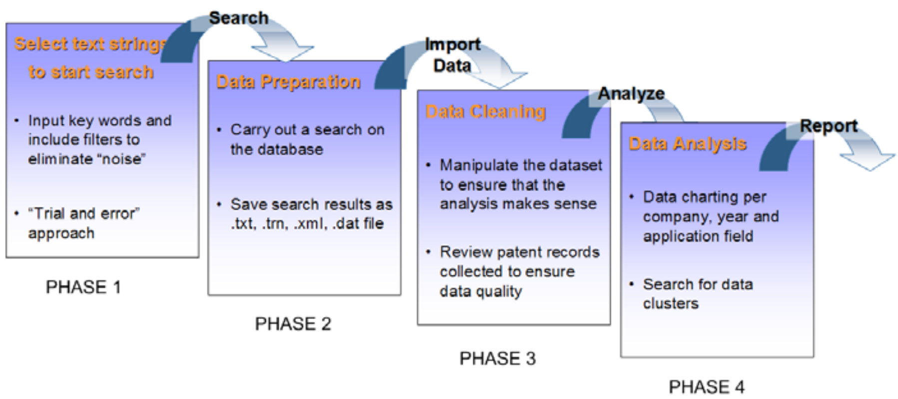
The future will bring demand-driven innovation and technology that seeks to answer consumer's demands in a faster and more efficient manner. But this will only be possible through the development of "whole-of-the--chain" collaborative projects that engage growers, retailers and manufacturers. Collaboration may take the form of information sharing and forecasting, adopting electronic data interchange or improved traceability systems, which are all supply chain and logistics (SCL) technologies that are investigated in this report.

Further, the present report highlights technologies that need to be embraced, understood or at least acknowledged by horticultural growers, to ensure successful communication with clients and suppliers. The report also presents the opportunities and challenges for innovators in the vegetable industry and case studies that illustrate the possibilities to enhance adoption of new technologies.

Methodology

This research encompassed the following stages:

1. **Desk review of the current level of technological uptake.** This review drew information from HAL reports and professional associations (*e.g.* the Council of Supply Chain Management Professionals). Other sources of information were trade magazines, industry associations and submissions to recent Government inquiries and reviews. Examples of the latter included the National Innovation Review and industry submissions to the ACCC supermarket grocery prices inquiry.
2. **Scanning of technologies in pre-commercial and commercial stages with a potential impact in the vegetables industry.** This phase was conducted through a review of scientific literature and patent search. The specific databases used were SCOPU[5]S and Delphion ® [6].
3. **Search of patents.** For the purposes of technology forecasting, the number of patents per year was used as an indicator of technological effort. Other indicators were considered, such as the number of articles published in the technologies investigated. However, this was considered to represent 'blue sky' research, which may or may not be commercialized. Uptake indicators such as sales/volumes of units sold, were considered to represent technologies in full commercial development, as distinct from 'emerging'. Therefore, patent activity represented the middle ground between full commercialization and blue sky research. The Delphion database was used to perform full-text searching of US, European, and World Intellectual Property collections. Multiple patent searches selecting keywords and terms for each technology investigated were carried out as follows:



4. **Technology forecast.** The patents obtained as per step 3 were collected in spreadsheets (attached to this report in a CD) and the historical trends were analysed. Given that the aim of the analysis was to obtain a forecasting model, all patents from all years up to 2008 were included in the analysis (i.e. from the 1st patent registered to the patents registered in 2008). Historical cumulative patent trends were analysed using the Loglet Lab software package to obtain its

[5] http://www.scopus.com. SCOPUS provides access to a wide range of scientific citations and patents.
[6] www.delphion.com. Provides access to over 35 million records from 70 patent offices worldwide.

corresponding growth curve, as per the methodology discussed in Appendix 1. Unless specified otherwise, the search for patents was performed targeting agriculture/ horticulture/food applications. For example: a search for patents related to electronic commerce provided 1,790 references. However, from these patents only 75 specifically relate to the fields above. Exceptions to this rule were cases where the search reported insufficient data or did not provide a true reflection of the stage of technological development. In these cases, a wider search was performed.

5. **Expert opinions.** Using the consultant's and HAL's network of contacts, experts in the platform investigated were contacted to provide their opinions on challenges and opportunities for technology uptake, barriers in the implementation, outcomes of technology uptake (*e.g.* financial, organizational, environmental) and lessons learned from these events. Additionally, an internet search for published case studies was performed. These opinions are presented as case studies or as part of the environmental analysis presented in the following section.
6. **Economic considerations.** Cost benefit considerations for each of the technologies highlighted in this report were included**.**

Scanning of emerging SCL technologies

The concept of supply chain has evolved from a logistics-based activity to the "management of the upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole" [24]. Therefore, any technology that enhances value, coordination, communication and transparency throughout the chain can be classified as a supply chain technology. This view increases the complexity of screening technologies that can influence horticultural supply chains because most technologies are expected to add value and efficiency to these activities.

Technological developments with impacts in 'fresh' supply chains were selected according to expert opinions from a variety of sources [6, 14, 24-27] were compiled. Additionally, a keyword search in the SCOPUS™ database was carried out. After analyzing keywords and trends, the areas summarized in Figure 2 were selected as examples of technologies that can impact the horticultural industry. These technologies were grouped in five categories to ease the analysis:

1. Emerging Technologies for Management of Supply, Demand and Inventories.
2. Robotics and Automation.
3. Emerging Packaging Technologies.
4. Cold Chain Logistics.
5. Emerging concepts in supply chain management.

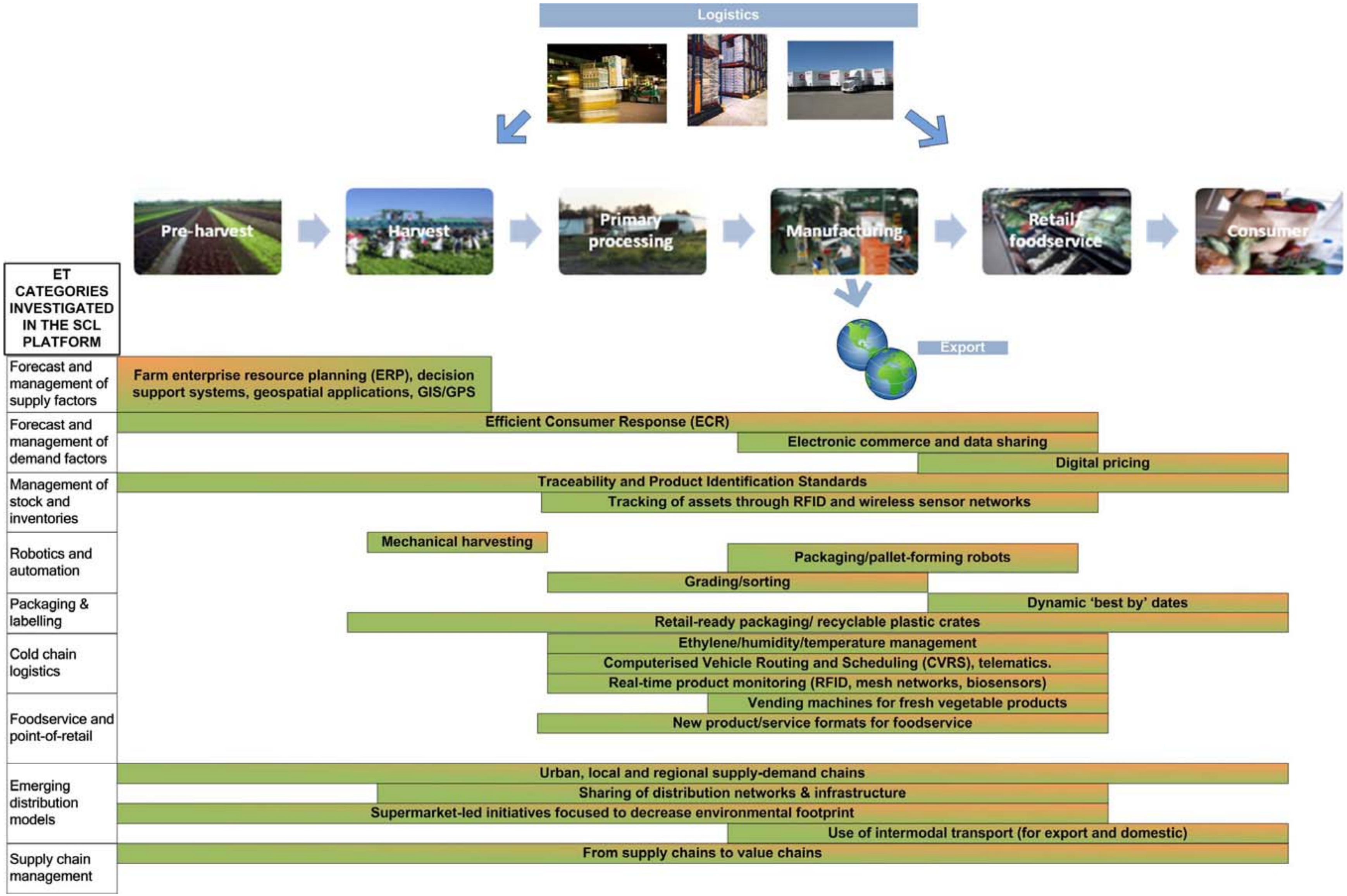


FIGURE 2. Scope of the emerging technologies (ET) investigated in the present SCL report.

HAL-funded projects in SCL technologies

To detect the major focus of investment in HAL projects, a list of the titles of all vegetable funded projects[7] was analysed to extract the frequency distribution of keywords within the title. Figure 3 shows the most frequent keywords associated to HAL funded projects; these keywords suggest that the focus of HAL funding has been on industry development programs, pest management and disease control.

The investment of HAL in projects specifically classified as SCL technologies was also investigated. Titles of SCL projects and start dates were extracted from the HAL's database by performing a keyword search that reflected SCL technologies (*e.g.* consumer response, electronic commerce, packaging). This search led to a sub-sample of 158 projects, funded since 1998 (Fig. 4)[8]. The analysis considered fruit and vegetable projects, as it is believed that diffusion of technological developments is common between these two project areas, particularly in the context of HAL's activities.

Figure 4 shows that the efforts in SCL projects ramped up in 2001 and reached its maximum rate of growth in 2005. In 2006, HAL's SCL strategy went through organizational changes and the development of a strategic plan for the supply chain program. These events explain the change on the rate of projects funded in SCL illustrated in Figure 4.

Logistics growth curve theory dictates that the inflection point is normally found in the middle of the trend life-cycle. This suggests that the peak number of projects in the HAL SCL platform would appear in 2010-2011, if no factors influence current investment policies and strategies in this platform.

Notwithstanding internal factors, one may ask what external (environmental) factors can change the priorities in SCL-related projects. These potential change factors are analysed in the following section.

Figure 5 show that about 40% of HAL's funding in SCL projects has been oriented to developing retail SCL knowledge. The specific projects considered in Figures 2 and 3 are described in an Excel spreadsheet (HAL_summary.xls) attached to this report in a CD.

[7] This list was provided by Karen Symes, HAL, on April 2009.
[8] The search of keywords In the HAL project database was performed by Dr Helen Sargent (HAL) on March 2009.

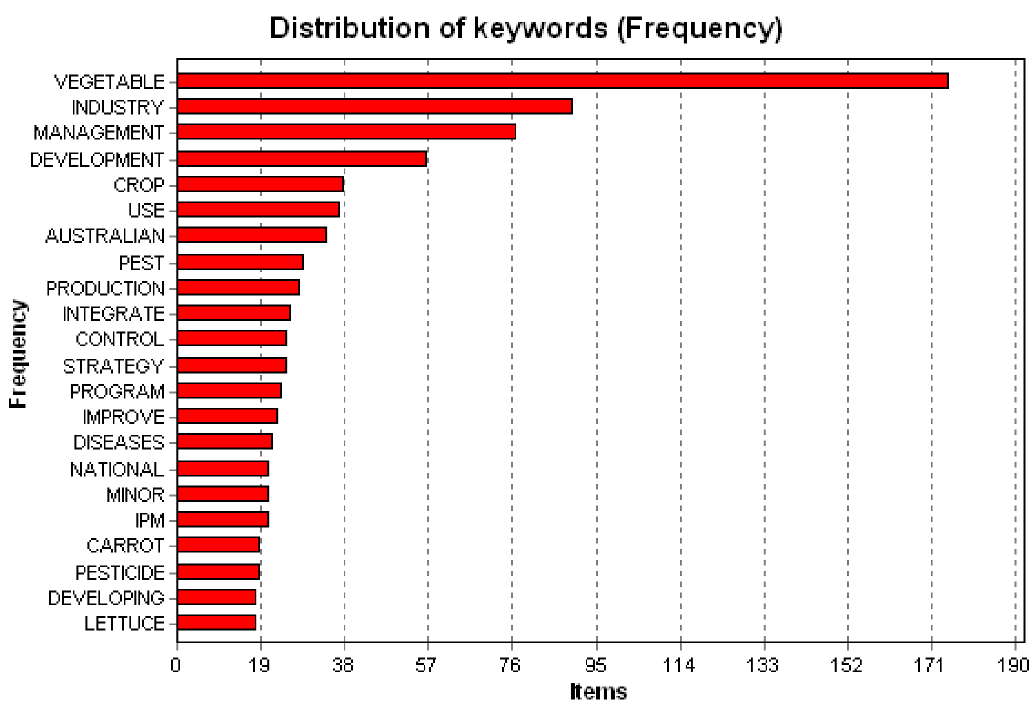


FIGURE 3. Analysis of keywords found in the titles of HAL-funded projects for the vegetable industry. Only the 22 groups with the largest frequencies of appearance on the titles are shown.

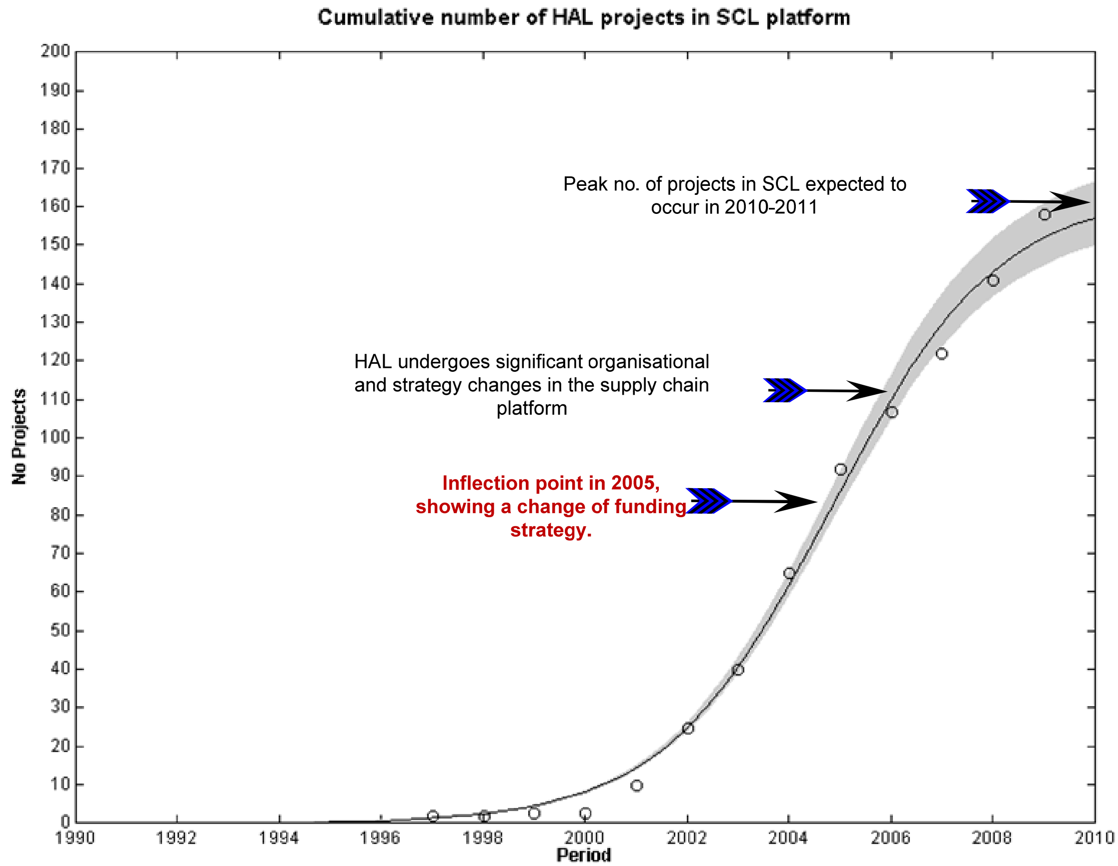


FIGURE 4. Historical cumulative number of projects developed with HAL funding in SCL platform technologies.

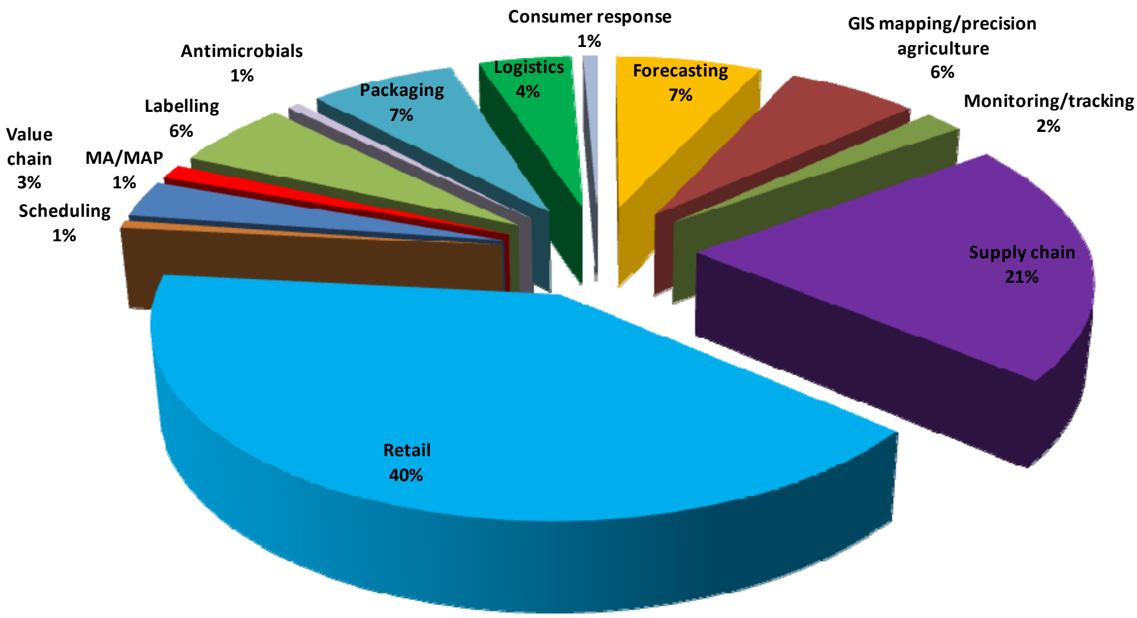


FIGURE 5. Percentage contribution of key SCL areas in 157 HAL funded projects in the SCL platform. Some projects contributed to more than two SCL areas.

Opportunities and barriers for the adoption of SCL technologies in the horticultural industries

Table 1 summarises the social, technological, economic, ecological and political/legal factors affecting the uptake of emerging SCL technologies. This table was compiled from views expressed in a variety of industry reports and forums, which are included in the References section.

Some supply chain issues analysed in Table 1 also impinge in other platforms that will be investigated in this project (*e.g.* food safety and quality, environmental issues, etc). This is mostly due to the broad concept of supply chain previously discussed and the fact that food chain activities do overlap and affect each other.

The next sections present an analysis of individual technologies, discussing the levels of adoption in Australia, the technology forecast (which provides an indication of where the technology lies in its development life-cycle) and cost-benefit considerations for those interested in adopting these technologies.

TABLE 1. Environmental (STEEP) analysis showing the opportunities, challenges and threats affecting the diffusion of emerging supply chain technologies.

VARIABLE	**TREND**	**OPPORTUNITY**	**CHALLENGE**
Social	Fragmentation of horticultural growers	Robotics can work at all scales of production (organic, niche and commercial)	Application of robotics at farm level needs to be adapted to deal with multiple crops/functions. COST BARRIER. **THREAT: Risk of overcapitalization if mechanical harvesters are not suitable for a variety of crops.**
	Increased interest in senior-friendly formats and extension of shelf-life	Product differentiation through packaging.	Unclear cost-benefit proposition *e.g.* benefits in quality and shelf-life improvements need to be balanced with the cost of packaging. AWARENESS BARRIER.
	Eating out is decreasing, while home cooking is increasing. Increased focus on price and value. "Top up" shopping trends (*i.e.* more shopping trips made to fill gaps or supplement main grocery shopping trip).	Opportunities to develop new vegetable presentations that substitute restaurant convenience and increase the value of homemade meals. Product formats that offer larger volumes at good prices may be well positioned in the downturn.	Grower's perception is that investing on emerging technologies is a high risk activity, yet successful developments only benefit supermarkets. COST BARRIER. Private label and branding by supermarkets obfuscates product differentiation [28]. COMMUNICATION BARRIER. In Australia, fruit and vegetable categories have an inability to buy retail shelf space. VALUE CHAIN POSITIONING BARRIER.
	Consumers are turning to frozen foods to minimise waste, shop with less frequency and save money.	Develop new products based on frozen vegetables. Use supply chain technologies to maintain the quality of frozen foods and assure the consumer on their purchases.	Quality of frozen foods is perceived as inferior than fresh presentations. AWARENESS BARRIER. **THREAT: Imports of vegetables now represent about 40% of the frozen vegetable sector.**

	Emergence of environmental concerns such as "food miles" and food carbon footprints.	The industry can proactively develop cooperation schemes to share transport, cold storage and packing houses. This strategy also increases the profitability of the industry.	Competition and fragmentation may make communication and trust-building difficult. COMPETITIVE POSITIONING BARRIER.
	By 2050, about 80% of the human population will live in urban centres[9]. Increased in local and regional sourcing of foods (the rise of the 'locavores')	Start new supply chains for urban settings (*e.g.* "vertical farms" and city-based glasshouses under contract with retailers). Start direct marketing channels between growers and urban consumers and drive 'local chains' marketing campaigns.	These trends may have passed undetected in strategic plans. AWARENESS BARRIER. **THREAT: Growers that are not prepared to take on more risks on the supply chain will miss on these opportunities.**
Technological	As major client segments (*e.g.* supermarkets, foodservice) implement new SC systems (*e.g.* electronic data interchange), they expect their suppliers to follow suit [29].	The uptake of retail and foodservice friendly electronic systems can improve compatibility with electronic business processes; cost reduction/supply chain management; reduction of supply chain transaction costs.	The use of computer-based systems is not sufficiently widespread in the horticultural industry, which slows down adoption of more sophisticated computer-based technologies. EDUCATION AND COST BARRIER Cost and risk sharing during testing of new electronic data interchange systems at grower level is not equally distributed among the supply chain partners that benefit from this technology. COST, COMPETITIVE POSITIONING AND COMMUNICATION BARRIERS.
	Retail wants shelf-ready packaging to reduce on-store costs.	Be selected as category manager, improve relationships with major client segments.	Unclear / unconvincing cost-benefit proposition *e.g.* benefits in quality and shelf-life improvements need to be balanced with the cost of good cold chain management. COMMUNICATION BARRIER

[9] http://www.verticalfarm.com/

	Pressure to shorten lead times yet "deliver in full on time" (DIFOT) New supply chain models are based on vertical and horizontal cooperation between firms. Push for an increase in private labeled produce in supermarkets.	Adoption of new supply chain structures can positions companies to be selected suppliers better than companies that are slow to adopt these.	The uptake of supply chain technologies is perceived as a responsibility of the transport provider, as opposed to a responsibility shared among all the chain partners. AWARENESS BARRIER. Little cooperation is currently achieved; there is mistrust in grower- supermarket and small farm-large farm relationships. COMMUNICATION BARRIER. **THREAT: Private label can lead to devalue categories and mask the entry of imported product into the market, thus decreasing opportunities to value-add and differentiate.**
Economic	Increasing costs of supplies for vegetable producers.	Mechanical harvesting, geospatial applications and robotics can decrease labour and management costs.	Technology uptake requires substantial capital investment. Access to bank loans and Government support is currently very difficult. COST BARRIER.
	Woolworths and Coles continue to hold the majority of the retail value share of the national packaged grocery market.	Opportunity for retailers to take a leadership role on supply chain innovation across the horticultural chain. Opportunity for the horticultural in seeking other channels/markets (*e.g.* convenience, export, healthy snacks, whole prepackaged meat& salads meals).	Innovation in horticulture is stifled from the imposed requirements of supermarkets; generally over-populated supply chains with tight margins and cost agendas [30]. Premium private labels will compete for shelf space and consumer spending, putting further pressure on suppliers. Current retail supply chain and packaging requirements will only increase for suppliers of private label products. PRIORITY AND COST BARRIER. **THREAT: Retail leadership may mean stagnation of innovation and technology uptake in area with high impact for farmers but low impact for retailers.**

	Increased energy costs.	Improvement of cold chain equipment to decrease energy consumption.	The cold chain is seen as a 'problem solved'; there is little investment in developing this area. AWARENESS BARRIER
	Transport and storage activities, which are key elements to an integrated supply chain, are price driven. Cost of transport is a significant proportion of costs for the vegetable supply chain. Domestic grocery supply chains continue to undergo significant consolidation to take advantage of scale economics. Vegetable supply chains are becoming longer (i.e. more links).	Incentive to adopt technologies that can reduce cost in the supply chain and provide services at a low cost to end users, thereby securing market share and generating scale economies Adopt technologies that decrease the number of transactions and software that allows optimization of supply chain nodes (*e.g.* telematics and computer-based vehicle routing).	Vegetable supply chains are heavily reliant on good transport and storage, yet chain optimization is mostly left to the service provider. Transport and storage services are accepted as provided. PRIORITY AND COST BARRIER.
Ecological	Although agriculture is not yet considered in the future emissions trading scheme, this will be reconsidered by 2015.	Improved forecast systems for vegetables production as affected by water scarcity, soil and temperature changes can better prepare the industry to deal with future production scenarios.	No immediate benefit seen in the uptake of new forecasting systems. COST BARRIER **THREAT: Restrictions on water use can disadvantage Australian vegetable exporters with respect to competitors, due to the unreliability of supply.**
	Vulnerability of food distribution systems can increase under climate change.	The vegetable industry can develop new local and regional distribution models that decrease the environmental impact of vegetable chains. Disruptions due to natural disasters (*e.g.* bushfires, hurricanes) can be better managed if there are alternative emergency distribution systems planned.	No assessments on the consequences of disruptions due to extreme weather events and bush fires have been undertaken for the vegetable industry. **THREAT: Recent experiences from the Victorian bush fires demonstrate that both supply and quality of fresh vegetables is disrupted. This makes the Australian industry more vulnerable to lose market share to imported product.**

Political/ regulatory	There is a growing need to better forecast supply and demand of food (*e.g.* vegetables) as part of a national food security system.	By moving first to implement traceability systems, the vegetable industry can build credibility on the area of food safety.	The industry has more pressing concerns, such as financial sustainability. PRIORITY BARRIER
	Under the carbon pollutions scheme, waste water streams from vegetable processing will be monitored for high organic content.	New technologies (e.g. precision agriculture) can reduce inputs at farm and processing levels (including water and energy) and decrease emissions and leaching to soils.	Given that only 4% of Australian-grown vegetables are exported[10], international trends in traceability do not significantly impact the vegetable industry. PRIORITY BARRIER. **THREAT: Decrease of profit margins due to new regulatory burdens around water use for vegetable processors.**
	FSANZ is currently developing Primary Production and Processing Standards for seafood, dairy, eggs, poultry and seed sprouts. It is likely that fruit and vegetables will be also included in the future.	Early movers in product identification codes and traceability technologies stand to gain market share over slower competitors, by becoming compliant before the standards are in place.	**THREAT: Decrease of profit margins due to new regulatory burdens around food safety for vegetable processors.**

[10] Lucy Keatinge, Industry Services Manager, personal communication. 8-April-2009.

Category 1: Emerging Technologies for Management of Supply, Demand and Inventories

Some significant sources of information that provided a broad view of the current levels of software and internet –based SCL technology in the vegetable industry were: (a) The ABS publications "Business use of information technology" and "Use of Information Technology on Farms", released in 2007 and 2006, respectively; and (b) the RMIT report "e-business diffusion in Australia's horticulture supply chain". This report summarises the results of a survey encompassing responses of 92 organisations involved in the supply chain of horticultural products (*i.e.* fruit, vegetable and cut flower growers, plant nurseries, logistics and marketing providers, wholesalers and other service providers). While the sample of this survey represents mostly micro and small businesses, it provides very useful information on the opportunities and challenges of emerging technologies in the small enterprise horticulture sector.

Current level of technology adoption

In Figure 2, most SCL technologies used in forecasting and managing supply, demand, and inventories are computer-based. Computers are the backbone of emerging SCL technologies and without the means to access databases, share electronic information and develop other IT activities it is unlikely that an enterprise will be involved in new developments in this area.

A previous study about the use of logistics chain technology from farmgate to port concluded that usage rates of computers and the internet impose upper bounds on the usage rates of other, more advanced, logistics chain technologies which depend on these components [31]. This study found that in 2002 the use of computers and the internet in the agricultural industry was lower than the Australian average. Results for other supply chain links showed that the transport and storage industry were using these resources in a level closer to the national average and the food and beverage manufacturing industry in a slightly higher level than the average.

Table 2 shows the use of computers and internet in farms engaging in fruit and vegetable growing. While NSW has the largest number of farms, it also has one of the lowest usage rates of computer-based technologies.

In comparison to other types of farms (*e.g.* grain production, cattle farms), fruit and vegetable farms showed the highest proportion of computer use (62%). They also reported a higher internet usage than other types of farms (60%). These percentages suggest an expansion of IT-based technologies with respect to 2002, where the proportion of horticultural farms using computers and internet were 59% and 51%, respectively.

TABLE 2. Use of of computers and internet in fruit and vegetable growing farms by State in 2004-05 [32].

REGION	**Number of farms**	**Farms using a computer**		**Farms using the internet**	
		Number	**%**	**Number**	**%**
New South Wales	4,991	2,783	56	2,765	55
Victoria	4,485	2,801	62	2,724	61
Queensland	4,050	2,611	65	2,554	63
South Australia	3,614	2,256	62	2,192	61
Western Australia	1,911	1,282	67	1,237	65
Tasmania	880	595	68	571	65
Northern Territory	148	81	55	76	51
Australian Capital Territory	9	8	89	8	89
Australia	*20,088*	*12,416*	*62*	*12,126*	*60*

The relative increase in computer use during 2004-05 can be partly explained by a decrease on the total number of farms surveyed by ABS with respect to 2002-03: in the latter period, the total number of fruit and vegetable growing operations was 21,213. However, even in States where the number of horticultural operations remained relatively constant during 2002-2005 (*e.g.* WA), there is evidence that the penetration of internet and computers increased in that period.

It is often assumed that the size of the grower's operation is an indicative factor of the level of technological uptake [29]. Table 3 supports this view: large fruit and vegetable growing operations use computer-based technologies in higher percentages than smaller operations.

TABLE 3. Use of computers and the internet in fruit and vegetable growing farms by size of operation in 2004-05 [32].

Estimated value of agricultural operations	**Number of farms**	**Farms using a computer**		**Farms using the internet**	
		Number	**%**	**Number**	**%**
Less than $50,000	5,393	2,730	51	2,691	50
$50,000 to $149,999	5,821	3,495	60	3,441	59
$150,000 to $249,999	2,842	1,663	59	1,607	57
$250,000 to $499,999	2,675	1,934	72	1,860	70
$500,000 to $999,999	1,765	1,295	73	1,235	70
$1m or more	1,592	1,300	82	1,292	81
Total	*20,088*	*12,416*	*62*	*12,126*	*60*

Figure 6 shows the variety of computer and internet activities that farmers undertake. All of these can be potentially related to SCL technologies. This figure also illustrates the potential productivity benefits through the introduction of technologies. Technological advances in forecasting, logistics management, procurement and inventory management are some examples.

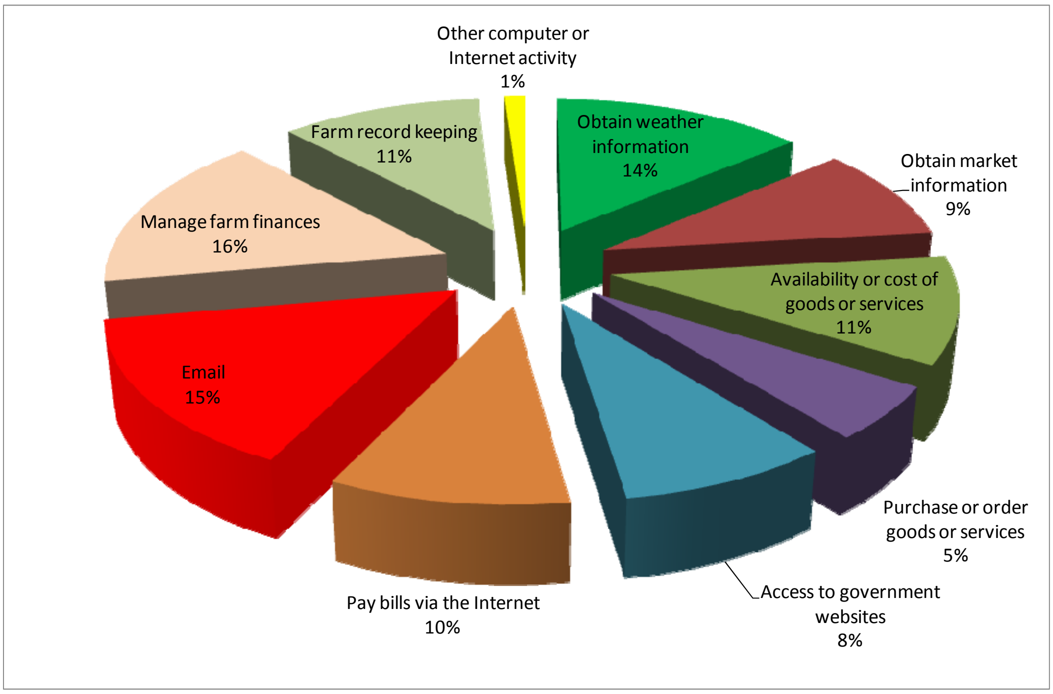


FIGURE 6. Proportion of computer-based activities undertaken by farmers in 2004-05 [32].

The actual diffusion of IT-based technologies in micro and small Australian horticultural growers, service providers and associations was investigated recently [29]. The results shown in Table 4 indicate that acceptance for general internet transactions such as accounting, mobile and use of internet-based services is high. Acceptance for more advanced uses of IT technology that specifically relate to precision farming, EDI and cold chain traceability remains low.

TABLE 4. Adoption of IT technologies in horticultural farms [29].

IT technology	Adopted	Intend to adopt	Will never adopt	N/A
Computerized farm accounting	76%	11%	7%	7%
Broadband Internet	71%	11%	9%	9%
connection				
Mobile and wireless technologies	65%	18%	9%	8%
Website	43%	32%	18%	7%
On-farm electronic monitoring	36%	16%	36%	12%
Bar-code	29%	29%	30%	11%
GPS (Global Positioning System)	24%	25%	40%	11%
EDI (Electronic Document Interchange)	21%	22%	46%	12%
Internet enabled tracking systems	15%	29%	42%	13%
Internet enabled cold chain systems	3%	25%	54%	17%

Overall, the study also found that current IT-enabled functions in the 92 supply chain players investigated tend to be informational (e.g. web surfing) and there is a limited use of IT technologies for monitoring, forecasting, procurement and supply chain collaboration.

It could be argued that the cost of internet services and the lack of infrastructure or critical mass to ensure availability of broadband has slowed down the uptake of internet-related innovations in rural Australia. However, the major impediment seems to be the lack understanding on how internet-based technologies can deliver benefits to the grower's operations. Examples of potential uses to improve supply chain operations include internet auctions, climate and management information collection and storage system, on-line scheduling facilities for harvesting services, online scheduling, cooperative buying of supplies (*e.g.* fertilizers, seeds, transportation services) and many others.

Technology forecasts

Farm enterprise resource planning

Farm enterprise resource planning (ERP). An integrated software solution used to manage a farm's resources [2]. Managed functions include budgeting, planning, production, inventories, sales and accounting. All the farm's data is placed in a central repository, where it can be matched, cross-matched, and shared across departments and other trusted companies using Internet or EDI [6].

An ERP system for horticultural farms can incorporate the following functions:

- Business & activity control
- Traceability practices
- Business profit enhancement
- Cost management and control
- Budget management
- Staff accountability and management practices

The patenting trends of ERP applications for a variety of manufacturing industries are presented in Figure 7. The application of a logistic growth model indicates that these technologies entered maturity in 2005 and the decline on R&D performance (as indicated by the number of patents published in the area) will commence in 2012. The curve shows that HAL funded projects in ERP-related technologies (*e.g.* crop forecasting) started during the growth phase. The investment in crop scheduling programs for vegetables is now occurring in the mature stage.

Cost-benefit considerations

Australia has an active farm software industry, producing over 650 products, with 250 product developers and more than 190 companies and agencies involved in its production. Products range in price from free to $36,750, with the average price being $1,436 [33].

Cost activities and capital costs that should be considered when evaluating an ERP system are:

- Staff time for developing the business case.
- Staff time for software selection and evaluation.
- Purchase of operating system and PC that fulfill the requirements for efficient use of the ERP software.
- Software license fees.
- Staff time and cost of training.
- Maintenance and support fees.
- Cost of upgrading versions.
- Purchase of handheld readers or PDAs for warehouse/inventory/tracking management.

Some ERP options specifically marketed for farm application and indicative costs were investigated in this report, through e-mail and phone interviews. The product, functions and cost considerations are presented in Table 5.

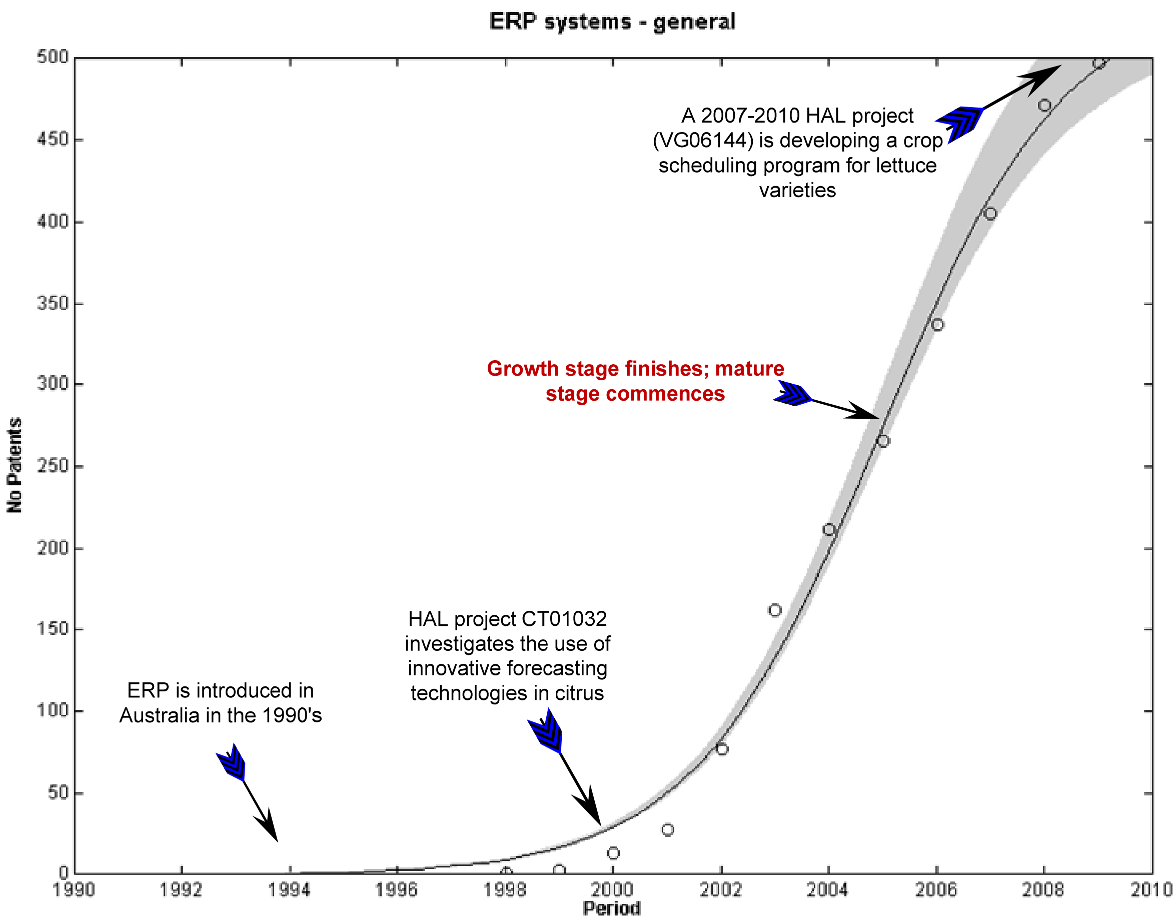


FIGURE 7. Growth curve of ERP applications for a variety of enterprises.

TABLE 5. Some ERP software solutions specifically marketed to fruit and vegetable growers.

Product	International representatives	Functions	Cost considerations	Website
ProducePak Farm ERP	Australia, US, UK	The primary focus of the system is on business control, traceability, profit, cost management and control, budget management, staff accountability and management practices. Specific functions include: prepare production budgets prior to the start of each season, monitor budgets on a daily basis to identify budget overruns, profit reporting down to individual areas of land at any time during the production process, activity monitoring systems to identify mistakes and deviations, automatic traceability of materials and labour used in production; instant recall from block, crop, and material inputs and others.	ProducePak Farm ERP retails for around $18,000. This includes training, installation, configuration, support, ongoing upgrades for 1 year, and system audits. The price is subject to increase if there are more than five users, and optional integration projects can integrate with financial packages.	www.producepak.com
Agevo Farm Manager R1 – Packhouse and Field Tasks	Australia, UK, USA, Middle East, Africa, Europe, South Pacific, Asia.	The Agevo Pack house solution manages costs for labour and materials. The system covers the entire pack house processes including incoming stock management, quality management, stock and inventory management, purchase orders, sales orders, consignment and dispatch, and sales analysis. The Agevo Field Tasks solution records spray, irrigation, planting, block inputs, harvest, fertilisation and any other crop cycle tasks. It manages traceability of	No response to query about cost.	http://www.agevo.net

		inventory used during field tasks, generates staff/team instruction sheets, alerts for withholding periods, reports cost analysis for each block/crop, maintains labour traceability for all field tasks, displays annual, monthly, weekly and daily views of field tasks .		
Phoenix FARMS Cropping	Australia	Production records, income & expense recording, manage by paddock/sub-paddock or season;machinery maintenance log with schedules, inventory system for chemicals, fertilisers, produce & water etc. Water storage calculations with graphs. Monitor soil, crop growth and plant health observations,pProduce storage tracking, crop plans, share farming allocation, Q.A. compliance.	Software cost: $585.00 (inc GST).	http://www.agdata.com.au
SeedTrack™	Canada, USA	Tracks seeding information, (*e.g.* production location, seeding rates, and harvested quantity), customers, bookings, pick-up, invoicing and payments. Reporting system for inventory control and technical fees.	USD $3,000	http://www.cvctech.com
FarmERP	India	Annual crop planning, daily schedule management; maintain and manage the stock & inventory;irrigation, fertilizer, chemicals application managemen;Water requirement, fertilizer, pesticide dose, spray mix, calculators; can be used to keep track of planting -to-marketing history for multiple farmers.	No response to query about cost and suitability to countries other than India.	http://www.farmerp.com

Geospatial applications

Geographical Information Systems (GIS). A combination of computer hardware, software, and geographic data designed to capture, store, manipulate, analyze, and display data that is referenced to specific points on the earth's surface. The capacity to perform many sophisticated spatial operations on these data differentiates GIS from simple mapping software [8].

Global Positioning System (GPS). Precision Agriculture makes use of satellite systems such as the U.S. Department of Defense's 24 earth-orbiting satellites, which emit radio signals at precise intervals accurate to a billionth of a second. Through triangulation, a ground-based receiver translates the time lag between emission and reception of the signals into precise geographic coordinates on the targeted cropland [8].

Remote sensing (RS). A group of instrument-based techniques employed in the acquisition and measurement of geographically distributed data/information. Remote sensing applications can identify spatial features and variability in a field through differences in color or solar energy reflectance of water, soil and vegetation. This enables determination of crop health, plant emergence issues, insect infestations, accidental herbicide damage, uniformity of fertilizer or water application, drainage patterns, record of crop type and acres, and other crop devastation issues during the growing season [11].

The technology life cycles of geospatial and remote sensing applications for agriculture are presented in Figure 8. Maturity in GPS and GIS applications occurred in 2003, while applications of remote sensing in agriculture are still growing. The peak of R&D investment in GPS and GIS technologies is expected to occur in 2012.

HAL timed well its investment in geospatial applications; particularly in remote sensing, where the promising integration of remote sensing in unmanned vehicles is being investigated.

Cost-benefit considerations

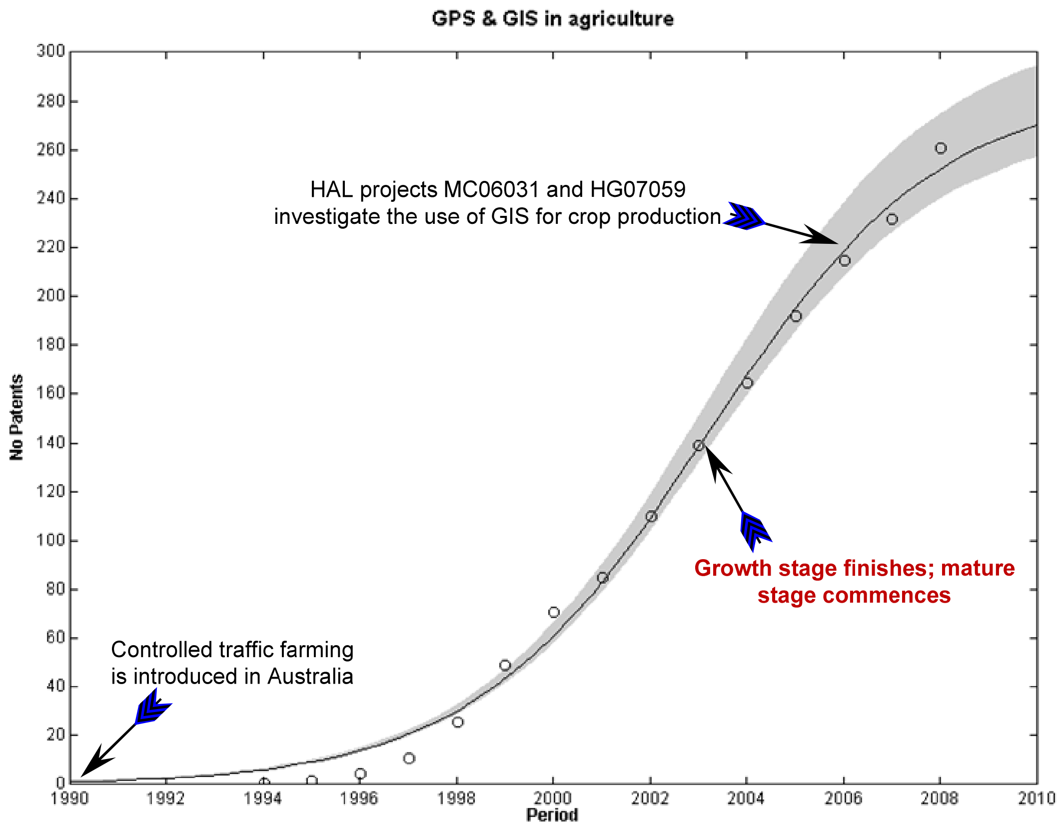
Adoption of controlled traffic farming by GIS, augmented global navigation satellite systems (GNSS) and automated steering in Australia was around 10% in 2006-07, but mostly in broadacre[11] crops. For these crops, real productivity gains from the use of the technologies above are estimated to be 0.93%. Spatial information uses such as variable rate application, yield monitoring, whole farm planning, natural resources management and pest and disease management are expected to report 0.15% gains in productivity and resource availability [34].

As an indication of the specific costs and benefits of adopting geospatial technologies in crop production, a CSIRO study [35] suggested the following implementation costs:

[11] Grains, oilseeds, wheat, barley, peas, sorghum, maize, hemp, safflower, and sunflower. From: OECD glossary of statistical terms (http://stats.oecd.org/glossary/detail.asp?ID=235).

- For a farm of 2,600 ha, yield mapping costs in 2006-07 were $30,000. The detailed mapping information is a pre-requisite for variable rate technology (VRT), which enables matching of inputs with crop and soil requirements as they vary within a field [34].
- For a farm of 5,000 ha, zone analysis and zoning can cost up to $20,000.
- The cost of equipping tractors with GNSS with ±10 cm accuracy is approximately $30,000 including installation. It costs an additional $15,000 to upgrade to 2-centimetre accuracy [36].
- The cost of purchasing a single base station is estimated to be as low as $6,000. This cost varies depending on property layout, farm size and the requirements of the guidance systems. This explains why estimates can be as high as $50,000.
- International cases indicate that telemetry for asset management (particularly for fleet management using remote diagnostics) can decrease in about 15% the harvesting fleet's operating costs, principally due to the increased efficiency and reduced maintenance[12].

[12] http://theland.farmonline.com.au/news/nationalrural/horticulture/general/gps-system-onthelevel/1380797.aspx?storypage=0



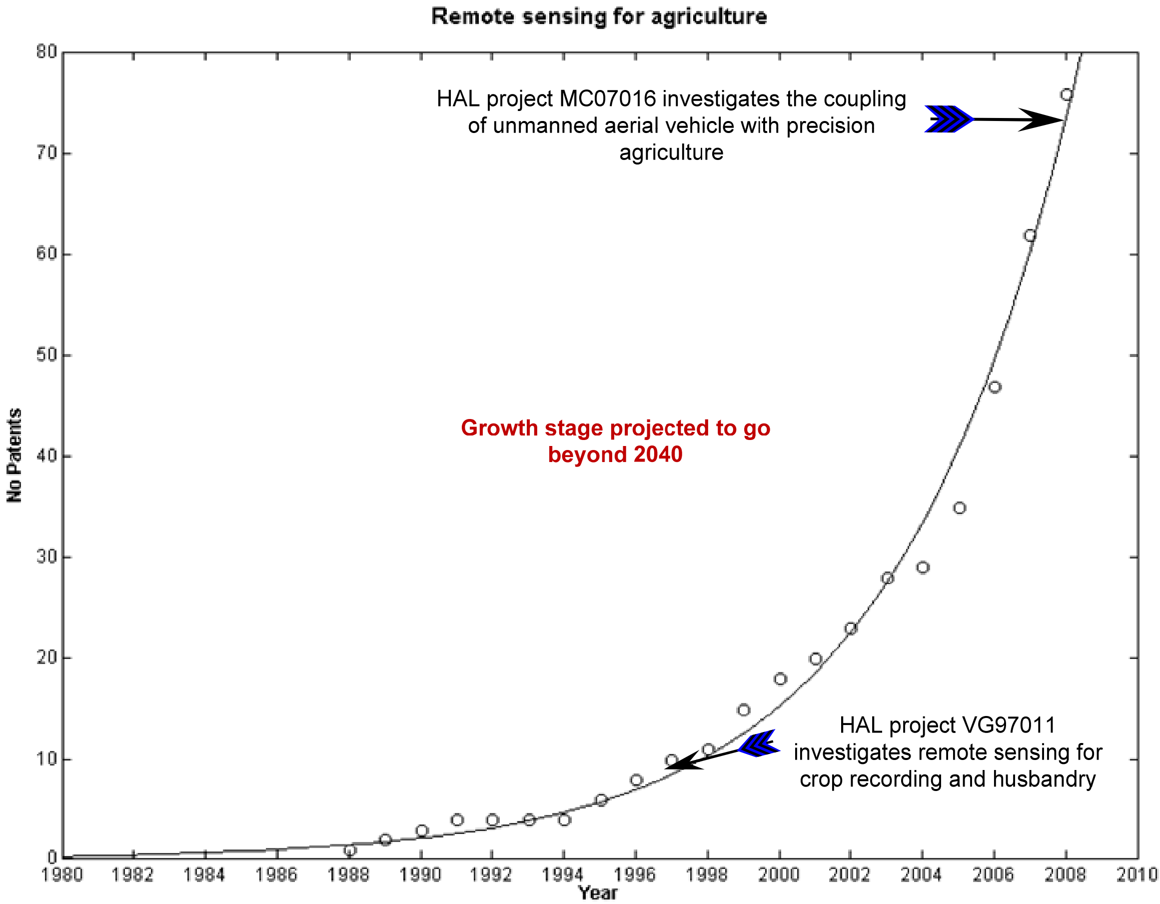


FIGURE 8. Growth curve of geospatial and remote sensing technologies for agriculture.

Electronic commerce and data sharing

Electronic commerce (e-commerce).	Electronic Data Interchange (EDI).
Electronic commerce (e-commerce). Activities conducted using electronic data transmission via the Internet and the World Wide Web. Examples of activities are: (a) consumer shopping on the web or business-to-consumer (B2C); and (b) transactions (*e.g.* sales or supply chain management) between businesses (B2B) [6].	**Electronic Data Interchange (EDI).** The direct electronic transmission, computer to computer, of standard business forms between two organizations. Forms exchanged can be purchase orders, shipping notices, invoices and quality assurance forms, among others [6].

The history of e-commerce in Australia goes back to the 1970s, when pharmacies started to order supplies by electronic means [37]. However, the modern era of e-commerce started in the 90s and by 1998 it was well established in banking, airline ticketing, bill payments and other similar applications.

The use of e-commerce for the trading of perishable items has developed at a slower pace than for non-perishable goods, must likely due to the special supply chain conditions (*e.g.* time and temperature) required for the trading of the former category. In 2000, Telstra created a B2B e-commerce portal for the Australian agri-food Industry called FoodConnect Australia. In conjunction with Supermarket to Asia, FoodConnect Australia was built to assist Australian food producers and manufacturers market their produce more cost effectively to domestic and international markets. FoodConnect seems to the transforming into a different B2B platform now connecting local markets and local consumers; this will be further explored in the section 'Urban, local and regional chains' (Category 5).

Realtime Markets[13] provides procurement of produce through B2B transactions on the internet. The company was developed in the Queensland-based *i.lab* technology incubator in 2000. In 2006 Realtime Markets secured a COMET grant for the development of Go5Live™, a patented online trading software focused specifically on the primary and perishable industry (*e.g.* cattle, flowers, fruit and vegetables, wine). The company is now looking to expand the Go5Live™ platform for seafood trading.

The technology life cycle of e-commerce applications specifically related to applications in food and agriculture are presented in Figure 9. The patent trends fit a bi-logistic curve, meaning that there are two waves of developments in the area. The earliest wave seems to correspond to the use of e-commerce for accounting, purchasing, and other typical service-oriented applications. The second wave is related to electronic biding of agricultural products, integration of electronic coding and food safety and other more sophisticated uses of EDI. The first and second waves entered maturity in 2001 and 2007, respectively. While the 1st wave disappeared in 2003, it is expected that the 2nd wave will reach its peak patent development in 2015.

[13] http://www.realtimemarkets.com.au/

Benefits from the uptake of e-commerce include lowering the cost structure of retailers, removing some intermediaries and promoting competition [38]. However, the uptake of online retailing of horticultural goods has been slow in Australia. Some of the inhibiting factors were discussed before and include the lack of internet access in the vegetable sector, misgivings in regards to the privacy and security of data transferred online and a general lack of knowledge on how to exploit online marketing channels for fruit and vegetables.

No specific projects funded by HAL were found in the area of e-commerce applications for the vegetable industry. This is partly explained due to the tendency of analyzing benefits of e-commerce for businesses situated at the end of the supply chain (*e.g.* wholesalers and retailers).

In 2005, the Australian Food and Grocery Council (AFGC) funded the report *From Barcode to Electronic Code*, which provided the retail and grocery sectors with an indication of the readiness of the Australasian grocery industry to embrace radio frequency identification and electronic product code technology. Another project in this area was the *National Food Industry Strategy (NFIS) Foodchain project*, which involved member companies of the AFGC's Foodservice Forum and distributors. The aim of the project was to develop foodservice industry standards and to show the benefits to the whole supply chain flowing from the implementation of EAN•UCC standards. This included the development of numbering and bar coding guidelines and the creation of the latest version of the Australian Retail Industry message implementation guidelines (MIGs) for Purchase Order and Dispatch Advice.

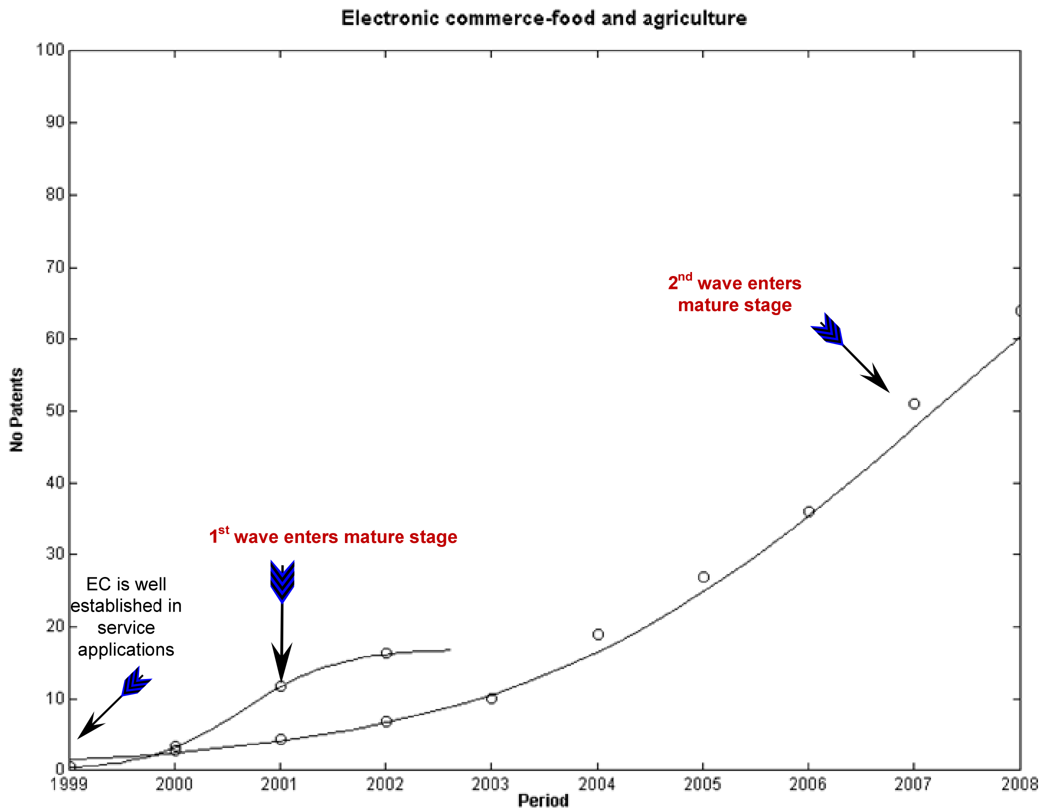


FIGURE 9. Growth curve of electronic commerce technology for food and agriculture.

Digital pricing

Electronic shelf label. A system used by retailers for displaying product pricing on shelves. Typically, electronic display modules are attached to the front edge of retail shelving. These modules use Liquid Crystal Display (LCD) or similar technology to show the current product price to the customer. A communication network allows the price display to be automatically updated whenever a product price is changed.

The theory of digital pricing is the use of efficient consumer response (ECR) and electronic data interchange (EDI) systems to update the price of goods real-time, based on supply-demand information. Digital pricing is based on the use of electronic labels which allow price changes to be automatically and wirelessly sent to the displays. The intention is that retailers save costs through decreased labor time formerly dedicated to manually changing the prices, introduce real-time inventory, and shorter time for preparing orders.

Digital pricing also opens the possibilities of reducing the price (*i.e.* marking down) and initiating promotions of perishable items as their "sell by" date becomes closer [39]. This system is currently being trialed at Whole Food Markets[14], a retailer based in the US specialized in organic produce. Californian grocery stores use a similar system to change the price during hours of non-operation. The check-out price must be equal to or less than the displayed price.

With digital pricing, a store can update the product information displayed on 10,000 labels in less than an hour[15]. Some of the stores piloting the system in the US have typically installed two RFID readers to control 25,000 shelf labels deployed across a 4,650 m^2 sales floor.
An aspect that is of interest to the Australian vegetable industry is that, given that fruit and vegetable categories have an inability to buy retail shelf space (see Table 1), these categories are likely to miss out on the benefits of real-time price corrections as fluctuations of supply-demand occur.

Figure 10 indicates that there is an increasing movement to electronic price labels in supermarkets around the world in both perishable and non-perishable categories.

[14] http://www.wholefoodsmarket.com/
[15] http://www.altierre.com/Articles/rfidjournal_Altierre.PDF

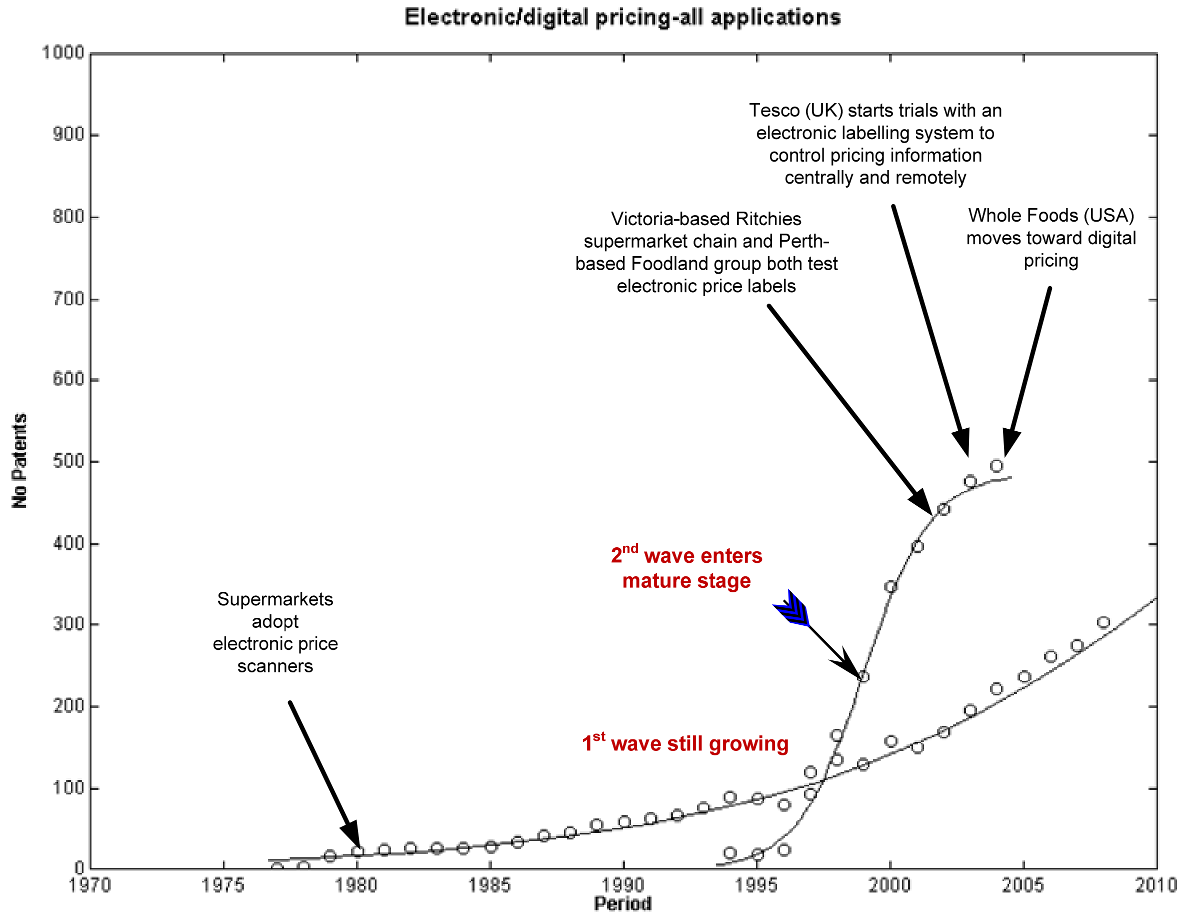


FIGURE 10. Growth curve of electronic / digital pricing technology (all applications).

Figure 10 shows a bi-logistic behavior, indicating two waves of technology. Further analyses suggest that the 1st wave reflects the development of electronic label technology, which reached its maturity stage in 1999 and is now in full commercial uptake. Further development is currently centered on individual, one-time use wireless electronic tags (as distinct from fixed wired systems); while labels were designed to sit on shelves and price information flows to specific product types and brands, future tags will be attached to individual products and will provide individual information on an item. This wave is still in the growth stage and maturity is expected to occur in 2017.

Cost-benefit considerations

Although e-commerce has an immediate value proposition for retail, the costs and benefits for primary producers (*i.e.* growers) is poorly understood. Projects that look at how growers can gain value from advanced e-commerce technologies and how they can integrate their farms to pilot trials are needed. Value chain projects that determine the flow of profits to growers integrated to e-commerce chains as compared with those integrated to traditional marketing channels would be also valuable. With the exception of one reference [29] no reports on these aspects have been published in Australia.

RFID-based tracking, traceability and monitoring

Radio Frequency Identification (RFID). A method of identifying unique items using radio waves [1]. An RFID system for traceability and monitoring purposes generally encompasses a sensor, a tag and a reader, that communicate with each other by means of radio transmission. RFID tags can store an EPC for logistics management purposes, and, if equipped with the appropriate sensor and battery power, a limited number of temperature readings [14].

Traceability. The ability to track any food, feed, food-producing animal or substance that will be used for consumption, through all stages of production, processing and distribution [5].

Traceability has two main components: tracking, which is the ability to follow the path of a traceable item through the supply chain as it moves; and tracing, or the ability to identify the origin, attributes, or history of a particular traceable item located within the supply chain by reference to records held [40].

It is generally agreed that, for a product to be traceable, the following information needs to be known: (1) a Global Trade Item Number (GTIN), which identifies who the "manufacturer" is (*i.e.*, the owner of the brand that appears on the product case) and the type of product inside that case; (2) a lot number that specifically identifies the lot from which the produce came; and (3) the produce's harvest or pack date (if that date is not already incorporated in the lot number) [41]. This information can be carried across the supply chain in two forms: (a) a label that can be read by a human operator, or (b) a label that can be read by a machine. In the latter category, information can be carried in the form of a barcode or in the form of electronic data contained in a chip. RFID technologies are commonly used in the latter carrying technology.

Radio Frequency Identification (RFID) technologies are said to improve the performance of perishable supply chains through the following uses:

a) As a means to track the geographical position of individual packages, pallets, shipping containers, or trucks, which can be stationary or in movement during distribution.

b) As a means to identify items through a unique electronic product code (EPC) or other barcode alternatives.

c) As a means to store real-time environmental data (including temperature) and transmit this information in near real-time, allowing corrective actions to be taken before products are irrevocably damaged.

Although RFID technology has been around since the 70s, its application in food and agriculture started in the late 80s[16]. The technology life cycle of RFID in food and agriculture presented in Figure 11 indicates that this area reached maturity in 2006. The peak in R&D development (as represented by the number of RFID patents) is estimated to be reached at around 2014.

Australian companies were 'first movers' in testing RFID systems for traceability purposes, but the most notable cases are in the livestock industry. HAL initiated projects related to understand the potential of RFID and its role in traceability systems during the embryonic/ growth stages.

The notion that track & trace RFID technologies are now in the maturity stage has also been raised in a study published by Gartner Consulting in 2008[17]. The study evaluated the "hype cycle" of RFID used for pallet and case tracking at retail level. The "hype cycle" is built through datamining of internet media that assesses a measure of "hype" (*e.g.* media releases, websites and blog notes about the technology). The interpretation of the curve obtained is shown in Figure 12.

The cycle for RFID pallet and case tracking indicates that mainstream adoption of RFID may occur in 5 to 10 years, as the market transitions from a compliance-oriented uptake to a revenue-generating uptake. This estimate agrees with the life cycle predicted through the analysis of patent trends in Fig. 11, where the peak R&D development is expected to occur in 5 years.

Gartner estimates that current penetration of retail case and pallet tagging at retail level is between 1% and 5% worldwide.

[16] http://www.rfidjournal.com/article/view/1338/1
[17] http://www.gartner.com/

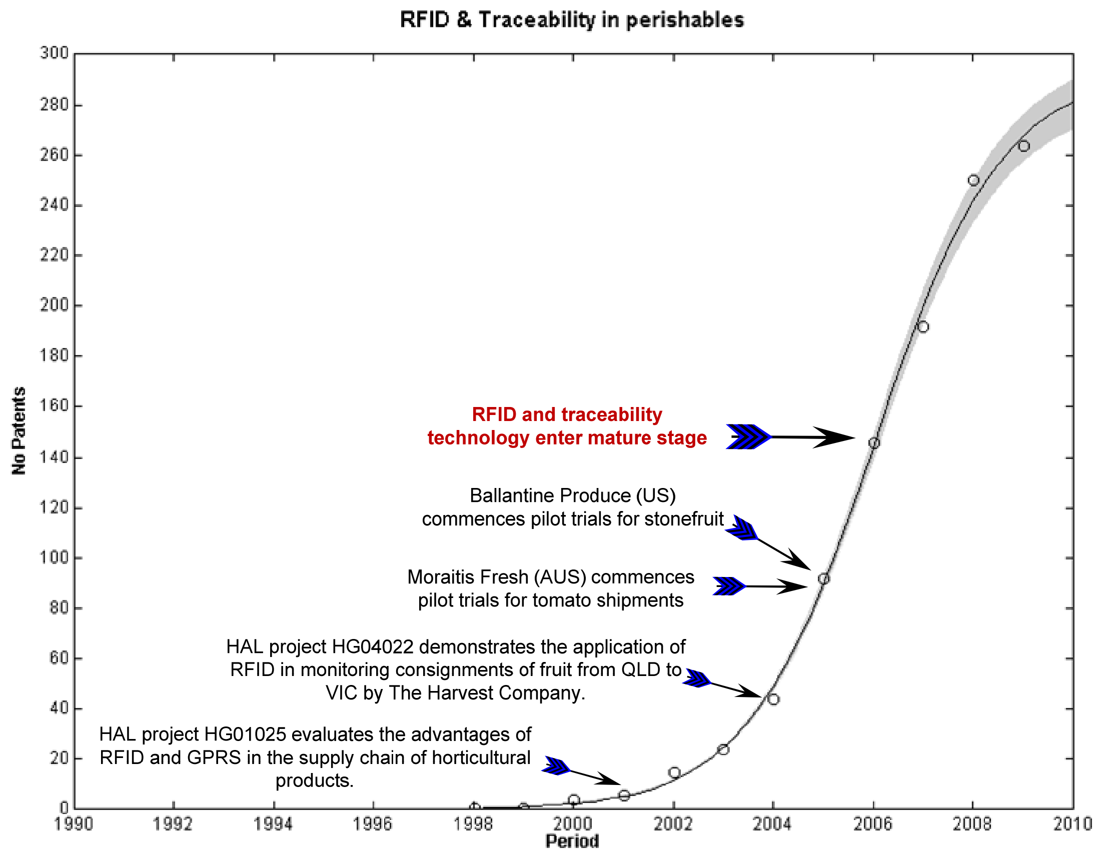


FIGURE 11. Growth curve of RFID and traceability technologies for food and agriculture.

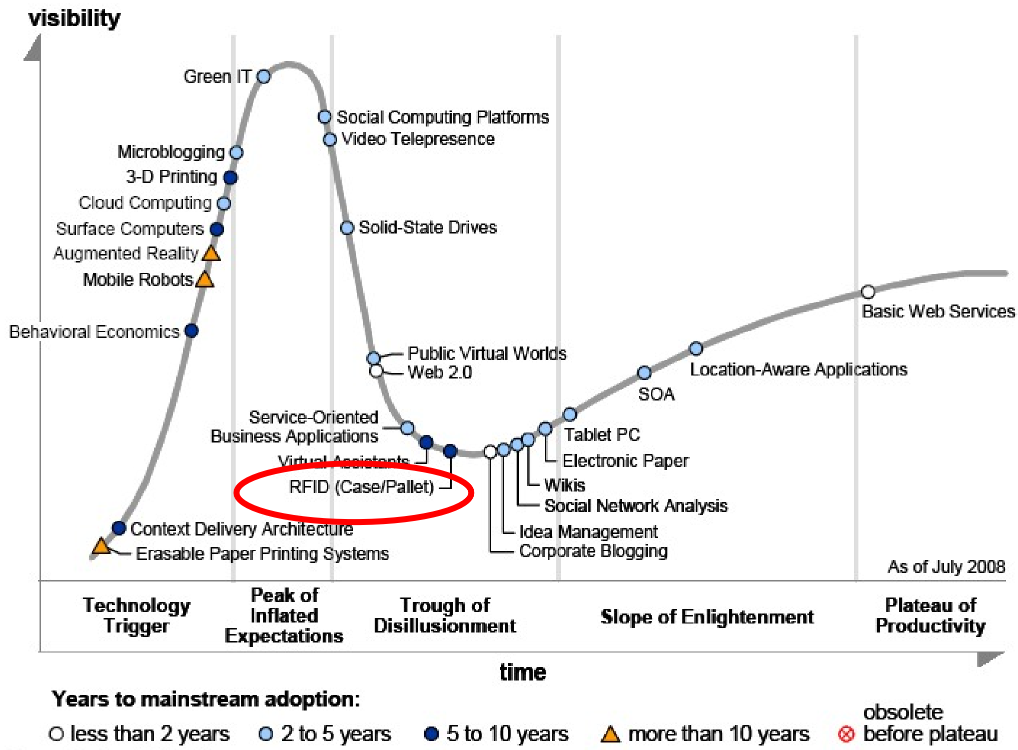


FIGURE 12. Gartner's "Hype Cycle" for emerging technologies, showing the situation of RFID for case/pallet tracking. The "Trough of Disillusionment" is in the middle of the cycle, and indicates that mainstream adoption is between 5 and 10 years away.

Cost-benefit considerations

Table 6 shows some examples of commercial RFID trials in the produce industry, alongside reason for uptake and cost considerations.

TABLE 6. Examples of commercial pilot trials of RFID for traceability purposes. Most of these cases enabled cold chain monitoring.

Company	Supply chain link	Application	Year	Implementation Costs	Benefits
Ballantine Produce (US)	Grower and distributor	Tracking fresh fruit shipments (nectarines, peaches, grapes) from packing house to retail DC	2005	US$400,000	Competitive advantage (1st fruit supplier to comply with Wal-Mart's RFID initiative).
Moraitis Fresh and Testarossa Packers (VIC)	Grower, wholesaler and processor	Tracking tomato shipments	2004	AUD $100,000 (1 year to recoup investment)	To gain supply chain visibility, optimize communications with retail partners and improve processes.
Manor (Switzerland)	Retail	Monitoring of supermarket freezers and refrigerators	2003	AUD$330,000 (30 stores instrumented)	Decrease of shrinkage due to food spoilage; speed up response to equipment failures.
Apo Conerpo-University of Parma (Italy)	Grower	Tracking the entire supply chain of fresh cherries	2007	Unknown	Traceability and QA (management of ripeness).
Rio Blanco (Chile)	Grower	Tracking of avocado temperatures exported from Chile to US (excluding sea voyage)	2007	Unknown	QA.
Chiquita Brands-University of Arkansas-Deloitte Consulting (US)	Marketer, producer and distributor of fresh fruit	Trial shipment of 20 pallets in a refrigerated container transported by road	2006	Unknown	Traceability.
Samworth (UK)	Food marketer and distributor	Tracking of temperatures in refrigerated trucks transporting meats, salads, desserts and other perishables.	2005	Unknown	Maximise shelf-life and avoid shrinkage due to spoilage.
Dole FreshVegetables (USA)	Grower, marketer and distributor.	Tracking of pallets and cases of leafy greens.	2007	Pilot program: US$2 million; Full scale operation: several millions.	Traceability.

A recent study on the reduction of warehouse activity through RFID tagging [42] indicates that the overall impact on cost savings is in the range of 20-60 % through shorter cycle times in receiving, storing, order selection and shipping .

Case studies in the retail industry suggest the following potential savings [43]:

- An increase in sales of 1–2% due to reduced out-of-stock ;
- Shrinkage reduction of 10% ;
- Labour cost reductions of 20% in warehouses ;
- 20-30% reduction in inventory due to lower safety stock ;
- Improved return on investment ;
- Transformation to a demand-driven enterprise ;
- Improvement of visibility and transparency in the supply chain.

Category 2: Robotics and Automation in Harvesting

Current level of technology adoption

Mechanical harvesting provides several advantages over hand-picking, primarily: (1) decreased risks of contamination by human contact at the field; (2) decreased labour needs; (3) flexibility on speed and timing of harvesting; and (4) the ability to work at night. For the Australian horticulture industry, the major points of interest are the ability to increase harvest rates and the reduction of workers in the field, with the associated cost reduction in salaries, training, sanitary measures on field and lifting aids, among others. These characteristics make mechanical harvest a very appealing proposition for farms which traditionally experience labour shortages during the harvest season.

HAL project VG05073 [44] investigated the feasibility of mechanical harvesting of selected vegetables in 2006. Mechanical harvest systems have been developed for carrots, potatoes, radishes, beetroot, iceberg lettuce, celery, cabbage, Brussels' sprouts and cauliflower. The study found that the interest in Australia is on mechanical harvesting which allows in-field harvesting, grading and further processing. Less interest has been detected on the development of sensors to evaluate the readiness of crops for harvesting.

Some examples of adoption of mechanical harvesters for vegetables include the Matilda Fresh Foods broccoli harvester, the lettuce harvester used by the Ruffo family in Bacchus Marsh and the VegeFresh harvested in the Lockyer Valley.

At packing house and processing level, adoption of robotics for grading and sorting is suspected to be higher than at farm level. However, applications on palletizing systems seem to be less common. Some examples include:

- A "Pick & Place" robot packaging system was installed at the Simplot factory in Kelso to pack retail products.

- SPC Ardmona recently installed a high-speed palletizing system capable of handling a wide variety of pack types, sizes, and pallet patterns ranging from wrap-around cartons to open-top and shrink-wrapped trays of canned food [18].

There is a scarcity of information on the current adoption of automation and robotics in the Australian vegetable industry, which strengthens the view of the report VG05073 in that the uptake and awareness at farm level are low.

It should be noted that in this study we have not included robotic applications for quality and safety (*e.g.* x-ray, ultrasonic testing, acoustic testing). These applications will be investigated in the emerging technologies for safety and quality report.

Technology forecasts

Some authors have a dim view on the future of mechanical harvesting technologies [45]. Issues that have contributed to this view are excessive product damage, lack of selectiveness (so that changes in production systems and crop varieties are required for once-over harvest), the mismatch of capacity with other links in the chain (thus creating supply chain bottlenecks) and the cost, particularly when it is considered that mechanical equipment becomes obsolete very quickly. There is also a risk of unintentionally decreasing the availability of workers for non-mechanised farmers, as jobs dry out in one region and workers choose other regions to work in.

Given that mechanical harvesting research started on the 1960's, a reasonable expectation would have been that these issues would be resolved with increased sophistication in robotics and automation. However, this has not been the case. Researchers in the area hope that the integration of new technologies including differential global positioning systems (DGPS), automatic machine guidance and computer-based vision systems will significantly improve current performance. It is also expected that, as the costs of these technologies decline, commercial adoption of these new methods will increase [46].

The technology forecast in Figure 13 indicates that mechanical and robotic harvesting entered the mature stage in 2004. This indicates that the peak of R&D development should be expected around 2040.

[18] http://www.myfen.com.au/Article/Case-Study-SPC-Ardmona-cans-in-safe-hands/478592.aspx

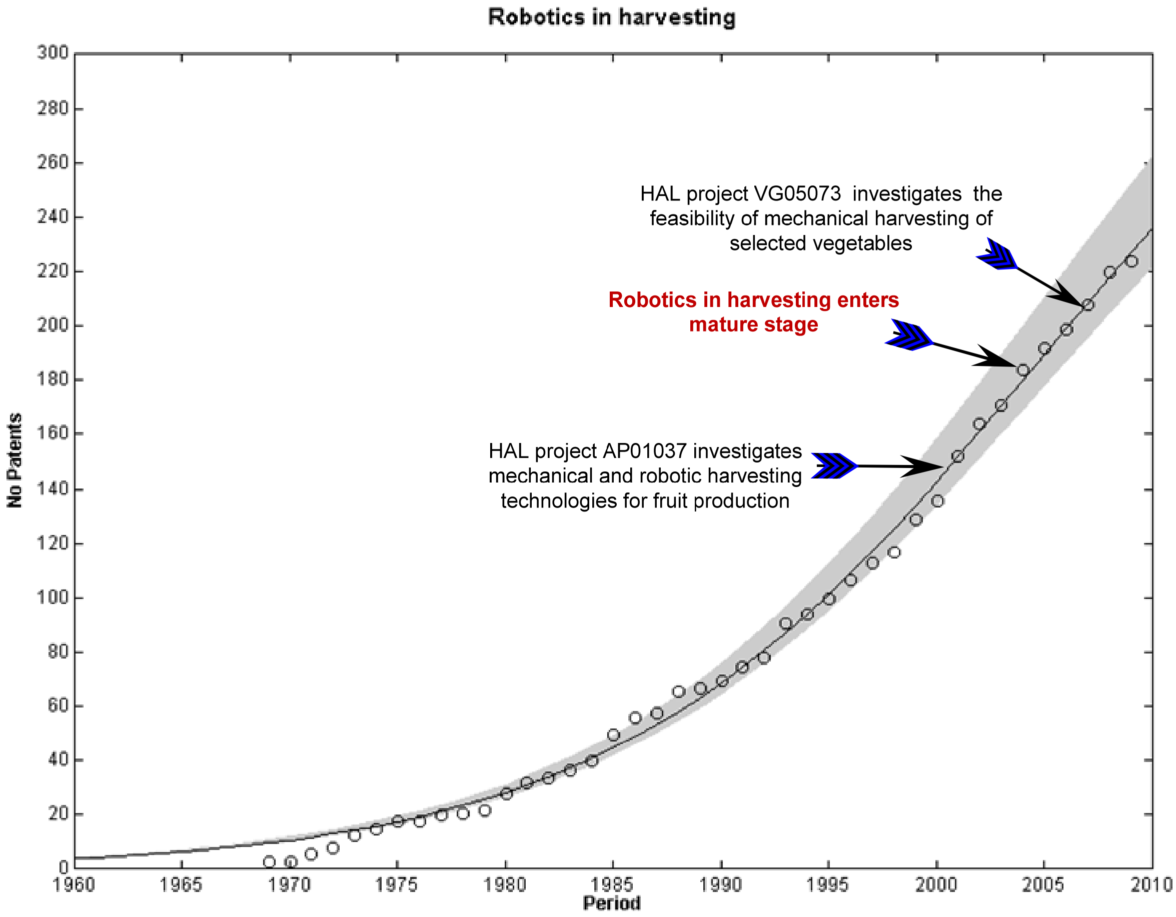


FIGURE 13. Growth curve of robotics and mechanical harvesting technologies for fruit and vegetables.

Cost benefit considerations

Project VG 05073 provided some benchmark cost benefit estimates for mechanical harvesting. The report indicates that for each crop an expenditure of about $3 to $5 million over a 3 to 5 year period should be expected. This cost includes agronomics, harvester development, materials handling systems, mechanized /automated minimal processing, logistics and marketing. The cost also includes system development in at least two regions (thus including variation of geography-dependent factors).

The report also provided some estimated gains achieved through mechanical harvest, based on marketable production with the specific quality required by buyers. These estimates are presented in Table 7. The results show a particularly attractive proposition for cauliflower, leafy greens and tomatoes.

A recent study in the US [47] compared selective and non-selective mechanical harvesters for asparagus in terms of efficiency levels, profitability, and yield harvested. A bioeconomic model was used to determine the impact on profits and harvested yields by the two mechanical harvesters and their levels of profitability compared to manual harvesting. The results showed that at the efficiency levels observed for the selective mechanical harvester (*i.e.* 80% of spear recovery rate, 5% of damage rate to the existing spears, and 5% of damage rate to the harvested spears) the profit generated by mechanical harvesting was $1,497/ha, lower than the profit observed for manual harvesting ($1,666/ha). However, the results suggested that further development of the selective mechanical harvester would likely lead to higher profitability ratios than those found for manual harvesting.

TABLE 7. Cost-benefit estimated for selected vegetable crops through the use of mechanical harvesters.

Crop	Benchmark yield range (kg/ha)	% harvesting cost reduction targets	Estimated improvement
Asian brassicas	Depends on type	70-78	$5,000,000
Broccoli (fresh market)	15,000 to 20,000	65-75	$6,000,000
Broccoli (processing market)	19,500 to 24,000	68-75	$4,000,000
Celery	48,000 to 52,000	55-65	$5,000,000
Cauliflower	40,000 to 45,000	50-70	$30,000,000
Leafy greens	20,000 to 27,500	55-65	$24,000,000
Tomato Roma and bunches	Depends on type	45-55	$20,000,000

Category 3: Emerging Packaging Technologies: Intelligent/Active Packaging

Active Packaging. A packaging that perform functions beyond the protection and identification of its contents [3]. Its main objective is to extend the product shelf-life or to maintain or to improve the condition of packaged food by deliberately incorporating components that would release (those called emitters) or absorb substances (for absorbers) into or from the packaged food or its surrounding environment [15].

Intelligent packaging. Packaging technology that provides external data and/or relays information relative to the status of the contents [3].

We often think of active and intelligent packaging technologies as relatively new technologies. However, in-package (*i.e.* sachets) oxygen scavengers have been commercially available since the 1970s. On-package battery testers, introduced in the mid-1990s and used with alkaline batteries, are one of the earliest types of intelligent packaging [3].

Some typical functions of available active and intelligent packaging are described in Table 8.

Current level of technology adoption

In 1994, HAL funded a project (HG431 - ANL Active Packaging - Market research) that analysed MAP as a competitive advantage for sea shipments of fresh fruit and vegetables. Interestingly, the report predicted a global growth of only 10% on the adoption of MAP between 1994 and 2000. In fact, the adoption of active packaging in the US alone was above 10% per annum, as shown in Figure 14. Demand for active packaging is projected to reach $975 million in 2011, with gains mostly driven by growth for oxygen and ethylene scavengers in food, beverage and pharmaceutical packaging [3].

This discrepancy illustrates the challenges of accurately predicting future uptake scenarios on emerging technologies during the embryonic stages, using only market research: the limited commercial data for projections makes it difficult to project trends. The analysis of emerging technologies through patent trends increases the level of accuracy on the predictions.

TABLE 8. Types and functions of active and intelligent packaging [48, 49].

Type of packaging	**Packaging activity**	**Significance**
Active	Antimicrobial surface Antimicrobial release Oxygen scavenging	Delay of microbial spoilage
	Oxygen scavenging Odor absorption Antioxidant release	Slow rates of rancidity reactions
	Oxygen scavenging	Decrease of nutrient loss and delay of colour changes
	Absorption	Decrease of off odours/flavours
	Dessication Humidity buffering Absorption of condensate	Delay of microbial spoilage and retention of texture
	Ethylene scavenging 1-MCP release Atmosphere modification	Delay of ripening
Intelligent	Time-temperature indicators	Signal temperature conditions and storage time
	Oxygen /carbon dioxide indicators	Signal packaging leaks and storage conditions in MAP
	Microbial growth indicators	Indicate microbial spoilage
	Pathogen indicators	Indicate presence of specific pathogenic bacteria (*e.g.* E.Coli O157)

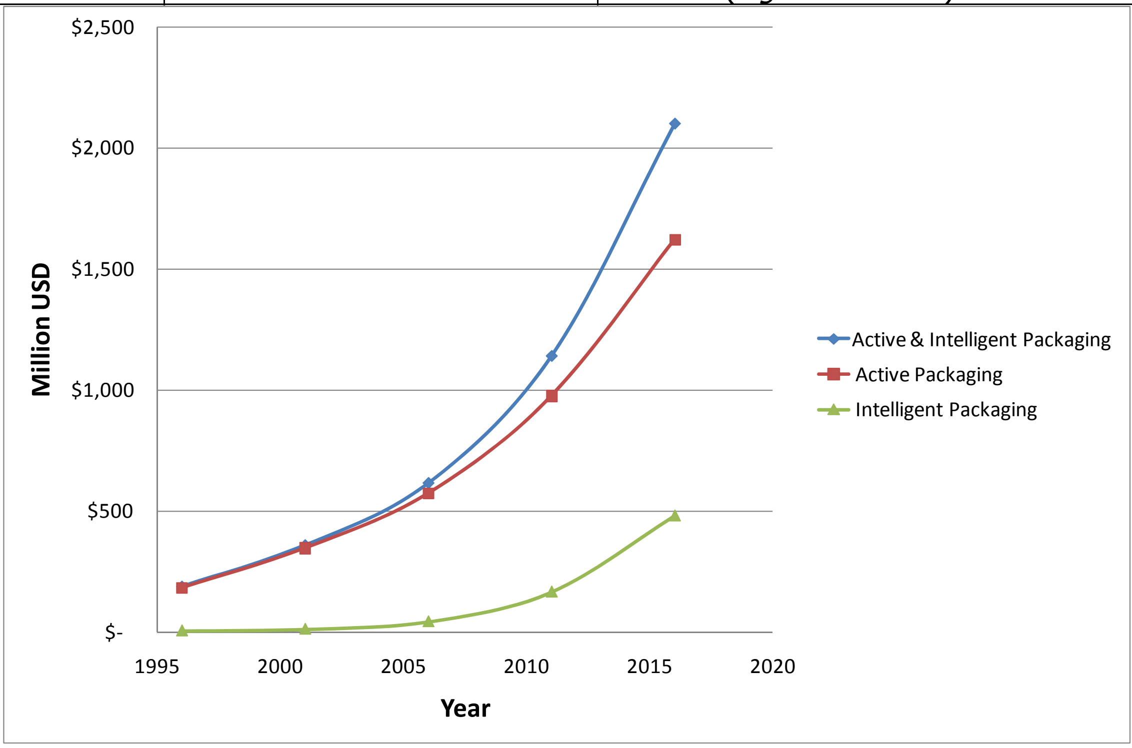


FIGURE 14. Historical data (1996, 2001 and 2006) and forecasts (2011 and 2016) for active and intelligent packaging demand in the US [3].

Technology forecasts

As suggested before, active and intelligent packaging technologies are now mature (Figure 15). Given that these technologies reached their maturity in 2005, it is estimated that the peak of R&D development will be reached in 2042.

Overlapping of Figures 14 and 15 allows us to calculate the time lag between initial patenting activity and commercial uptake. While patenting activity initiated in the mid-60's, revenue of active and intelligent packaging was only significant until 1995. While commercialization initiates with patenting, it is clear that some innovations take over 30 years to give fruit.

Recent active packaging developments are illustrated by the modified "interactive" packaging (MIP) for fresh produce. The technology is based on the ability of fresh produce to adjust its respiration rate via a biofeedback mechanism. Rather than forcing an atmosphere around the produce via a feed forward mechanism (as in MAP), the packaging allows self-regulation of the atmosphere through higher gas permeability rates than typical MAP[19] .

Active and intelligent packaging are expected to develop further through the use of nanotechnology. The present generation of nanocomposite materials has shown enhanced product performance characteristics including thermal stability, increased mechanical strength and improved gas barrier properties. For example, nylon films have now better gas barrier properties due to the introduction of nanoscale additives.

There are many other opportunities to tackle current and future consumer trends through the use of functional packaging. Some opportunities are described in Table 9.

[19] http://www.wrap.org.uk/downloads/LLS_Final_Report_Approved_RS_adp_-_2_9_08_2_.f57ab19c.5798.pdf

TABLE 9. Opportunities to respond to current market trends through active and intelligent packaging design.

Driver/challenge	Opportunity
Supply Chain Integrity	• Anti-tampering packaging (e.g. colour change when package is perforated). • Monitoring of supply chain (temperature, atmospheres, humidity).
Supply Chain Efficiency (environment and cost)	• Carbon-neutral packaging production. • Biopackaging, environmentally-friendly packaging.
Food Quality and safety	• Assessments of quality through reactions to ethylene and other gases. • Use of antimicrobial compounds on the packaging structure.
Convenience and preservation of food quality	• 'Fit-for-purpose' packaging • Oxygen/ CO_2/$H_2$0 permeability • Modified atmosphere packaging
Cost reduction	• Reduce packaging bulk by switching to polymeric materials or by optimizing volumes.
Health and wellness	• Delivery technologies of healthy ingredients (e.g. bioactives) • Ready-to-eat meals combining protein-based meal and vegetables.
Convenience	• Tags/labels compatible with digital pricing strategies • Easy opening packaging for elderly population (e.g. salads) • Retail-ready packaging for vegetables.

Cost benefit considerations

Costs of intelligent and active packaging vary widely [3]. For example:

- Chemical-based time-temperature indicator (TTI) labels average from US¢2 to US¢5 per unit,
- Electronic TTI labels capable of transmitting downloadable data can cost more than $10 per unit.
- In-package desiccants and oxygen absorbers generally range from US¢2 to US¢5 per unit, but it depends on the type of dessicant used: molecular sieves, which are capable of significantly higher moisture absorption, cost as much as five times the price of silica gel on the basis of equivalent volume.
- While the absolute cost of products such as labels using thermochromic inks is low, the use of such inks cans easily double the cost of a primary packaging label.
- In general, prices of active and intelligent packaging are expected to fall or remain stable through 2011, with prices of more costly types expected to drop further by 2016 as innovations and higher volume enable greater cost efficiency.
- However, active and intelligent packaging products do add to packaging costs. This will keep many product types limited to niche applications.

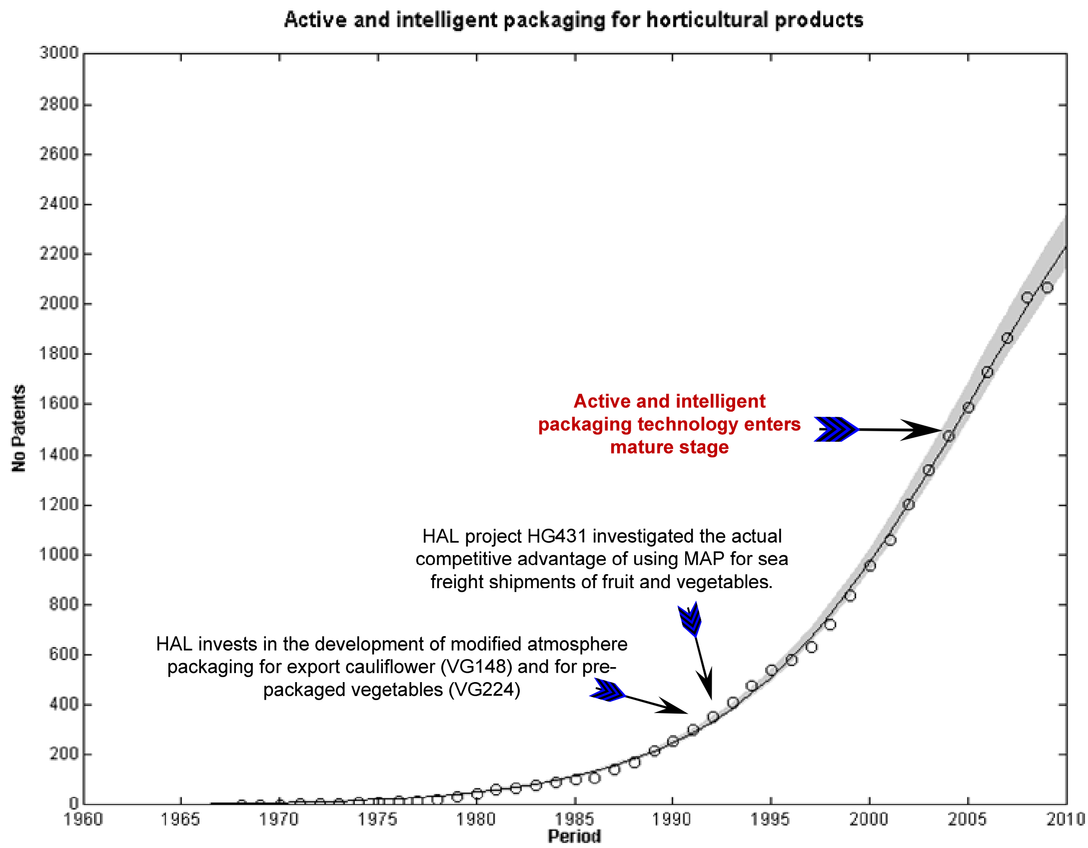


FIGURE 15. Growth curve of active and intelligent packaging technologies for food.

Category 4: Cold Chain Logistics

Cold chain. The continuum of temperature-controlled operations required to maintain food quality, from harvest to domestic storage [4].

Logistics. The activities required for the movement and handling of goods and materials, from inputs through production to consumers and waste disposal. […] Some of the major activities covered by this definition are transport, storage, packaging, procurement, and inventory management [13].

Logistics management. The part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption. Activities include inbound and outbound transportation management, fleet management, warehousing, materials handling, order fulfillment, logistics network design, Inventory management, supply/demand planning, and management of third party logistics services providers [16].

Horticultural products require specific environments (*i.e.* combinations of temperature, gas composition and humidity) to reach their final markets with the best possible quality.

Temperature is a critical parameter and the term "cold chain" has been coined to describe the particular supply chain operations used for these products.

Although the use of cold chain technologies in Australia is widespread, breaks in the cold chain are still largely blamed for losses of fresh food estimated between 2% and 23% in industrialized countries[20].

Common embodiments of cold chain technologies are:

1. **Packaging systems.** Although temperature control is often accomplished by the use of active cooling systems (*e.g.* refrigerated transport), there are instances where the energy supply required to drive refrigerated equipment is not available. Examples include transshipping operations, non-refrigerated air freight containers and during loading/unloading of product in non-refrigerated docks. "Thermal packaging" is used as an alternative solution. Thermal packages contain their own source of cold and their own thermal insulation. They protect the product from environmental temperatures and avoid the need to have a power outlet or diesel engine nearby. These solutions are also popular when the volume of parcels/boxes transported is small and do not justify the cost of refrigerated shipping. Thermal packaging is also used when there is restricted availability of refrigerated equipment or limited temperature ranges in refrigerated transport. Thermal packaging is normally used once and then discarded or recycled. They are able to provide between 10 and 120 hrs of passive cooling and they provide capacities of about 100 L. Packages can integrate temperature sensors, RFID tracking and modified atmosphere technologies.

2. **Containment systems.** These include electricity-powered or hybrid[21] mini-containers and insulative /reflective pallet covers. Typical examples in this category are the Qpod™, ThermoChill pallet insulated covers and the Ospack insul-dry container liners. Containment systems are fully reusable, they can provide above 120 hrs of passive or active cooling and can handle volumes of less than 400 L. They are suitable for integration with temperature sensors, RFID tracking and modified atmosphere technologies.
3. **Refrigerated road, sea and air transport systems.** These are the modes that growers normally encounter in their cold chain operations. The characteristics of each transport mode are summarized in Figure 16.

[20] Kader, A.A. 2003.A perspective on postharvest horticulture (1978-2003). HortScience38(5):1004-1008.

[21] Hybrid systems can run on passive cooling provided by a phase-change material and electricity, thus they are useful in situations where no power outlet is available.

Technology forecasts

All cold chain logistics systems have common characteristics such as insulation, a source of cooling and the means to distribute the cooled air/water/refrigerant around the product. However, different technologies take different innovation paths. For example, thermal packaging innovations focus on increasing the cooling capacity of the phase-change materials, decreasing costs or improving recyclability. In containment and transport systems, innovation has focused on improving energy efficiency, increasing insulation effectiveness and enhancing the integration of refrigerated transport with QA systems (*e.g.* traceability and temperature monitoring).

The majority of these improvements can be classified as evolutionary, rather than revolutionary. We are yet to see a radical change in the design of refrigerated transport or storage systems that matches the success of the invention of containerized transport, for example. However, the advent of nanotechnology could indeed open the doors to such a change. An example is the so-called nanoskin material [22], a micron-thickness film that provides thermal protection by using small cells containing a vacuum [50]. It can be applied during packaging production, either on the inside or outside of a container and is sufficiently flexible to be formed and shaped without losing its vacuum properties. If this technology can be employed in the development of large insulated systems such as marine containers and trucks, it would be feasible to decrease the weight of these and increase carrying capacity significantly, thus reducing shipping costs.

It should be noted that advances in cold chain logistics should also be placed in the context of the comments made about RFID, temperature sensing and traceability, which have had a significant influence in modern cold chain technology. This is observed in the patent trends shown in Figure 17.The bi-logistic curve means that there are two waves of technology: the first wave (from 1968 to 2008) is likely to be related to the development of cold chain equipment (*i.e.* better refrigerated transport systems), which currently focuses on low-volume transport solutions such as thermal packaging. The second wave (1995-2008) reflects the integration of temperature monitoring and tracking systems. Therefore, the focus in cold chain R&D shifted from creating refrigerated equipment to creating integrated logistics systems including temperature monitoring.

While the fastest rate of growth (midpoint) of the first pulse occurred in 1993, the second pulse cantered in 2001. This indicates that the maximum R&D effort in the first wave will be reached by 2018. There are indications of the second wave having past its peak in 2007, thus indicating saturation and current decline in R&D.

The challenges of 'selling' the proposition of wireless temperature monitoring in horticultural chains will be further discussed in the case studies presented later on this report.

[22] http://www.generalapplications.com/technologies.html

TRANSPORT MODE	TYPICAL VOYAGE TIMES	INSULATED BODIES COMMONLY USED	REPRESENTATIVE TYPES OF TRANSPORT	TYPICAL DIMENSIONS: Size (external dimensions)	L	W	H	Typical loading capacity	TYPICAL COOLING SYSTEM[a]: M/D	M/E	E/D	EP	C
VAN OR COMPARTMENT IN MULTI-TEMPERATURE TRUCK (URBAN/SHORT-DISTANCE DISTRIBUTION)	1 TO 12 HRS	(1) Normal van with sidewalls and doors foamed with polyurethane or polystyrene (2) Insulated box specially designed to fit inside a van	Panel van		3.265 m	1.736 m	1.633 m	13.4 m^3	✓		✓	✓	✓
		(3) Non-insulated van carrying (a) product packaged in insulating materials and aided by phase change materials or (b) insulated boxes with refrigeration coupled with van's engine	Van truck		5.805 m	2.155 m	2.180 m	20.6 m^3	✓	✓	✓	✓	✓
TRUCK/TRAILER/SEMI-TRAILER (SHORT/LONG-DISTANCE DISTRIBUTION)	12 HRS TO 3 DAYS	(1) Integral container: the refrigeration unit is fitted in the insulated body; the unit may run by means of a separate engine or it may be coupled to the truck's engine	Highway and intermodal trailers	20 ft 40 ft 45 ft High Cube	6.096 m 12.192 m 13.710 m	2.438 m 2.438 m 2.438 m	2.438 m 2.438 m 2.890 m	33.0 m^3 54.9 m^3 75.4 m^3		✓			✓
		(2) Insulated box: polyurethane or polystyrene layers reinforced with fiberglass or steel	Truck	45 ft High Cube 48 ft	13.710 m 14.500 m	2.438 m 2.580 m	2.890 m 2.920 m	75.4 m^3 88.0 m^3	✓	✓	✓	✓	✓
RAIL (LONG-DISTANCE DISTRIBUTION)	3 TO 16 DAYS	(1) Non-mechanically refrigerated insulated cars: cooling by (a) dry ice or other cryogenic substances or (b) air cooled by ice/water mixtures	Double-axle insulated wagon	WAI28B	16.500 m	2.700 m	2.550 m	84.8 m^3	Typical system comprises two ice tanks and electric fans				
		(2) Mechanically refrigerated cars: run on electricity supplied by a central power unit on the train or by an autonomous motor	Double-axle wagon	WAF26	15.500 m	4.230 m	2.400 m	74.7 m^3	✓	✓			
			Four-axle wagon A	WAF36	21.480 m	4.060 m	2.400 m	107.1 m^3					
			Four-axle wagon B	WAF34.2	21.040 m	4.060 m	2.400 m	107.1 m^3					
		(3) Multi-modal container	integral containers, semi-trailers and swap bodies (see intermodal trailers)										
AIRPLANE (LONG-DISTANCE DISTRIBUTION)	1 TO 100 HRS	(1) Passive insulated system: Sizes vary depending on specific needs of product. (2) Active system: Envirotainer ™ is the mayor manufacturer of these units. All models have a similar cooling range of -20 to +20 °C. Capacities are: (a) model RAP =8.2 m^3; (b) model RKN =2.9 m^3 (c) model CLD =0.164 m^3	B 727-100	Main hold Forward hold Aft hold	2.240 m	3.180 m	2.500 m	82 - 88 m^3 11.9 m^3 13.3 m^3					✓
			B 757-200	Main hold Forward hold Aft hold	2.240 m	3.180 m	2.500 m	155 - 178 m^3 19.8 m^3 30.3 m^3					
			B 767-300	Main hold Forward hold Aft hold	2.240 m	3.180 m	2.500 m	474 - 479 m^3 41 - 47 m^3 31 - 37 m^3					
			B 747-100	Main hold Forward hold Aft & Bulk hold	2.240 m	3.180 m	2.500 m	301 - 344 m^3 59 m^3 47.5 & 28.3 m^3					
SHIP (LONG-DISTANCE DISTRIBUTION)	3 DAYS TO 2 MONTHS	(1) Porthole container: Containers with portholes, through which cold air from the ship's refrigeration plant can be delivered to the cargo space (2) Integral container: the refrigeration unit is fitted in the insulated body; the unit may use energy supplied by the on-board electricity system, an independent diesel engine or cryogenic systems (3) Refrigerated vessel: All or part of the holds are insulated and have ducting to channel cold air from evaporators using expanded refrigerant or brine	1st gen converted cargo vessel	Years 1956-1970	135 -200 m	Draft <9 m	For container sizes see intermodal trailers	TEU[b] 500-700	✓	✓			
			1st gen converted tanker	Years 1956-1970	135 -200 m	Draft <9 m		TEU 800					
			2nd gen cellular containership	Years 1970-1980	215 m	Draft 10 m		TEU 1000-2500					
			3rd gen Panamax class	Years 1980-1988	250-290 m	Draft 11-12 m		TEU 3000-4000					
			4th gen post Panamax	Years 1988-2000	275-305 m	Draft 11-13 m		TEU 4000-5000					
			5th gen post Panamax plus	Years 2000-?	335 m	Draft 13-14 m		TEU 5000-?					

[a] M/D: Mechanical/Diesel; M/E: Mechanical/Electricity; E/D: Vehicle's engine or alternator; EP: Eutectic plates; C: Cryogenic;

[b] TEU= twenty-foot equivalent unit; a TEU is a measure of containerized cargo equal to one standard 20 ft container.

FIGURE 16. Refrigerated transport technologies for road, sea and air [51].

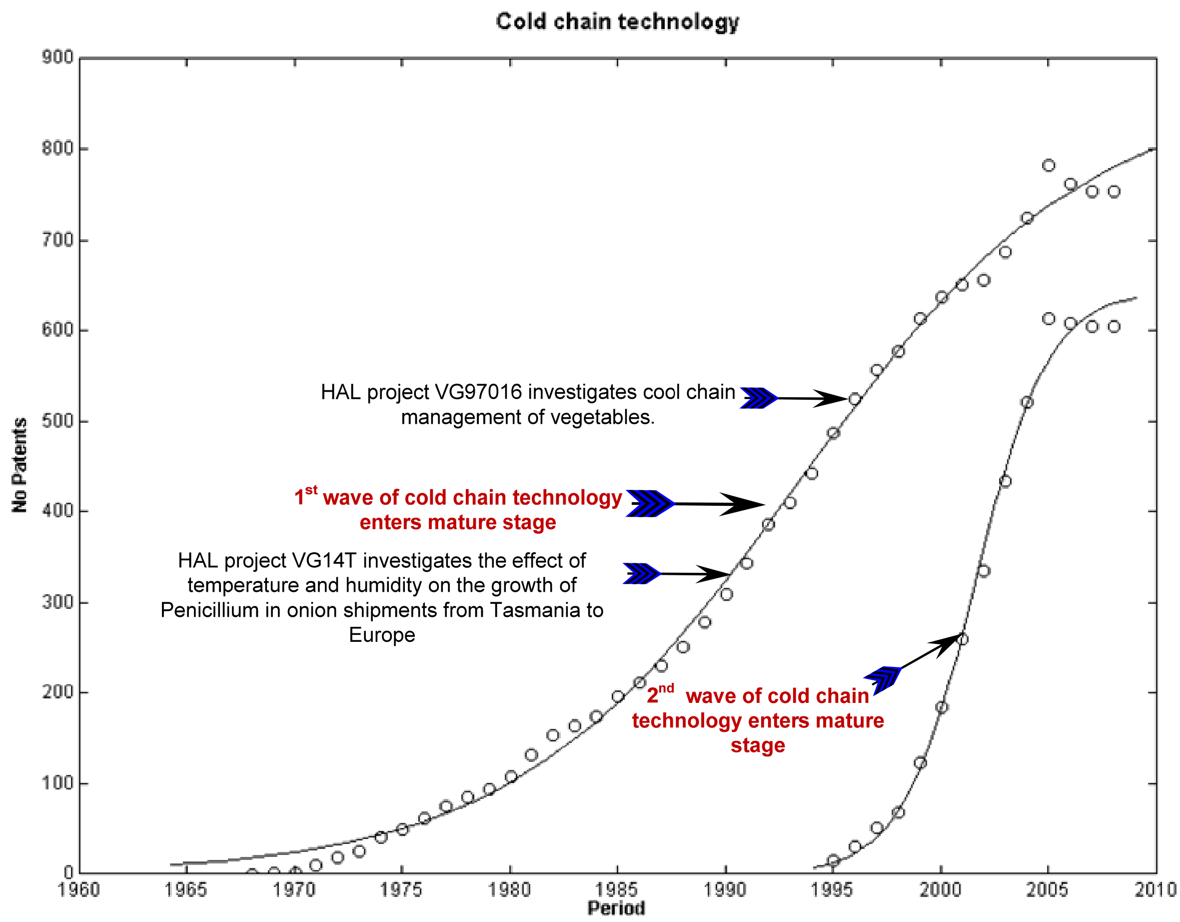


FIGURE 17. Bi-logistic growth curve of cold chain logistics technologies for perishable food.

Cost benefit considerations

The capital cost of cold chain logistics (*e.g.* refrigerated trucks and cold storage) is not always an item in the balance sheet of the growers' operations, as many of the logistics services needed are outsourced. There are instances where pre-cooling and storage facilities are needed at farm level and the necessary capital is outlaid by the grower. However, refrigerated transport is normally sourced from third party logistics (3PL) companies.

As an indication of the cost of refrigerated transport, Figure 18 shows the 2004 costs of transporting a pallet of produce under refrigeration as a function of the distance travelled in Australia.

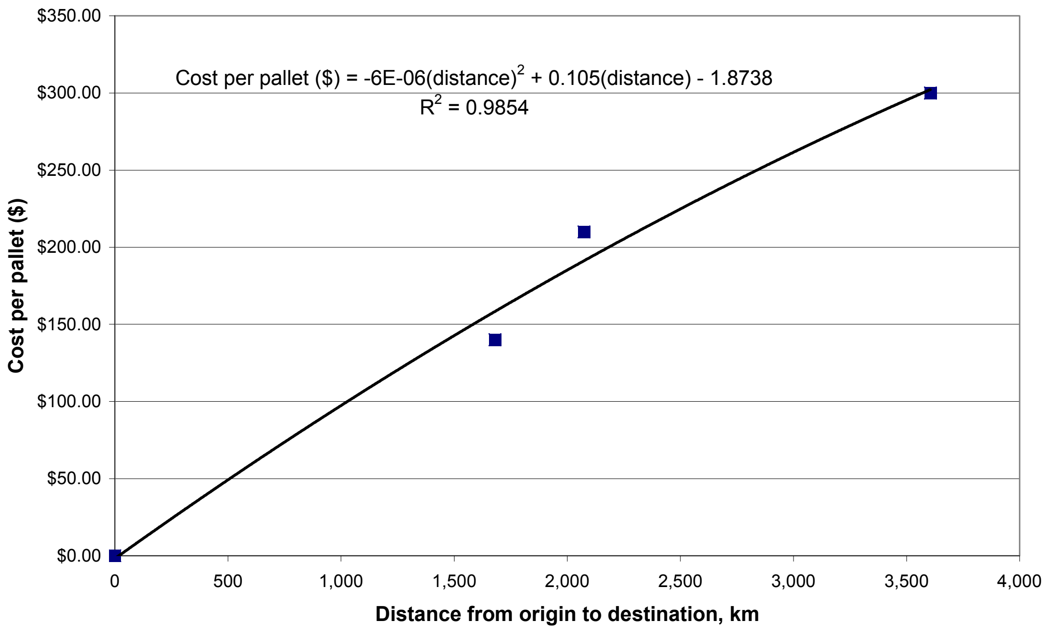


FIGURE 18. Relationship between cost of transportation per mango pallet and transportation distance [52][23].

Although transport costs can vary significantly between and within categories, depending on product origin and handling stages, the largest element of transportation costs is on the segment between farm gate and wholesale/retail [53].

There are very few published studies that show the improvements in the profitability of well managed cold chains. Smale investigated the case of asparagus for export, transported in a container to Japan [54]. The case study is summarized next.

[23] Only variable costs considered.

Assumptions:

- Average return from Japan = \$4.50 / kg (1)
- 3 saleable grades
  - ✓ Premium (\$5 /kg) average rating <3; unsaleable rates <1%
  - ✓ Market price (\$4 /kg) average rating <3.5; unsaleable rates <5%
  - ✓ Low quality (\$1 /kg) average rating <4; unsaleable rates <10%
- Sea freight costs ~ \$0.75 /kg (2)

(1) Horticulture Australia (2004) The Australian Horticulture Statistics Handbook
(2) Victorian Airfreight Council (2003) The freight operations of Melbourne Airport

In a well managed sea freight operation:

- ✓ Time from harvest to precooling is kept between 2 to 8 hrs.
- ✓ Coldstorage temperature is maintained between 1.5 and 3°C and storage time before transport is between 6 hrs and 3.6 days.
- ✓ Transport temperature is maintained between1.5 and 4°C and transit time is 15 days.

Results:

- ✓ 1.9% unsaleable product
- ✓ \$4.13 / kg average return

In a poorly managed sea freight operation:

- ✓ Time from harvest to precooling ranges between 2 to 12 hrs.
- ✓ Coldstorage temperature is maintained between 1.5 and 5°C and storage time before transport is between 6 hrs and 5 days.
- ✓ Transport temperature is maintained between1.5 and 5.5°C; transit time remains as 15 days.

Results:

- ✓ 4.8% unsaleable product
- ✓ \$2.80 / kg average return

While in this case intervention to maintain optimum cold chain conditions has a clear benefit on the profits of the export operation, the case for improvement may be less spectacular if other modes of transport are selected (*e.g.* air freight), where transport timeframes are shorter.

As with all the technologies investigated in this report, it is difficult to present an average case study representative of costs for cold chain logistics. Each case is unique and depends on a number of factors, including the size of the logistics operation, contractual arrangements with refrigerated transport providers and preferred service providers by buyers (*e.g.* retailers). To date, there are few studies that provide in in-depth view of the cost structure and limitations such as the limited availability of refrigerated transport and restrictions in contractual arrangements that horticultural growers face in Australia.

Category 5: Emerging Concepts in Supply Chain Management

There are emerging concepts that cannot be classified as "technologies" nor can they be forecasted by patent trends because there are no patents that cover their uptake. However, they are major factors of technological change in 'fresh' supply chains. These concepts are discussed in this section.

Emerging distribution models for fresh vegetables.

The environmental and social factors described in Table 1 are major drivers behind the food industry moves to decrease transportation distances, reduce packaging, decrease the complexity of the food chains and decrease the need for storage and distribution nodes in supply chains. There are three basic categories of changes, which are described in this section.

Urban, local and regional chains

Local supply-demand chains. Distribution models that aim to decrease the distances between supply and city markets and that emphasize direct supply models between growers and city-based consumers.

The local food movement has its roots in the 1960s movement *back to the land*, initiated in the US as a reaction to the growth of global, multinational food companies. Local food systems promote collaborative building of self-reliant food economies, whereby food production, processing, distribution, and consumption is integrated to enhance the economic, environmental and social circumstances of a particular region.

Current challenges in global food systems include food security, power imbalances in food chains, environmental impact of food transport, obesity and other health issues attributed to the strategies of multinational food companies. The disillusion of consumers on current food systems led to the growth of companies that embrace the concept of local food chains. Examples of such companies are:

- The FoodConnect enterprise in Brisbane (http://www.foodconnect.com.au/) that links local growers with local markets directly. Food Connect is a community shared agriculture enterprise that distributes ecologically sustainable, affordable produce by collaborating with local farmers for a financial return. The produce from Food Connect is all sourced from within a 5-hour radius of Brisbane. Green vegetables will have been picked with the shortest time frame being possible between picking and delivery.

- The “Von hier” (from here) private label brand from the German retailer Feneberg (http://www.vonhier.com/). The project is a joint initiative of the retailer, growers/farmers and social organizations from Brandenburg and Berlin. Mostly organic products are sourced within a radius of 100 kilometres from the retailer's headquarters. Approximately 300 organic farmers and 15 producers form part of the "Von hier" -project that guarantees clients that beef, eggs, vegetables and fruit are of local origin. The market share of these regional products in the Feneberg-supermarkets is about 20 %.
- Aussie Farmers Direct [24]. This is a nation-wide Australian company which provides free delivery services of fresh quality products that are 100% Australian owned and produced. Current products offered include milk, bread, eggs, cream, cheese, smallgoods, juice and fresh fruit and vegetables. It will soon encompass meat products.

While the penetration of the ‘local’ movement cannot be measured by patenting trends, Figure 19 (generated by Google Trends), shows world trends in internet searches using the term ‘locavore’[25]. Interest has ramped up since mid 2007 and it is on the increase. Australia ranks third in the number of searches and Adelaide is the city with most searches using this term.

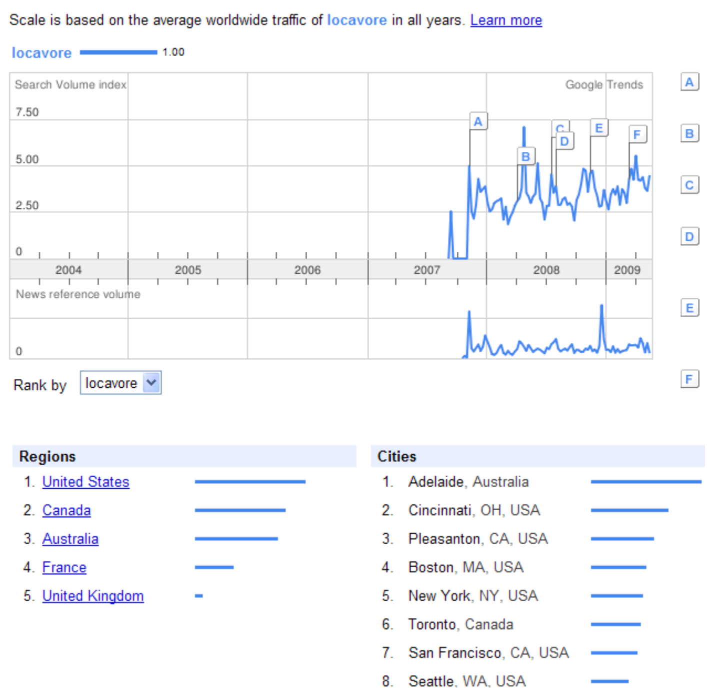


FIGURE 19. Volume of internet searches using the term ‘locavore’. Source: www.google.com/trends.

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[24] http://www.aussiefarmers.com.au/

[25] A locavore is a consumer who prefers food produced locally or within a certain radius of his/her neighbourhood (50, 100, or 150 km). The locavore movement encourages consumers to buy from farmers’ markets or even to produce their own food, with the argument that fresh, local products are more nutritious and taste better.

Sharing of distribution networks and infrastructure

Sustainable distribution systems. These consider a range of measures which can be used to cut carbon emissions within a company's logistics system. They looks at the storage and movement of goods in a way that supports continued economic growth, while protecting the environment [7].

Examples of this type of model include:

- The ECR Sustainable Distribution Group initiative (UK), which aims to save food and grocery industry mileage by sharing vehicles and improving the efficiency of warehousing networks.
- The SmartWay^{SM} Transport, an innovative collaboration between EPA (USA) and the freight sector designed to improve energy efficiency, reduce greenhouse gas and air pollutant emissions, and improve energy security.
- The Clean Cargo Working Group (USA), which is a multi-sector, business-to-business collaboration between ocean carriers, freight forwarders and shippers of cargo. Members of this group include Coca-Cola, Wal-Mart, Chiquita Brands and Starbuck's, among others. Tools used to enhance communication between participants are annual environmental surveys, intermodal emission calculators and CSR performance surveys.

Supermarket led initiatives in sustainable distribution

Optimised distribution networks. Distribution models used to optimize transport distances, modes of transport and land-based infrastructure. The aim is to decrease the environmental impact of food freight within and across states.

Examples of this type of initiatives include:

- The Woolworth's Environmental Sustainability plan (Australia). Woolworth's aims to achieve a 25% reduction in CO2-e per carton delivered by 2012 through the reduction of the distance travelled by the product, the introduction of new vehicle designs (*e.g.* hybrid vehicles) and the use of alternative fuels.
- The Woolworths Proprietary Limited initiative (South Africa) aims to reduce relative transport emissions by 20%, through restricting airfreight of food products and sourcing food regionally wherever possible reducing reliance on long distance road transport.
- The Wal-Mart's Sustainability 360 initiative (USA) aims to reduce the number of trucks by re-designing the supply chain network, changing the presentation and size of food products and using auxiliary power units in their truck fleet.
- The redesign of the Tesco distribution network (UK) aims to reduce 50% emissions per case by 2012. Tesco holds over 76,000 SKU's and 95% of volumes delivered via centralised distribution. Its current supply chain infrastructure includes 29 warehouses and over 2,000 vehicles travelling 659 million km across the primary and secondary

transport operations. Tesco is measuring the carbon footprint of three of its major food categories (tomatoes, potatoes and orange juice). Tesco has also committed to reduce packaging by 25% over the next 3 years.

The shift from supply chains to value chains

> **Value chain management.** The collaborative allocation and utilisation of resources within and between businesses in the value chain, the purpose of which is to improve the competitiveness of the value chain as a whole […]through process improvement for existing products/services beyond business boundaries and the development of new (value added) propositions for distinct customers and targeted consumer segments [12].

Michael Porter created the concept of value chain as the generic value-adding activities of an organization [55]. The value chain framework has evolved in the food industry context to identify vertical alliances, potential collaboration in logistics and distribution channels to drive out costs, pricing strategies and strategic planning. The value chain's ultimate goal is to maximize value for all stakeholders while minimizing costs.

Professor Andrew Fearne pointed out the paradigm shift transforming supply chains to value chains and the thinking that goes with it. Basically, supply chain relationships are transforming from transactional, adversarial cost-based relationships to collective value addition through collaboration between supply chain partners [56]. From this evolution, a new conceptual framework of value chain management is required.

Why horticultural enterprises should adopt a value chain concept? Some authors [57] suggest three major reasons:

- to be able to respond better to consumers;
- to improve efficiency; and
- to reduce risks.

These three drivers can be better achieved by collaboration. Collaboration among firms in a value chain can: (a) ensure that specifications have been met at every point in the chain; (b) allow companies to detect opportunities to increase efficiencies and decrease costs within firms and between firms; (c) hold lower inventory through made-to-order systems; (d) share infrastructure, such as storage and transport; (e) integrate IT systems between firms; and (f) adopt technologies and systems that are unavailable or uneconomic for single firms. Therefore, forming part of a value chain can increase the development of innovations and access the technology to enable these, through collaborative efforts. Companies participating in a value chain oriented project ensure that the benefits of collaborative innovation (or co-innovation) are shared among the chain partners.

HAL, TIAR and AVIDG funded a report that provided recommendations to prioritize value chain innovation research and a methodology to assess and scope the efficiency and effectiveness of processes along the value stream [58]. This methodology is summarized in Figure 20.

FIGURE 20. Summary of the value chain analysis methodology proposed by Fearne et al., (2008)

Stage 1 - Securing Commitment	The realisation of the benefits from the projects depends upon participants' commitment and openness. Accordingly, the involvement of all value chain partners is critical. A project team is established with an independent chairperson, to ensure that the project progresses and to facilitate the removal of barriers. This group should comprise senior management, who are to authorise staff to co-operate and be honest and open.
Stage 2 - Confidentiality and Privacy	Before data gathering, confidentiality agreements should be put in place with the value chain partners. These safeguard the commercial and personal sensitivity of the information provided, thus encouraging all parties to be candid and share information.
Stage 3 – Selecting the value stream	This involves the selection of a specific value stream as the focus for improvement, where a value stream is typically defined as a specific product family serving a specific consumer or market segment. When the number and diversity of products is high, the selection of a value stream is usually guided by the relative importance and/or the recognition of problems associated with product lines.
Stage 4 - Establishing what it is that consumers value	The most critical aspect of value chain analysis is whether consumer value underpins every activity and decision. Failure to identify what value means to the final consumer results in the misallocation of resources to activities that are unnecessary or wasteful. The analysis should identify how much and where value is currently added, and the opportunities for adding more value. Consumer research through focus groups and interviews may need to be undertaken: the former identifies the value consumers apply to different product attributes and the potential interest in new product variants. Interviews assess the relative importance of the multiple product attributes and the scale of the opportunities.
Stage 5 – Mapping the current state	This involves the graphical representation (process map) of the material flows, information flows and relationships within and between the businesses that constitute the value stream for existing products, from inputs to primary production through to final consumption.
Stage 6 – Identifying improvement projects	The generation of a state map facilitates the identification of bottlenecks and weaknesses in the value stream, within and between partners. The final stage in the methodology is the identification of improvement projects. The emphasis is on inter-organisational opportunities. These are notoriously difficult to achieve and, as a result, can deliver benefits that are difficult to replicate by competitors,providing a potential source of sustainable competitive advantage.

Co-innovation

Collaborative innovation, also known as "open innovation" (Sarkar and Costa, 2008) or "co-innovation" (Fearne, 2007) can be particularly advantageous to small and medium-sized enterprises (SMEs), which can tap into skills and knowledge beyond their own capabilities (Grunert *et al.*, 1995). Large manufacturers can achieve a more systematic approach to new product development (NPD), an increased emphasis on market-oriented NPD and a stronger network for product market intelligence.

Co-innovation often requires the development of global innovation networks, which add further advantages, such as:

(a) Supporting collaboration among geographically dispersed teams of suppliers, manufacturers and retailers.
(b) Speeding time-to-market and reducing costs for all the parties involved in the NPD process through resource pooling and reduction of the learning curve times.
(c) Meeting customer expectations in a more accurate manner, due to the direct input of retailers into the main purchase drivers of products.
(d) Enforce consistency and quality of brands and innovations.
(e) Creating a compliance audit trail through sharing of quality documentation.
(f) Most importantly, creating a repository of protected know-how and intellectual property, only available to the chain participants.

The challenges of co-innovation and other value chain oriented projects are better understood in the context of recent public hearings on the balance of market power between food suppliers, manufacturers and retailers: In Australia, the Australian Competition and Consumer Commission (ACCC) investigated the relationship between grocery suppliers and retailers (Australian Competition and Consumer Commission., 2008). Although the ACCC report did not identify "anything that is fundamentally wrong with the grocery supply chain", the report did not appease concerns of grocery suppliers and the overall sentiment of a lack of transparency in the Australian grocery chain and the dominance of retailers remains (West, 2008). Given that a pre-requisite of the value chain framework is trust and communication between supply chain partners, it is indeed a priority for all to promote the levels of trust required for these projects to take place.

Adoption of SCL Emerging Technologies in Australia and Other Countries: Opinions and Case Studies

AUSTRALIA
Pervasive Telemetry Pty Ltd and Crodex Technologies (May 2009).

Prashant Maharaj is the Director of Pervasive Telemetry (PT), a company headquartered in Sydney with a presence in Los Angeles, (USA). PT provides solutions that combine wireless mobile network technology with Internet-based platforms. PT solutions normally encompass a remote agent, which is an intelligent device that links the responses of sensors and that can control a range of physical devices – switches, motors, pumps, actuators, valves. Remote agents combine the roles of programmable logic, data logging, position awareness (with optional GPS module) and communications. If these devices are linked through telemetry server software, the systems developed can provide a range of services such as cold chain management, asset tracking, machine monitoring (including engine temperatures, oil pressures, fuel levels).water quality monitoring, automatic irrigation systems, environmental monitoring and industrial control applications in pack houses, to name some. All these aspects can be monitored remotely.

Prashant believes that the major issue for providers of emerging technologies is reaching the threshold of customer's critical mass to make a tailored solution worthwhile. For example, a potential solution developed for monitoring environmental changes in cold storage of fruit and vegetables will have different technical specifications than a solution provided for the meat industry (*e.g.* the measurement of ethylene). This solution will again be different if the monitoring system is designed to be used in transit (*e.g.* during road transport). From a technical point of view, all these applications can be achieved as per the client's specifications. Yet the crucial issue is in reaching a mass of customers that brings the costs of the service and hardware down.

Llyn Williams works in Crodex Technologies, a partner company of PT. Llyn says: "My challenge has been to tackle the "political" scene in my goal of making the technology commercially viable. Many end-user customers are unwilling to deploy real-time monitoring technology…they probably know that poor operating conditions are likely to be uncovered and corrective actions will need to be taken. The messenger invariably gets shot!"

"Particularly relevant when various parties have different objectives and limited budget to resolve any adverse operating conditions is premature elucidation, that is, providing solutions to problems that the customer doesn't actually know it has or more frequently doesn't want to know about".

"Many of my existing customers have internal conflicts that end up as barriers to the deployment of our new remote monitoring technologies This is true for the monitoring of environmental conditions associated with waste water systems where problems are known but the severity hidden", concludes Llyn.

AUSTRALIA
Dr. Andrew Higgins, CSIRO Sustainable Ecosystems (May 2009).

Dr Andrew Higgins is a Principal Research Scientist at CSIRO Sustainable Ecosystems. Andrew leads a multi-disciplinary research group "Decision Technologies for Sustainability" which applies operations research and information technologies to improving economic and environmental outcomes in various applications. These include agriculture, biological conservation, land use planning, transport, international development, housing and biosecurity. Andrew also specialises in developing innovative adoption strategies for operations research tools, and as a result has achieved savings to industry of over $2M per year. Andrew has received numerous CSIRO and industry awards for his achievements in taking operations research theory to practice.

"New supply chain technologies have the potential to reduce costs, improve quality and increase retail value in most horticulture industries" says Andrew. "The difficulty of achieving a fair distribution of benefits and risks across growers, packers, processors and retailers is one of the biggest hurdles to achieving adoption of supply chain technologies in Australia. For example, optimisation tools for improving the harvesting and transport/distribution systems may lead to greater returns to retailers but no increase in price paid to farmers along with a greater risk from increased variation in workforce requirements."

Andrew believes that forecasting and optimisation tools can provide many growers, particularly large ones, with the ability to simultaneously manage their harvest planning, crop rotations, labour force and logistics so as to maximise their whole-of-farm profits whilst managing costs and risks. "They allow horticulture growers to better manage their desired level of supply throughout the year and better manage co-ordination with their buyers and service providers (*e.g.* transport) and farm inputs. In Australia, a bottom up approach (*i.e.* grower led but with support from processors and retailers) is most likely to succeed due to the need for grower acceptance for such initiatives, which also need to be integrated with the grower knowledge base of farm and risk management" Andrew concludes.

UNITED STATES

United Fresh Produce Association establishes new Supply Chain Technology & Logistics Program (Oct 2008).

United Fresh Produce Association has announced that the association will establish a new Supply Chain Technology & Logistics Program to serve its members in all areas of supply chain management, including transportation, cold chain quality control, information technologies and systems for traceability, facilities management, packing and packaging needs and related areas.

"From the increasing costs of distribution to the need to enhance traceability and quality control as produce moves from farm to table, our members are facing significant challenges to their profitability," said United Fresh Chairman of the Board Tom Lovelace of McEntire Produce. "Yet, with appropriate investments in technology and sound management practices, we can increase efficiencies, reduce the potential costs of product recalls and deliver to consumers even better tasting, higher quality produce," he said.

The new program will support education programs and tools to assist industry members with the rising cost and complexity of transportation, including trucking, rail, air and ocean shipping. The initiative will also include an increased focus on transportation and logistics solutions at the United Fresh convention April 22-24, 2009 in Las Vegas. Stenzel announced that the association will hire a new full-time staff expert to lead the Supply Chain Technology & Logistics Program. In addition to new education programs supported by the Robinson grant, United Fresh will launch a new legislative and regulatory initiative related to policy issues in transportation and distribution.

From: http://westernfarmpress.com/news/logistics-program-1020/

INDIA

eFarm.in: Innovating the Indian Agri Supply Chain (Apr 2009).

eFarm is a Farm-to-Home supply chain platform for procuring and delivering farm produce in a transparent, economical and efficient manner.

eFarm connects farmers, intermediaries, logistics providers, distributors and small retailers to local road side vendors. The objective is to deliver high quality produce at farm prices. eFarm clients include household buyers, food and hospitality providers, institutional buyers and exporters. They now have over 500 clients using "Word of Mouth" as the marketing strategy. eFarm makes a revenue of 5 to 10% per successful transaction.

The eFarm concept grew out of the need to improve on the state of agriculture in India through the application of technology and supply chain efficiencies in a rural setting. eFarm currently delivers vegetables and fruits in the Chennai area, using techniques which have evolved from collaboration and discussions with key traders in the area.

From: http://www.matchboxsolutions.in/eFarm.html and http://startupstory.in/2009/04/12/efarmin-innovating-the-indian-agri-supply-chain/

UNITED KINGDOM

Fresh Direct delivers perfect produce with Paragon (March 2009).

Fresh Direct, one of the UK's major fresh fruit and vegetable suppliers to the Food Service sector, has boosted its customer service levels through the smart application of Paragon Software Systems' Multi Depot routing, scheduling and transport optimisation solution.

By using the software to model the ideal fresh food delivery solution for its customers in fine detail, Fresh Direct is able to optimise its resources and services. The additional benefit of this accurate planning is improved efficiencies for both Fresh Direct and its customers, including better management of the company's carbon footprint.

Fresh Direct makes more than 10,000 deliveries a week from its 6 regional depots that serve catering businesses across the UK – these include pubs and restaurants, hotel groups, premium retail, colleges, conference centres and event organisers. The depots are located in Bicester, Cambridge, Evesham, Manchester, Skelmersdale and Glasgow.

The company's fleet ranges from 1.2 tonne local delivery vans to 44 tonne tractor and trailer units, as well as dedicated rapid response vehicles for urgent deliveries. With Paragon the company can accurately plan the ideal route from the appropriate depot and choose the most efficient vehicle for each delivery to meet the customer's specific requirements.

"We work very closely with our customers to ensure that we provide the best delivery option for their individual business model. In order for them to meet their own customer's expectations, we must provide on time deliveries as well as provide short life span products that are in perfect condition. Our goal is to meet this requirement consistently. Our investment in the Paragon technology means that we can achieve this and at the same time reduce the number of trips we make through better utilisation of vehicles and by using the most suitable depot. The system gives us a base line from which we can view our performance and provides the control we need to achieve a dependable high quality service," says Nick Allen, Head of Logistics, Fresh Direct.

From*: http://www.paragonrouting.com/news.asp?articleid=328*

AUSTRALIA
CostaGroup: Web Service and Workflow Forms Smooth Data Path into Microsoft Dynamics GP (Nov 2008).

Family-owned Costa Group is Australia‟s largest private producer, marketer, and exporter of high-quality fresh fruit, vegetables, and grain. Based in Victoria, the group owns approximately 40 specialist growing, trading, and logistics companies, with a combined annual turnover of A$1 billion.

Costa‟s fully owned subsidiary, Grape Exchange, specializes in table grapes. Employing 50 staff, with revenue of approximately $80 million, Grape Exchange operates across the product supply chain. The company allots contracts to its own farms and third-party suppliers, and organizes packaging and distribution. Grape Exchange also sells table grapes directly to major supermarkets and overseas customers.

The separation of Grape Exchange‟s operations into separate businesses means that internal accounting is highly complex. A single order from a supermarket generates four sets of purchase orders and sales orders, as the transaction filters through from the originating supplier to the end customer. In addition, Grape Exchange manages logistics, and these costs have to be calculated and inserted into the invoice and billing chain.

In 2007, Costa initiated a revamp of Grape Exchange through the application of innovative web applications, which improved the flow of information from operations to accounting. With the new system, every original invoice is done at the operations level and all the additional charges are automatically calculated and inserted. Since the data for each order needs to be entered once, there has been a 75 % reduction in manual labor. Other benefits included improved accounting accuracy, time saving in reporting and increased traceability of shipments, down to pallet level.

From:
*www.smartconference.com.au/__files/f/10512/**Costa**Group%20release%20May%202008.pdf*

AUSTRALIA
GPS system on-the-level (Dec 2008).

Large-scale Werribee South horticulturalist Amo Mason, Victoria, is a noted GPS steering enthusiast with four tractors sporting AutoFarm receivers but he's also using GPS for 2cm precision height control of his land plane. The result is perfectly graded beds with water quickly draining away in the aftermath of excessive falls.

"Good drainage is really important," Mr Mason says. "You can see the water running out and away with no pooling."

Growing three crops a year of lettuce, broccoli and fennel on an aggregation of 101 ha, the total area will amount to 141 ha when another property, some 40km away is fully-developed.

Trading as Mason Brothers, and supplying markets throughout Australia, Mr Mason bought his first GPS unit four years ago. A GPS-Ag unit, it was used only for steering for the first 12 months before its levelling capabilities were put into effect with a trip to the US, to better understand data logging technology, proving especially worthwhile.

Essentially, auto levelling utilises the same processing box and monitor in the cabin but requires a separate receiver dish on the grader. The signal comes from a tower on Mason Brothers' shed.

"First we pop a card into the processor and then drive the tractor up and down the paddock every 12m, recording heights every second," he said. "The card then goes in the computer and the AutoFarm programme plots the heights on a grid and displays them as red, green or blue. Green is 'on grade', red is 'low' and blue is 'high' - so it's very easy to see where you need to be cutting and dumping. That's followed up with fine-tuning to get a constant grade across the block."

Mr Mason has also used GPS height guidance on dam work with "excellent results" but precision steering is still the main application for GPS guidance at Mason Brothers. All four tractors are used for 2cm steering accuracy while only two have auto-levelling capability.

The enterprise's right-hand man, Nick Pratt, is a big fan of auto-steering, being responsible for all land preparation and bed forming. Three beds at a time are formed using a 6m wide home-built machine that is mounted behind a 225kW (300hp) New Holland TG 285 tractor.

A matching 6m wide rotary hoe completes the system. The bed former's combination of discs mounted at acute angles are said to produce perfectly formed beds. Small discs on each side toss soil against the system's sprinkler lines with the outer wings folding up hydraulically for transport. Importantly, the accuracy of the AutoFarm unit is such that it can be accurately programmed to clear the property's sprinkler risers.

"We can drive faster, never damage any sprinklers and feel of a hell of a lot better at knock off time," Mr Pratt said.

From: *http://theland.farmonline.com.au/news/nationalrural/horticulture/general/gps-system-onthelevel/1380797.aspx?storypage=0*

Implications and Recommendations

We previously analysed the trends of HAL-funded projects in SCL technologies. Our analysis indicated that, while the rate of investment in the area is decreasing and the peak number of HAL funded projects in the SCL platform is expected to occur in 2011, there may be external factors that influence current investment policies on SCL projects. This section provides some 'food for thought' in the areas that are impacting the profitability of vegetable growing operations and some key areas of future technological development.

The role SCL of emerging technologies in improving returns for horticultural growers

During the investigations of the ACCC on the relationship between producers and retailers in the grocery chains, the impact of retail supply chain strategies on the horticultural sector was discussed in detail in the HAL submission [59] and submissions from other organizations representing fruit and vegetable growers [60, 61]. These impacts are discussed in Table 10 below.

TABLE 10. Supply chain issues detected in the ACCC inquiry into grocery prices and emerging SCL technologies that can aid growers in counteracting these trends.

Supply chain issue	Emerging technologies /concepts that can decrease the impact on growers
• Award Wage Rates have increased 27.5 % over 2003-2008. • Actual rates of pay have increased at a faster rate due to labour shortages.	Mechanical harvesting, robotics and automation. Geospatial applications to harvest planning. RFID (in warehouse management)
• Indicative freight rate increases over 2003-2008 were over 33%, although where there is a lack of competition the increase has been over 40% (anecdotally). • Demands that product be delivered on pallet sizes that suit the retailer distribution centre pallet racking sometimes leads to under utilization of a truck's capacity. As a consequence the transport cost per kilogram can increase. • Increase on diesel fuel prices (until mid-2008 but trend likely to reappear as markets stabilize). • Anecdotal evidence suggests that the price of all fertilisers have increased significantly in recent years	Sharing of distribution network infrastructure, emerging distribution models and cold chain logistics. Use of ERP to control farm inputs. Use of precision agriculture to decrease fertilizer inputs.
• Packaging prices increased between 5-12% during 2003-2008, potentially as a result of the introduction of RPCs. • The major driver of price in the marketplace for fruit & vegetables is the force of supply and demand. However the lack of transparency in the supply chain	Emerging packaging technologies, value chain management.

often blurs the signals back to growers/producers.	
• Costs of through chain compliance associated with retailer initiatives.	Value chain management, cost reduction through uptake of ERP and electronic commerce.
• With the notable exception of the major foodservice chains (*e.g.* McDonalds, Hungry Jacks, Pizza Hut), few foodservice companies source produce direct from growers. • In metropolitan centres, the intermediary is used as they have skills associated with the purchasing of produce from the Central Markets and distribution skills direct to the customer. Generally these intermediaries purchase product on behalf of a number of food service outlets. • Imports of vegetables increased by almost 67% between 2001 and 2005.	Value chain management, emerging distribution systems (*e.g.* direct grower-urban consumer channels and 'locavore' movement).

Summary of forecasts and recommendations for future R&D funding

Table 10 summarises the analyses performed for each of the five categories discussed. This analysis needs to be placed in context of the application of the technologies investigated in horticultural enterprises: for example, the classification of GPS and GIS applications in agriculture as mature may seem preposterous. However, the technology growth curve shows that the R&D effort, represented by the number of published patents in the area since its invention, is already in decline. This does not mean that GIS/GPS applications will not continue to evolve: they will, although the areas of development will be different to the scope of previous applications. Future GPS/GIS developments are likely to be computerized navigation and the assessment of renewable energy (involving biomass, geothermal, solar, wind and hydro/wave types), among others.

Further, the fact that a technology is "in decline" (*e.g.* cold chain equipment) does not mean that innovation has ceased in the area. Better control, decreased energy use (or use of renewable energy sources), faster throughput and faster cooling will still be investigated. However, advances on these technologies are likely to appear in industries such as energy, electronics, thermal engineering and others.

From Table 11, the following observations can be drawn:

- From the SCL technologies analysed, only remote sensing and the application of digital pricing through wireless technology are in the growth stage, where there is still technological uncertainty and R&D costs are not well defined yet.
- Excepting the technologies above where basic knowledge and designs are still being developed, investment in all other areas should emphasize pilot trials, demonstrations and commercial improvements.

- So far, HAL has not invested in the development of pilot trials for e-commerce and digital pricing. This is expected, as these technologies are mostly implemented at retail level and it is difficult to visualize how HAL's stakeholders can benefit from such projects. However, there are some areas that may grant exceptions:
    - The importance of electronic shopping and auction systems and their role in providing an alternative channel for marketing of fresh produce has been long recognized [62], yet development of this industry is still in its infancy. This report reviewed specific issues in regards to diffusion of computer and internet -based applications that remain to be solved. Some recommendations to improve technology uptake on this area are provided in the next section.
    - Digital pricing and other SCL technologies implemented at the retail end can affect the entire distribution of profits in horticultural chains. Projects that increase understanding on how new technologies at retail can increase / decrease margins and costs for all chain partners are needed.
- Technologies that can bring benefits for growers with a relative modest investment include ERP, GPS / GIS, and, for niche products, active and intelligent packaging.
- Areas that require medium to large investment are cold chain integration, RFID for traceability, remote sensing and mechanic/robotic harvesting.

TABLE 11.Summary of the status of emerging technologies selected as examples of the five SCL categories.

CATEGORY	EMERGING TECHNOLOGY	STAGE OF TECHNOLOGICAL DEVELOPMENT	PREDICTABILITY		LIFE CYCLE (Benchmark: 2009)		APPROX. INVESTMENT	HAS HAL INVESTED ON THIS AREA?	LEVEL OF ADOPTION
			Technical	R&D costs	Time to full-scale commercialization	Time to R&D decline			
MANAGEMENT OF SUPPLY, DEMAND AND INVENTORIES	**Farm enterprise resource planning (ERP).**	MATURE	HIGH	HIGH	1-4 years (Fair commercial advantage)	3-4 years	$500-$20,000 (farm level)	YES	LOW-MEDIUM
	GPS and GIS applications	MATURE	HIGH	HIGH	1-4 years (Fair commercial advantage)	3-4 years	$5,000-50,000 (farm level)	YES	LOW-MEDIUM
	Remote sensing	GROWTH	FAIR	MODERATE	2-7 years (Moderate commercial advantage)	70 years	$20,000-$50,000 (farm level)	YES	LOW
	Electronic commerce	MATURE	HIGH	HIGH	Under way (short commercial advantage)	6 years	UNKNOWN (retail level)	NO	LOW-MEDIUM
	Electronic/ digital pricing	Electronic labels-MATURE	HIGH	HIGH	Under way (short commercial advantage)	6 years	UNKNOWN (retail level)	NO	LOW
		Wireless price tags-GROWTH	FAIR	MODERATE	2-7 years (Moderate commercial advantage)	50 years	UNKNOWN (retail level)	NO	LOW
	RFID	MATURE	HIGH	HIGH	5-10 years (high commercial advantage)	5 years	$100,000 to several millions (packing house, processor and retail level)	YES	LOW-MEDIUM
ROBOTICS & AUTOMATION	**Mechanical / robotic harvest**	MATURE	HIGH	HIGH	5-10 years (high commercial advantage)	31 years	$4,000,000-$30,000,000 (farm level)	YES	LOW
PACKAGING TECHNOLOGIES	**Intelligent /active packaging**	MATURE	HIGH	HIGH	Under way (short commercial advantage)	33 years	From $0.02 to $12.00 per package (packing house level)	YES	MEDIUM
COLD CHAIN LOGISTICS	**Cold chain logistics**	Equipment development-DECLINE	VERY HIGH	VERY HIGH	Under way (short to null commercial advantage)	0 years	VARIABLE (management)	YES	MEDIUM-HIGH
		Integrated cold chain-MATURE	HIGH	HIGH	Under way (short commercial advantage)	9 years	VARIABLE (management)	YES	MEDIUM

The bubble chart in Figure 21 places some context of the life expectancy and expected commercialization window for each of the technologies analysed in this report. The chart suggests that there are only four technologies that can be considered as truly emerging: (1) remote sensing; (2) wireless price tags; (3) mechanical/robotic aids at farm level and (4) intelligent/active packaging. In Figure 21, the size of the bubble indicates the level of adoption. While adoption of intelligent/active packaging is relatively high, the other three technologies lag behind.

Using these observations, we propose a three-tiered strategy for HAL funding in the SCL area:

Tier I: technologies that are currently being commercialized, with medium-to high adoption and R&D decline expected in the next 10 years. This tier, which includes electronic commerce and electronic labels, has well defined R&D predictability profiles and the investment is expected to be low. Projects in this category could include retrospective, state-of-the-art and benchmarking projects, *e.g.* analysis of gaps between 1st class supply chain standards and current practices in Australia, providing solutions to close those gaps. Another example is the investigation of the impacts of downstream technology such as electronic labelling and digital pricing on the horticultural value chain and the margins among supply chain players.

Tier II: technologies that are expected to be fully commercialized in the next 5-10 years, with medium levels of adoption and R&D decline expected in the next 10-20 years. This tier includes integration of cold chain technologies, ERP systems, RFID for traceability, GPS and GIS applications. Projects funded on this tier should go beyond pilot trials and proof-of-principle and include well-developed business cases for the industry. For example, the commercial uptake of RFID technology now depends on the development of sound cost-benefit analyses and the demonstration of a return on investment rather than just demonstrating the technology. The same can be said of projects aiming to demonstrate GPS and GIS technologies.

Given that these applications are close to full commercialization, there is an expectation that service providers can collaborate to develop case studies in the horticultural industry as part of their marketing effort. However, not all providers are willing to participate: they may see their product offering as having a selling point that is not based in cost-benefit outcomes. For example, traceability may be seen as a way to comply with regulations and not as providing cost advantages.

Tier III: technologies that are expected to be fully commercialized in the next 5-10 years, with low-to-medium levels of adoption and R&D decline expected in the next 20-70 years. This tier includes intelligent/active packaging, mechanical/ robotic harvesting aids, remote sensing and wireless price tags. This is the wave of emerging technologies that are still growing or have just entered maturity and still have a relatively long "shelf-life" for commercialization. Remote sensing and mechanical/robotic technology are particularly attractive because the benefit can be traced directly to farm gate productivity. However, intelligent and active packaging are technologies that can substantially increase product differentiation between private labels and branded products, and also between imports and Australian-grown product. It is also expected that packaging technologies will reap the benefits of performance improvements and cost reduction through nanotechnology.

Given that digital pricing is expected to reflect the real-time fluctuations of supply and demand, the investigation of the impacts of such a technology on the horticultural sector would be timely. Would real-time pricing benefit growers by improving the response between supply and demand or would it lead to price manipulation? Would real-time pricing systems lead to decrease vegetable wastage or would it increase it?

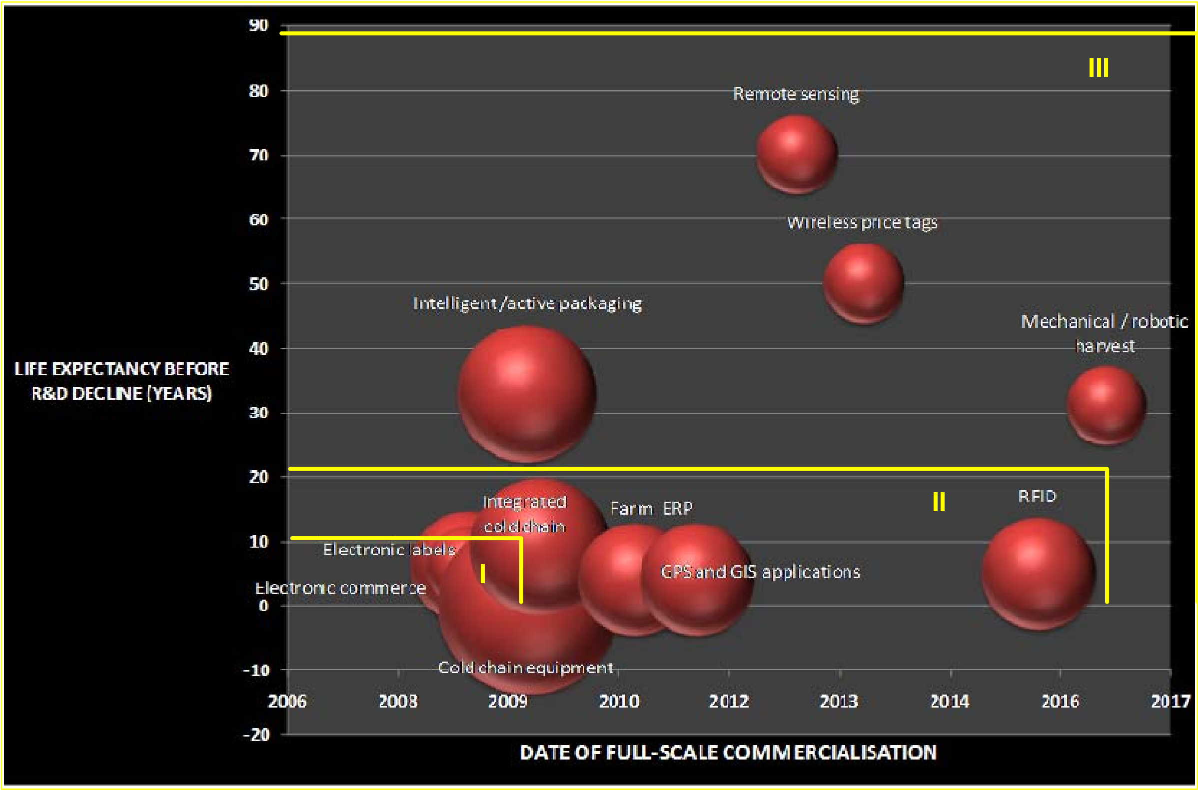

FIGURE 21. Bubble chart identifying a three-tier strategy for HAL investment in supply chain and logistics projects: (a) Tier I- technologies that are currently being commercialized, with medium-to high adoption and R&D decline expected in the next 10 years; (b) Tier II-technologies that are expected to be fully commercialized in the next 5-10 years, with medium levels of adoption and R&D decline expected in the next 10-20 years; and (c) Tier III- technologies that are expected to be fully commercialized in the next 5-10 years, with low-to-medium levels of adoption and R&D decline expected in the next 20-70 years.

Summary of barriers and opportunities per SCL category

Emerging Technologies for Management of Supply, Demand and Inventories

A prerequisite for the exploitation of technologies to optimize supply, demand and inventory management is the adoption of computer and internet technologies. Despite national issues on broadband communication in rural areas, the low percentages of horticultural farms using a computer (62% according to 2006 ABS statistics and 76% according to the Molla and Peszynski study in 2008) can and should be improved. This issue is particularly critical in small operations (*i.e.* operations with revenues of less than $50,000). There is little hope in achieving supply chain excellence if vegetable growers can't access these basic requirements. There are two basic needs that should be considered:

1) Access to computers and internet. This could be achieved by grants supporting basic IT equipment in frams and packing houses, the installation of rural "internet cafes" which can be accessed by rural communities in horticultural areas or rental arrangements that provide installation and maintenace services to horticultural growers for a reduced fee. Further, contract arrangements with service providers that allow a number of farmers to access software at reduced costs could be sought. Normally, the larger the number of users, the lower the licensing costs. This same deal could be sought for internet services (*e.g.* farmer webpages, electronic auctions, trading posts and others).
2) Access to training. AUSVEG has a list of training courses focused on leadership and business skills [26] . Among these there are only five course that relate to IT training: Maintain Business Technology, Develop and use Databases, Develop and use Complex Spreadsheets, Prepare Financial Reports and Produce Complex Business Documents. These courses were developed on the basis of a 2007 needs analysis for training in business management and leadership [27]. Given the focus of this study, it is not surprising that none of the courses offered deal with the use of e- commerce, supply management, cold chain and packaging, demand forecasting, ERP and other supply chain technologies at farm level. There is an oportunity to engage with software and supply chain service providers to generate training programs addressing these gaps. While there would be a need to monitor the contents of such courses to ensure a balance between marketing and substance, there is also great potential in promoting discussions between farmers and supply chain service providers to enhance both the services offer and the understanding of what benefits IT technology can bring to horticultural growers.

[26] http://www.ausveg.com.au/PDNA-courses.cfm
[27] http://www.ausveg.com.au/docs/Training-Needs-Analysis.pdf

Robotics and automation in harvesting

Previous reports on the levels of adoption of robotics in the Australian vegetable industry suggest that uptake and awareness are low. Barriers to uptake include the need to adopt once-over harvest, capacity mismatch with other supply chain operations and cost. However, it is expected that the integration of robotics with other emerging technologies (*e.g.* GPS, automatic machine guidance and computer-based vision systems) will significantly improve current performance. It is also expected that, as the costs of these technologies decline, commercial adoption of these new methods will increase.

Future projects in mechanical harvest could emphasize the impact of shifting from multiple vegetable harvesting practices to once-over harvest which is necessary to make many mechanical harvesters feasible. Even when adopting the latter, research suggests that losses in some vegetables (*e.g.* leafy greens) can be as high as 20% [63]. Therefore, the marketable quality resulting from robotic/mechanized harvesting and the trade-offs between decreased labour costs and increased damage in products is another aspect that should be investigated.

Projects that solve or minimize issues around risks of overcapitalization due to uptake of capital-based technologies would benefit the industry. This applies at grower's level and also at processing level: fruit and vegetable processing present low levels of annual investment in machinery and equipment per year, in comparison to the levels observed in meat processing and dairy manufacturing [64].

Emerging packaging technologies

Barriers to the adoption of active and intelligent packaging are the cost and the fact that the benefits of improved product shelf-life do not necessarily flow back to growers. The same can be said about retail-ready presentations and the introduction of RPCs. To date, there are no case studies that show the value proposition for the uptake of these technologies at grower level. However, growers have adopted these technologies to respond to supermarket requirements. The quantification of costs across the chain and technical aspects that affect efficiency due to the adoption of RPCs, retail-ready, intelligent and active packaging, is of interest to HAL's stakeholders to obtain solid information for negotiation of technologies required by retailers.

This report described several opportunities in the development of functional packaging targeting current market trends. There are other opportunities related to biodegradable, recyclable and reusable packaging, which will be further investigated in the next report about environmental challenges and opportunities.

Cold chain logistics

A major barrier to the use of modern (and old) cold chain technologies is the difficulty in proving a cost-benefit case. As with all the technologies investigated in this report, there is no average case study that can be representative of costs for all types of operations and products. Each case is unique and depends on a number of factors, including the size of the logistics operation, contractual arrangements with refrigerated transport providers and preferred service providers by buyers.

To date, there are few studies that provide an in-depth view of the cost structure and limitations (*e.g.* availability of refrigerated transport and restrictions in contractual arrangements) that horticultural growers face in Australia.

Commercial software packages that enable supply chain managers to optimize their distribution network on the basis of distance travelled, storage points and others is currently available. Examples include Llamasoft, Cognos, TRANSLOGIX Route Optimizer & Scheduler and many others. However, these solutions do not encompass trade-offs between quality, shelf-life and network optimization. Supply chain software developed for the horticulture sector encompassing costs and benefits for cold chain operations in terms of transport costs, safety and shelf-life could further enhance decision-making and design of supply chain networks.

Emerging food distribution systems

Notwithstanding the scientific misconceptions and uncertainties of food miles as an indicator of the environmental impact of food chains, the wide acceptance of 'local food' and 'food miles' indicates genuine concern on the way we produce and transport food. Even while research has shown that purchasing the most geographically local produce per se does not necessarily mean the lowest carbon impact [65], consumers are driving a change in distribution systems which ultimately will impact supply chains for horticultural products.

Increased urban population coupled with an increased awareness in the impact of food chains on the environment will lead to the development of new food chains. Fruit and vegetable growers can capitalize on these trends by re-developing farmers' markets chains, direct grower-urban consumer chains and local /regional chains that appeal to 'locavores'.

A range of questions arise from these trends:

- Do local chains present an opportunity to leverage the position of growers in the balance of market power in retail supply chains?
- Can direct grower-urban consumer channels provide an opportunity to improve profits for farmers? This opportunity may be further enhanced by the adoption of e-commerce technologies.

- What role growers have on the environmental initiatives of supermarkets in decreasing the carbon footprint of fresh and processed vegetables?
- In practical terms, what changes need to happen in current chains to contribute to foodservice and supermarket's environmental goals?

We will discuss some of these aspects further in the next report.

Shift to horticultural value chains

It is clear that the major challenge for the implementation of value chain and co-innovation in horticultural chains is creating the level of trust and commitment required for these alternative business models. In Australia, the recent outcomes of the ACCC investigation on grocery prices [66] did not appease concerns on the lack of transparency in grocery chains and the dominance of retailers in the market.

A potential avenue for implementation of value chain concepts is using the current balance of power to place retailers in the role of innovation leaders for the horticultural industry. This already happens informally, as many supply chain innovations investigated in this report have been implemented at the request of large supermarkets. However, the notion of sharing profits obtained through the uptake of emerging technologies requires acknowledgement by all chain partners.

The development of more balanced value chains with the foodservice and hospitality sectors could also be pursued. In sectors such as Government procurement, the concepts of value chains can generate better outcomes than in the private sector. Further, opportunities in export value chains are yet to be investigated. Future horticultural value chains will take different shapes and forms. Opportunities may lie on decreasing the current reliance in domestic retail markets through the exploration of riskier, but potentially more rewarding distribution channels, markets and technologies.

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Appendix 1. Methodology used for technology forecasting

Technology forecasting aims to provide an insight on the direction and rate of technology changes in the future. There are four basic elements in this analysis:

e) A time horizon. For the analysis of patent trends, the period covered from the 1st patent registered to 2008.
f) A specific technology. The technologies selected for patent analysis were: (a) farm enterprise resource planning and decision support systems; (b) geospatial applications; (c) electronic commerce and data sharing; (d) RFID-based traceability, monitoring; (e) mechanical harvesting, robotics and automation; (f) intelligent/active packaging; and (g) cold chain logistics systems.
g) A performance parameter for the estimation of the technology's advance. In this case, patenting trends were used as a performance indicator of R&D effort.
h) A probability about the outcomes predicted.

Technology development is often constrained by limitations or technological barriers (*e.g.* environmental, social, economic or scientific). As soon as any technology requires a set of resources to operate, the limitation of resources is considered as the root cause of incapacity of the technical system to meet quality standards.

Further, in niches or markets where several technologies compete, a technology's market share growth comes at the cost of growth for others. This process is well-described by a growth curve model as illustrated in Figure A1.1.

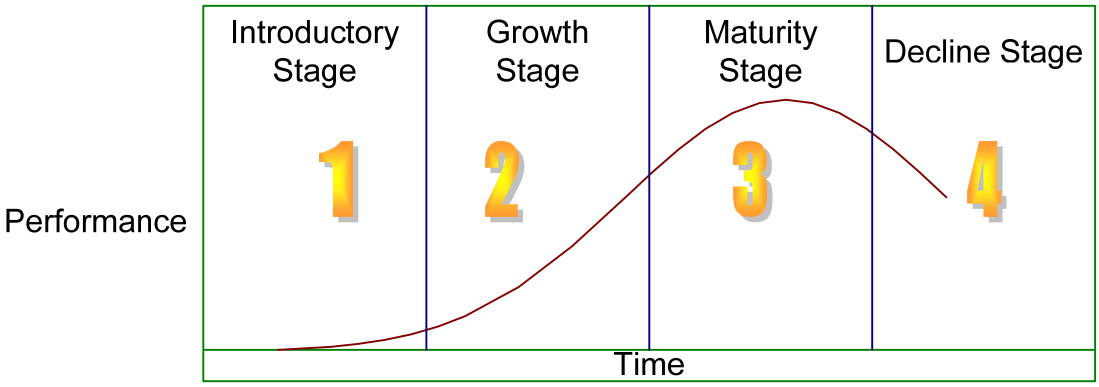

Figure A.1.1. Generic growth curve for assessing technological development.

The Loglet Lab software, a package created by the Rockefeller University, fits logistic curves to single time-series and applies the logistic substitution model to multiple time-series. The software is freely available at http://phe.rockefeller.edu/LogletLab/. In this study we used Loglet Lab to fit patent trends for the emerging technologies investigated. The construction and interpretation of logistics and bi-logistic growth curves for technology forecast is further explained in the following references: [67-70].