Agricultural Transportation Challenges of the 21st Century

Transportation, Handling, and Logistical Implications of Bioengineered Grains and Oilseeds: A Prospective Analysis

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Steven Sonka
R. Christopher Schroeder
Carrie Cunningham [1]

Introduction

After years of promise, biotechnology (biotech) advances are now being made which appear to have the potential to greatly change the production and marketing system for grains and oilseeds in the United States. These advances include improvements in crop production from the creation of seeds with greater production potential because of in-bred herbicide tolerance or resistance to particular pests. The planting of Bt corn, with its built-in resistance to the European corn borer, and Roundup Ready® soybeans, which have been modified to have tolerance to the herbicide of the same name, are now commonplace. Biotech advances also include those which will result in crops with the potential to provide enhanced quality-related traits of value to particular end users, such as corn with high lysine content and soybeans with high oleic or sucrose content.

Even though the biotech revolution is still in its infancy, significant transportation, handling, and logistical implications will likely result from the continued adoption of bioengineered crops by producers and end users. For the value of agricultural biotechnology to be ultimately realized, crop identity will have to be maintained in production and transportation, handling, and logistical supply chains. If crops bioengineered to have enhanced quality attributes are commingled with nonbioengineered crops, which are currently produced and marketed as homogenous commodities, the quality-enhancements in the bioengineered crops will be lost. Further, in some international markets, societal acceptance of bioengineered crops is a controversial issue. Labeling of bioengineered crops currently has been mandated in key international markets for some uses. Therefore, separate handling systems for bioengineered products and non-bioengineered commodities may need to be created as a result of the lack of immediate acceptance of genetically-modified crops in those markets.

[1] Steven Sonka holds the Soybean Industry Chair in Agricultural Strategy, is Director of the National Soybean Research Lab, and is a Professor with joint appointment in the Department of Agricultural and Consumer Economics and in the Department of Business Administration at the University of Illinois at Urbana-Champaign. R. Chris Schroeder is a principal, as is Sonka, in AEC/Centrec, a financial and management consulting firm in Savoy, IL. Carrie Cunningham is Project Director of the Economics and Management of Agrobiotechnology Center at the University of Missouri.

The production and marketing system for major commodity crops in the United States is designed to provide maximum value through the low-cost delivery of massive amounts of homogenous grains and oilseeds. Key characteristics, which result in successful operations in the current commodity setting, conflict with the needs that appear to be required for effective marketing of bioengineered crops. Further, forces exist which could foster change in the current commodity system, regardless of biotech forces. Some consumer segments desire greater traceability of food supplies for food safety and lifestyle preferences. Societal responsibility increasingly includes documentation of farm production practices as a necessary component. At the same time, advances in the capability of information technology offer the potential for greater traceability within commodity production and marketing systems. These include precision agriculture, the Internet, and e-Commerce.

The evolution of agricultural biotechnology in the marketplace and pressures for change in the commodity production and marketing systems, therefore, are highly interrelated. The studies described in this report explore these interrelationships and the dynamics for change they imply. Because of the highly volatile nature of today's agricultural marketplace, quantitative predictions based upon analysis of historical data are of limited value. Therefore, these analyses are conceptual and prospective in nature. Their purpose is as much to identify questions and key issues as it is to provide answers.

Goals

The overall goals of the analysis are to describe and analyze the transportation, handling, and logistical implications likely to result from the continued adoption of bioengineered grains and oilseeds in the United States, including such factors as the number and type of bioengineered products likely to emerge; product certification and testing requirements; and the transportation, storage, and handling requirements that will have to be met if bioengineered products are to be marketed successfully. To achieve those overall goals, a number of specific analyses were conducted. The results of these studies are integrated and reported in this report.

The remainder of this section provides a systems perspective of the dynamics inherent in marketing system change, driven by biotechnology. The report's second section will briefly review and assess biotechnology from the perspective of its potential implications for the marketing sector. The next two major sections will examine the evolution of the commodity marketing systems, employing alternative lenses. First, alternative market structures will be detailed by investigating key distinguishing characteristics relative to those of the commodity market channel. Second, the results of indepth futuring exercises with decision makers from throughout today's production and market system will be reported. The final section of the report will identify handling, storage, and logistical implications of alternative future paths for biotechnology.

The Dynamics for Change

If widely accepted by consumers, agricultural biotechnology offers the potential to provide substantial benefits but also challenges to participants throughout the commodity production and marketing system. As noted previously, the existing commodity system is not designed to produce and deliver diverse sets of differentiated output. The following discussion will examine the dynamic interactions likely to result in a setting where biotechnology drives structural change in the production and marketing system.

Investing in a Vision

The vision that there are potential benefits from biotech commodities has been strong enough to drive huge investment into research and development initiatives. Figure 1 suggests that *Theoretical Value from Biotechnology* supports [*S*] the *Speculative Investment* that in turn supports [*S*] *Biotech Development*. This tends to be a reinforcing process [R] where new developments generate more ideas for value that drives more investment. For many types of biotech value traits, this depicts the current situation—especially for value traits that provide benefits to participants further down the value chain beyond the producer. The bold dashed lines that intersect the linkage between *Speculative Investment* and *Biotech Development* denote that there are considerable time delays between the decision to invest and actual development of innovations. From an investment perspective, of course, the length of those time delays is critically important.

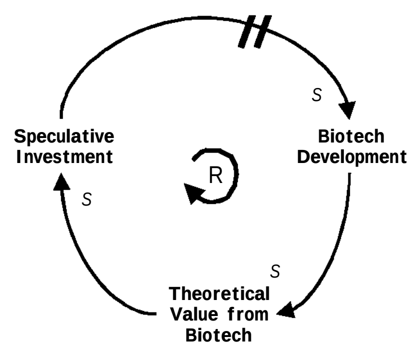

Figure 1

Moving from Theoretical Value to Realized Value

As development continues and biotech-driven quality improvements become reality, it becomes possible to move from theoretical value to realized value. Figure 2 expands the diagram to illustrate that *Transportation and Handling Infrastructure* will be needed in conjunction with the *Biotech Development* to generate *Realized Value from Biotech*. Other system components will be needed to facilitate the full adoption of biotech grains. For example, the factors below are just as important as the transportation component.

- New marketing and business arrangements that will be needed to facilitate the redistribution of value through the value chain,

- The utilization of information technologies,
- The evolution of testing technologies, and
- Public acceptance of different kinds of products.

This paper will touch on some of these issues, but the primary focus will be on the implications of the transportation, handling, and logistical infrastructure components.

Figure 2 illustrates where the current structure is lacking today and most likely in the near future unless changes are made to the *Transportation and Handling Infrastructure*. That is, the amount of *Biotech Development* is continuing to advance and build *Theoretical Value from Biotech*, while the *Transportation and Handling Infrastructure* is quickly becoming the limiting factor in realizing the potential value.

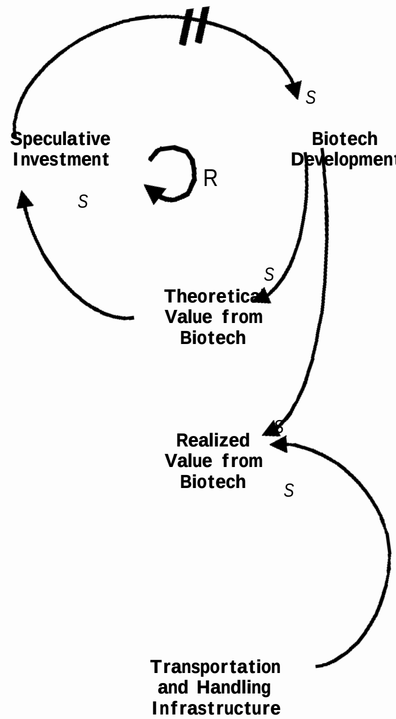

Figure 2

The Incentive to Invest in Infrastructure

The investment in *Transportation and Handling Infrastructure* is fundamentally different from the investment in *Biotech Development*. Investments in biotechnology are very large and very speculative, but perceptions of the long-term payoffs are very high. This tends to attract a high volume of long-term investors. On the other hand, investment in *Transportation and Handling Infrastructure* is more mundane but has a more tangible outcome. There is little question that a particular infrastructure can be built. The speculation is whether the market will provide adequate return to the *Transportation and Handling Infrastructure* to provide sufficient return to the investment—especially in a sector that has historically been characterized as highly competitive with very narrow margins. However, both components are equally important in realizing the value from biotech commodities.

Figure 3 builds on the previous figures to include a very important linkage from the *Theoretical Value from Biotechnology* to *Infrastructure Development* that supports the development of the *Transportation and Handling Infrastructure.* The notion here is that as the *Theoretical Value From Biotechnology* increases over time, it will reach a threshold at which time someone in the system will become convinced that it makes sense to invest in the development of infrastructure. (Of course, the perceived theoretical value can decline, which would retard investment.) Again the two short, bold lines that intersect the linkage between Theoretical Value from Biotechnology and Infrastructure Development denote the notion that this time delay is likely to be both significant and lengthy. Over time, this will provide the infrastructure needed to realize the value from the biotech developments. The time lag between the point where the biotech product is ready for market and the time when it is actually produced and processed to generate return is critical. For example, there is the potential for huge lost opportunity if a biotech product is ready for market but sits stagnant for a couple of years while the necessary infrastructure is being developed.

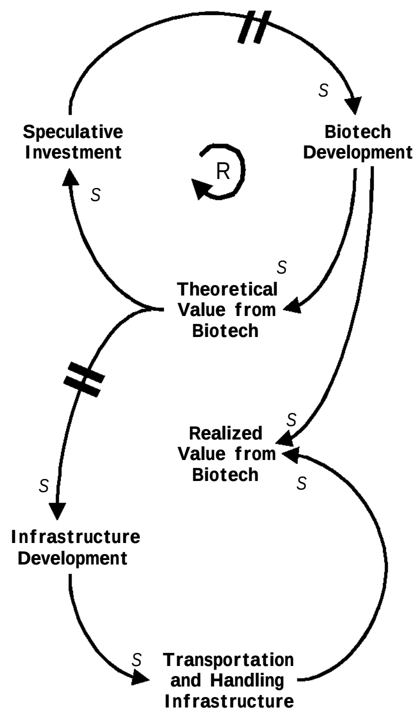

Figure 3

Closing the Loops

It will be important to understand the dynamics of the continued evolution of the *Transportation and Handling Infrastructure* as the system matures. Figure 4 illustrates the feedbacks that will provide a return to those who invested in the *Biotech Development* and the *Infrastructure Development*. Over time, these feedback loops will generate varying degrees of additional investment, depending on how successful (profitable) the existing products have been. Again, the magnitude of any delays between the time when value begins to be actually realized

(*Realized Value from Biotech*) and *Infrastructure Development* will significantly affect the pace by which returns accumulate and fuel further investment

Note that this diagram can be applied to different types of biotech traits. For example, the *Transportation and Handling Infrastructure* needs will be much different for a trait that is used in very high volumes (e.g., high oil corn) versus one that requires smaller volumes (e.g., used in the manufacture of pharmaceuticals).

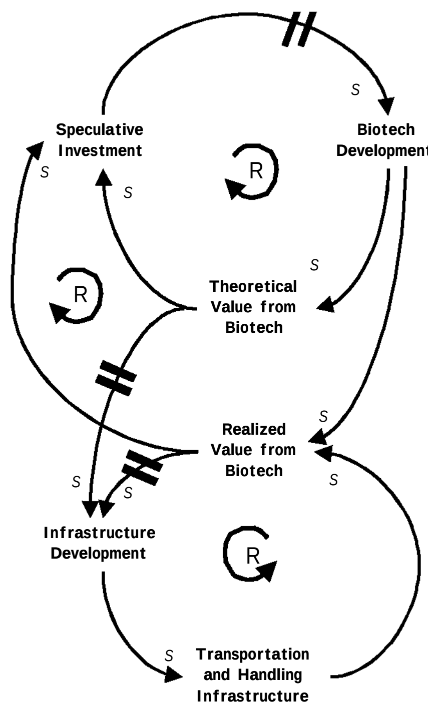

Figure 4

Key Factors for Consideration

The relationships and dynamics illustrated in the preceding diagrams will be used as a point of reference throughout the remainder of this document. The time lags noted in those diagrams are of critical importance. Not only can those lags be substantial, they identify a significant mismatch between investment to initiate biotech development and the timing of investment for infrastructure development. Although that infrastructure development is not needed until crops from biotechnology are in the marketplace, delay in the availability of that infrastructure will reduce profitability and restrain further investment in biotech development.

Biotechnology and the Commodity Marketing System

The production and marketing system for major commodity crops in the United States is designed to provide maximum value through the low-cost delivery of massive amounts of homogenous grains and oilseeds.[2] Key characteristics, which result in successful operations in the current commodity setting, conflict with the needs that appear to be required for effective marketing of bioengineered crops.

This section of the report first will specifically identify the general reasons that suggest incompatibility between the existing commodity market system and crops from biotechnology. The following section will briefly review key developments in the application of biotechnology to crop production to date.

Expected Challenges to the Commodity Marketing System

Even though the biotech revolution is still in its infancy, significant transportation, handling, and logistical implications will likely result from the continued adoption of bioengineered crops by producers and end users. For two very different reasons, it now appears that crop identity will have to be maintained in production and marketing supply chains for at least some portion of the crop.

So-called first generation crops were altered to enhance agronomic performance. Because output traits were not affected, segregation of these crops was not expected to be necessary. In some international markets, however, acceptance of bioengineered crops is a controversial issue. Labeling of bioengineered crops currently has been mandated for some uses. Therefore, separate handling systems for bioengineered products and non-bioengineered commodities may need to be created because of the lack of immediate acceptance of genetically modified crops in those markets.

The most significant impact of biotech crops on the crop transportation, handling, and logistical systems should occur with the second generation of biotechnology, where crops with quality-related traits that have added value for specific end users are available. The added value of these crops is found beyond the farm level. Potential examples include high lysine corn, high oleic soybeans, or wheat with improved processing traits. These products will require segmentation to preserve their identity through the grain handling systems to the point where the value is captured. If grain with specific end-use value is commingled with other grain, value is likely to be lost.

Adoption of Agronomic Biotechnology: A Review

Genetically modified corn and soybeans having agronomic value have been available since the mid-1990's. The two most widely adopted products for corn and soybeans were Bt corn and Roundup Ready™ Soybeans, respectively. U.S. acreage using genetically engineered crops increased from about 8 million acres in 1996 to more than 50 million acres in 1998 (USDA, 1998).

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[2] In reality, of course, homogenous commodities dominate the current system; however, there are a variety of value-enhanced crop products on the market as well. In general, market transactions and transportation logistics work smoothly for these niche products in small volumes and with premium pricing.

Although genetically engineered crops were widely adopted in the first few years after introduction, public acceptance concerns have driven farmers to question use of the technology. A January 2000 survey conducted by Agricultural Education and Consulting found that farmers intend to plant only 17.7 percent of acreage with genetically modified corn in 2000, compared with 23.8 percent in 1999. Similarly, farmers responded that they would plant only 48.4 percent of acres with genetically modified soybeans in 2000, compared to 51.3 percent in 1999. Respondents were from the States of Illinois, Indiana, Iowa, and Wisconsin (AEC, 2000a).

Development of Differentiated Output Traits

Several agricultural crops have been, and are being, developed which offer potential value to the farmer's customer and the end consumer. Examples include high oil, high lysine, high protein, pharmaceutical, and nutraceutical properties. Other valuable traits include low phytate, high sucrose, low saturate, high methionine, high tryptophan, low oligosaccharide and low linolenic (Hillyer, 1999; Coaldrake, 1999). These products also could mean higher farm gate prices and larger profit margins to producers. In addition, the possibility of stacking traits, the ability to insert both agronomic and output traits into one event, presents even more potential value (Coaldrake, 1999). A summary of selected differentiated output traits in the pipeline for corn and soybeans is listed in table 1.

Table 1. Summary of selected differentiated output traits in the pipeline

Product	**Technology**	**Developmental stage in 1999**	**Value**
Corn	High oil	Commercial	High
	High oil	Precommercial	Moderate
	High lysine	R&D	High
	Low nitrogen fertilizer need	R&D	Moderate
	Low phytate	Precommercial	Low
	Modified starch	R&D	Moderate
	Phyto-manufacturing[3]		
Soybeans	High oleic	Commercial	Moderate/high
	Improved protein	Precommercial	High
	High stearic	Precommercial	Low
	Phyto-manufacturing[4]		

Source: Kalaitzandonakes (1999)

Some differentiated output trait crops are already being used in feedstocks for livestock. Benefits have been shown, for example, by using high oil corn in poultry feed and high lysine products in swine feed.

[3] Phyto-manufacturing, also known as molecular farming, involves production of substances at molecular level (e.g., enzymes) (Kalaitzandonakes, 1999).
[4] Ibid.

Advances in technology for industrial uses of corn and soybeans are also in the pipeline. Soybeans have long been used in industry for making plastics, paint and other materials. Several new breeds of soybeans may be useful for these industries (Hillyer, 1999).

It may also be quite valuable in the future for corn and soybeans to have enhanced pharmaceutical and nutraceutical properties. Calcium enriched crops, high insulin corn, and crops genetically altered to carry vaccines or medicines are examples of useful traits that may be possible in the near future.

Overview of Genetic Modification

Transgenic crop modification is the process of inserting one or more genes from another species into a plant cell, along with promoter and marker genetic material. The result of this modification is labeled an event and is characterized by the genetic package created by placement of the novel DNA. After inserting the novel material, the event is fostered to grow an entire plant that reflects the properties encoded by the new genetic material (Nelson, et. al., 1999).

Genetically modified crops were introduced to the international marketplace in the late 1980's and early 1990's (Cunningham and Unnevehr, 1999). Genetic modification was first commercially introduced in the Flavr-Savr tomato, enhanced to provide longer shelf life. Other genetically enhanced fruits, vegetables, and rice varieties were introduced soon afterward. The first two commercially important genetically engineered seeds introduced in the United States were Bt Corn and Roundup Ready™ Soybeans. Bt Corn is designed to provide resistance to the European Corn Borer. Roundup Ready™ soybeans are designed to provide resistance to Roundup™ brand herbicide. This resistance carries with it a reduction in input costs, possible yield improvements, reduced need for tillage, and increased flexibility in crop rotations (Simone, 1998). Nelson, et. al. presented a brief summary of potential environmental and food safety effects of both Bt corn and glyphosate-resistant soybeans in a November 1999 report. Table 2 is taken from the report and reflects those findings.

Nelson, et. al. (1999) summarize potential effects of biotechnology. Some of the potential benefits of Bt corn are the reduction of harmful toxins such as aflatoxin and fumonisin, as well as a possible decrease in the use of pesticides. Some of the potential negative effects of Bt corn are the possibility of resistance developing in the targeted pest; unwanted crosses of traditional hybrids with genetically modified organisms (GMO); and potential harmful effects on nontarget species[5].

[5] In August of 1999, researchers from Cornell University published a report in *Nature*, presenting the potentially harmful effects of Bt corn on the Monarch butterfly. Brief discussion of this article can be found in Nelson, et. al. (1999) or in the article entitled, "Transgenic Pollen Harm Monarch Larvae" (Losey, 1999). Further research at several universities found that the original research was done under conditions not normal to farmer practices.

Table 2. Summary of potential effects of biotechnology

	Bt Corn	Glyphosate-resistant soybeans
Food safety		
Human toxicity	None from current Bt toxins Potential reduction in aflatoxin[6], fumonisin[7]	None known or likely
Allergenicity	Unlikely for current Bt toxins	None known or likely
Environmental		
Weediness	No	Possible from stray seed
Genetic flow	In region of origin, crosses with relatives likely because of open pollination	In region of origin but crosses unlikely because of nature of pollination
Resistance	Yes; both in target and nontarget economic pests	Yes for some weeds, but slow to develop
Changed use of chemical treatments	Minimal	Substitution of glyphosate for other herbicides; probably reduced total volume
Nontarget effects	Other lepidoptera (e.g., monarch butterfly); species that feed on target pests	None from GMO; potential increase in glyphosate use, reduction from decline in other herbicides

Source: Nelson, et. al. (1999)

Glyphosate-resistant (GR) soybeans also have potential effects. These potential benefits of GR are a reduced volume of herbicides used and a reduction of other non-target effects (environmental or otherwise) because of this reduction in herbicide use. Potential negative effects are weediness due to lost seed (also present with conventional varieties); development of resistance by some weeds; and an increase in glyphosate use.

Governmental and Public Resistance to Biotechnology

Initially, environmental concerns about GMO's motivated differentiated policy toward the use of GMO's. As consumers became aware of the material being present in food products, other

[6] Aflatoxins are toxins produced by a mold that grows on crops such as peanuts, tree nuts, corn, wheat, and oilseeds such as cottonseed. Although aflatoxins are known to cause cancer (carcinogenic) in animals, the Food and Drug Administration (FDA) allows them at low levels because they are considered "unavoidable contaminants" of these foods (OSO 1999).

[7] Fumonisins are toxic chemicals produced by molds on corn. Because the fungus that produces the toxic chemical grows within the corn plant from the time it is a seed, these toxic chemicals are almost always found in corn. Occasionally, the amount of the toxic fumonisin in the corn can become quite high and cause the death of horses and pigs.

concerns became apparent. Buckwell, et. al. outlined these concerns in a 1999 study:

a) ethical objection to the transfer of genetic material between species that could not occur naturally;

b) perception amongst some citizens that the deliberate, irreversible, release of artificially created genotypes of food crops into the environment should only be made after sufficient consideration of the long-run effects on human health and the environment;

c) specific concerns that adverse impacts on the environment may arise through possible out-breeding of GMO crops, weeds and organisms. There are also concerns that GMO technology may bring about further reduction in biodiversity through losses of beneficial plants, insects, and the creatures that depend on them.

d) concern about the long-term safety of diets containing GMO's, which may differ chemically from traditional food crops (Buckwell, et. al., 1999).

Opposition to GMO's appears as though it will continue for some time. The opposition of European activist groups and some European consumers sparked media attention around the world. These concerns and the growing use of these crops have brought about regulatory changes to address their special characteristics and risks. Australia, Canada, the United States, Mexico, Japan, and the European Union all regulate GMO's in specific ways that differ from regulation of traditional crops and inputs.

Alternative to the Commodity Market Channel

Biotech enhancements to grains and oilseeds have the potential to significantly impact the current crop transportation, handling, and logistical infrastructures. One aim of biotech crops is to create products with specialized traits that add value to users. Further, to export product to some nations, it will be necessary to separately identify output that has been produced from seed that was genetically altered, even if only agronomic traits were affected.

Biotechnology, although potentially significant if widely adopted, is not the only factor that appears to be driving structural change in the crop commodity sectors. The literature on the changing structure of U.S. agriculture is extensive and growing. Boehlje (1999); Sonka, et. al.; Tweeten (1997); U.S. Department of Agriculture (USDA), Economic Research Service (1999); Kalaitzandonakes (2000); and Kalaitzandonakes and Maltsbarger (1998) have written on the changing structure of agriculture.

Objective

The objective of this section is to provide a framework for thinking about how the use of biotech-enhanced grain and oilseeds will impact the commodity marketing system. Specifically, it will describe the type of market structures that may develop to accommodate the production and marketing of new value-enhanced crops. This discussion will encompass the entire value chain as depicted in figure 5. This broad view is especially important when considering the impact of biotech crops, since the cost and return factors tend to extend farther up and down the value chain than traditional commodity crops.

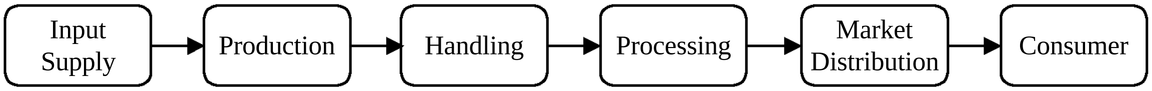

Figure 5. Grain and oilseed value chain

Marketing Channel Definition

The following discussion will delineate possible market structures that may develop to accommodate the production and marketing of biotech grains and oilseeds. Assessing these market structure alternatives is necessary for evaluation of possible transportation, handling, and logistical implications.

The marketing channels described as part of the U.S. Grains Council's *1998-1999 Value-Enhanced Corn Quality Report* will be used as a starting point for developing this structure. The marketing channels were developed as a way to describe the various alternative systems that can be used to produce and merchandise value-enhanced corn. This structure will then be amplified to accommodate other grain types, issues specifically related to biotech traits, and changes expected to occur in the grain marketing system.

The four marketing channels referred to in the *1998-1999 VEC Quality Report* are described in table 3. These definitions, not only describe the marketing channels that are used to produce and merchandise value-enhanced corn, but also characterize the types of corn products moving in those channels. Detailed descriptions of the individual marketing channels can be found in the U.S. Grains Council's *1998-1999 VEC Quality Report.*

The U.S. Grains Council marketing channel definitions work well for describing most systems used for the production and merchandising of value-enhanced grains. However, a few modifications to these structures may be useful in looking at the impact of biotech-enhanced grains on the crop marketing systems. Table 4 shows the modifications made to the original marketing channels. The structure is basically the same with the addition of another marketing channel and another set of differentiating characteristics. Vertical integration was added as an alternative marketing channel, and traceability was added as another differentiating characteristic. The new additions are shaded in the table.

Table 3. Alternative marketing channels for U.S. corn

Differentiating characteristics	Level I identity preserved	Level II specialty corn	Level III super commodity	Level IV standard grade
Relative value/premium	High	Medium	Low	None
Buyer control	Variety production practices certification other	Min/max attributes	Attribute preferences	Grades only
Attribute testing	Buyer's discretion	Cost/value-driven	Efficient/ consistent	Grade-driven
Types of producer contracts	Acreage production bushels	Production bushels normal/ Open	Normal/open	Normal/open
Producer linkages	High	Moderate	None	None
Minimum segregation	Farm	1st point of sale	Merchandiser-determined	Merchandiser-determined
Product volumes	Low	Moderate	High	Very high

Table 4. Modified marketing channels for grains and oilseeds

Differentiating characteristics	Level 0 vertical integration	Level I identity preserved	Level II specialty	Level III super commodity	Level IV standard grade
Relative value/premium	Any (high to low)	High	Medium	Low	None
Buyer control	Complete multiyear	Variety production practices certification other	Min/max attributes	Attribute preferences	Grades only
Attribute testing	Integrator's discretion	Buyer's discretion	Cost/value-driven	Efficient/ consistent	Grade-driven
Types of producer contracts	NA	Acreage production bushels	Production bushels normal/open	Normal/open	Normal/ open
Producer linkages	Complete	High	Moderate	None	None
Minimum segregation	Any desired	Farm	1st point of sale	Merchandiser-determined	Merchan-diser-deter-Mined
Product volumes	Any desired	Low	Moderate	High	Very high
Information carriers/ traceability	High	High	Moderate	Low	None

Vertical Integration

The addition of vertical integration as an alternative marketing channel may be necessary as end users try to gain greater control over the production and handling of inputs. The original channels assume a basically traditional ownership structure with independent control of production, handling, and processing functions. The original channels do account for the use of production contracts to secure production but not for the complete integration of the system.

Vertical integration provides buyers with an even higher level of control than the Identity Preserved (IP) channel. Under vertical integration, the buyer has complete control over all production and handling decisions. A significant advantage of vertical integration is that the system could be immediately responsive to the integrator's needs[8]. The integrator would not have to spend time and resources encouraging producers to raise the types of traits they needed. The integrator's entire production could be directed to any trait that they wanted each year.

Attribute testing under vertical integration would be at the integrator's discretion. Depending on the trait and the internal controls of the integrator, testing related to trait validation may be reduced with this marketing channel. Some testing would still need to be done to measure quality factors that are impacted by growing conditions such as protein content but testing may not be required on a load-by-load basis as it is for other production arrangements.

Vertical integration could be used for any type of product from high-value specialty products to low-value commodity grain. It would most typically be used for high-value products where the integrator wanted complete control over the production and handling practices to preserve the product's quality and identity. Vertical integration may be used as a system to keep the integrator's production out of the commodity channels in cases where the specialty product may have undesirable effects if used in the wrong application. For example, in the production of corn with pharmaceutical traits it may be very important to keep the pharmaceutical corn out of the commodity corn channel. Usually the segregation challenge with specialty crops is to keep other types out of the specialty channel. Here the problem may also be the reverse. Vertical integration could give the integrator greater control over the production and handling of the grain to limit the potential for the specialized grain to enter the commodity stream.

Information Carrier/Traceability

The ability for grain to carry information about its past and be traceable to its origin was added as another differentiating characteristic of the marketing channels. As mentioned earlier in this document, the increased number of end-use traits, food safety concerns, and consumer demands for information about the food they buy are all driving the need for better grain product traceability. In the future it will become increasingly important to be able to trace the input source of an end-use product back through processing, handling, and production.

When looking across the marketing channels, it is clear that the ability for grain to carry information about its past varies over the channels. In the vertical integration channel, the potential for information transfer and traceability is high. Depending on the types of systems they have set up, integrators can maintain information about given grain lots through their system. IP systems are set up to maintain information about the identity of the grain. This is in sharp contrast to the Standard Grades or the commodity channel where there is usually no

[8] As a form of business organization, vertical integration has disadvantages, including the challenge of managing business processes at differing levels of the supply chain. Most of these are not unique to the issue of biotechnology and will not be addressed here.

descriptive information transferred with the grain. All the buyer of commodity corn usually knows about the grain is that it is Number 2 Yellow Corn. Nothing is known about the origin or production practices.

Currently the ability to track information about grain history along with the product flow is constrained primarily by the level of segregation performed. Segregation that is maintained all the way from the farm level can enable detailed information to be carried with the grain about its history. An example would be an IP system designed to deliver organically grown grain. Here the producer, production practices, and variety can be determined. Conversely, a system used to originate low stress crack corn by segregating the corn as it is dumped at the elevator would provide little information about the production history. The only factor known is that stress cracks are low.

Advances in biotechnology may assist in product traceability. Biotechnology and gene markers may enable grain with specific traits to be marked with a visible indicator or even labeled by the producer. These advances may be a few years away but would dramatically change the system's ability to trace grain products back to their origin. Traceability would no longer have to be linked to segregation. Mixed lots could still be traced back to their origin.

Enhanced Grains and Oilseeds by Marketing Channel

With the marketing channels defined, a discussion of how some of the current and anticipated specialized trait grain and oilseeds products may be positioned in the channels follows. Table 5 provides a list of the specialized traits and an indication of where those traits are expected to fall in the marketing channels. It is important to point out that these classifications are not absolute. They are "best guesses" based on the current information about these products and how they are expected to be utilized in the market. The classifications serve more as discussion points and a way to frame the discussion of how markets for specific trait crop products may evolve. Also note the inclusion of all value-enhanced crops rather than only biotech-enhanced crops.

Note that for several of the products listed in table 5, the product may be produced and marketed through more than one marketing channel. This is the case for many products. Many products fit into more than one category depending on the unique characteristics of the product and how the players in the value chain determine how to market the products. Also, classifications of the product sometimes will change as the market for the product matures. For example, high oil corn started out strictly as a "specialty" product. It was typically grown under contract, product volume was low to moderate, and there were linkages between users and producers. Some of the high oil corn production has since shifted to the Super Commodity channel. It is grown for the open market, volume is high, and there are limited linkages between the end user and the producers.

Table 5. Expected marketing channel classifications for biotech products

Biotech product	Level 0 vertical integration	Level I identity preserved	Level II specialty	Level III super commodity	Level IV standard grade
Pharmaceutical production		□			
High protein soybeans				□	
High oil corn				□	
High lysine soybeans					
Organically grown crops					
Low stress crack corn					
Low phytate corn					
Non-GMO crops		□			
White corn					
Waxy corn					
Soybeans with uniform seed size					
High flour extraction wheat				□	
High starch corn				□	
Food grade soybeans		□			
Key	Most likely channel		□ Other potential channels		

Decision Makers Assess Future Structures

Market and technological forces in the U.S. grain and oilseed sectors suggest that there is considerable potential for significant market structure change (Sonka, et. al., 1999; Boehlje, Hofing and Schroeder, 1999). Due to rapid changes in technology, policy, and consumer preferences, decision makers throughout the sector are forced to adapt to the best of their ability using the information that is available. The ability to predict the future becomes more difficult because of the complex interrelationships among demand, supply, technology, regulatory environments and policy.

In the face of a dynamic market structure, there is very little past information or data to analyze for quantitative predictions of the future. The "normal" approach to research in agricultural economics has been to quantitatively analyze historical relationships to assess implications for the future (Boehlje, 1999). However, in times of dynamism, volatility, instability, and significant structural change, an *ex post* analysis approach using historical data sets is not effective in *ex ante* assessments (Boehlje, 1999). Therefore, in this analysis qualitative tools are used.

<u>Objective</u>

The working hypotheses of the analysis reported here is that industry leaders and experts have useful insights as to how the aforementioned factors will affect the future of agricultural market structure. Past management decisions have helped to build a set of tacit information that is useful to think about the future[9]. Use of scenario analysis and semi-structured personal interviews enables the researcher to extract that tacit knowledge. Scenario analysis allows the study participants to "project themselves" into alternative futures and to describe how individuals in managerial roles would respond to those futures. The objective of this section is to report on the insights discovered as to likely impacts of biotechnology on the market system.

Research Design

Qualitative research, the process of analyzing words and thoughts, is employed in this portion of the analysis. This type of analysis is routinely employed in strategic and market research (Wolcott (1992), Miles and Hubermann (1994), Creswell (1998)). After consideration of the options available for conducting qualitative research, the method of research chosen for this project was face-to-face interviewing. Thirty decision makers with extensive experience and who represent interests from throughout the production and marketing participated. Because the questions designed require a certain level of knowledge about the topic, outside sources were consulted to gain perspective on which individuals would have this knowledge. Academics, experts, and experienced researchers were consulted to build a list of possible contacts with positions from throughout the supply chain to be interviewed.

To ensure participation of the informants, strict confidentiality was promised. A listing of the sectors from which the respondents come is shown in table 6.

Table 6. Sampling categories for interview subjects and number of subjects in each category

Input supply (6)	Production (5)	Handler (4)	Processor (2)
Service/finance providers (6)			
Research & consulting (9)			
Academic/extension (6)			

Interviews ranged in length from 45 to 60 minutes, took place during the late winter and early spring of 2000, and occurred in the respondent's office (or a location of their choosing). More detailed information on the design process and the study participants is available in Cunningham (2000).

The interview consisted of six main questions, three for each of the two time periods in question. The three questions for each time period were the same, for the purpose of comparison. As reported in Cunningham (2000), four followup questions were administered to get richer, more

[9] Explicit knowledge is formal, repeatable knowledge; that which can be written down. Tacit knowledge refers to the informal, experience-based insights, judgment, and experience that decision makers employ (Nonaka and Takeuchi, 1995)

indepth answers; to explore newly discovered avenues; and to test and modify emerging themes (Rubin and Rubin, 1995).

Near-Term Non-GMO Segregation

Two market structures are examined in the research. The first is focused three to four years into the future and is centered on the notion that a 20-30 percent market share exists by that time for non-GMO corn and soybeans. The respondents were told that a premium is paid for segregation. Of the 30 respondents, 43 percent said the structure was realistic; 47 percent thought it was not realistic; and 10 percent said this was the current market structure. The main reasons given for not thinking that the scenario was realistic were that they did not see the premium occurring; they could not see the premium sustaining the market; and they could not see consumers paying more for what was once a generic product.

The main issues surrounding what would have to occur in order for a market structure such as this to occur are:

1) There would have to be a continued increase in consumer concern surrounding GMO's.
2) Similarly, there would have to be an increase in consumer demand for non-GMO products.
3) There must be a decrease in the level of risk associated with providing a pure and segregated product at all levels of the supply chain.
4) Issues with segregation and identity preservation must be resolved.
5) There would have to be increased concern regarding international trade losses with the European Union and Japan.
6) Governmental regulations and requirements will need to be better understood to certify the products.
7) There would need to be a market structure change to accommodate the differentiated product and premium.

Respondents were asked how their decisions and behaviors would change in response to a market structure where 20-30 percent of corn and soybeans was marketed as non-GMO. Of the 30 respondents, 60 percent said that their behaviors and decisions would change; 40 percent said that they would not change; and 30 percent said that they were already prepared or preparing for this scenario[10]. The major behavior and decision changes that were discussed were as follows:

1) Respondents said that in this sort of structure, there would be a need to establish a better infrastructure throughout the supply chain.
2) As there would be an opportunity for new markets, management decisions would change to facilitate these opportunities.
3) In order to provide segregation, new services, new products or other functions necessary to serve this market, respondents said that they would need to increase investments in some aspect of their business.

[10] Note that those who said that they were prepared or already preparing are included in the number of respondents who said that their behaviors and decisions would not change.

Longer Term Responses to Enhanced Output Attributes

The second market structure is focused eight to twelve years in the future and concentrates on a market structure where 40-50 percent of the market is sold as differentiated output traits. The respondents are told that the premium now lies in the value-added nature of the product. Of the 30 respondents, 80 percent thought that the scenario was realistic; 20 percent thought that the scenario was not realistic.

The responses about what would have to occur for the scenario to take place were similar to those given in the first scenario. They are as follows:

1) For the market to be heavily concentrated with differentiated output traits, there must be consumer demand for the products. Additionally, the consumer must realize some value in the product and have at least a few expensive substitutes. Many respondents thought that the traits would be part of niche markets driven by lifestyle or preference changes.
2) There must be an available supply of technology to grow the differentiated output traits. Biotech developers must have the incentive to supply products that are worthwhile and useful for a long period of time.
3) There will be a continued trend of market structure change. Respondents talked about consolidation, which has led to a high level of alliance both horizontally and vertically along the supply chain.
4) There must be a method of "insurance" against loss to the environment, misproduction, or commingling of high-value differentiated output products.
5) Issues of difficulty of segregation and purity must be resolved.
6) International trade concerns surrounding biotechnology and "American science" must be resolved.

Respondents were asked how their decisions and behaviors would change in response to a market structure where 40-50 percent of corn and soybeans was marketed with differentiated output traits. Of the 30 respondents, 67 percent said that their behaviors and decisions would change; 33 percent said that they would not change; and 20 percent said that they were already prepared or preparing for this scenario[11]. The behavior and decision changes were once again much like those that were discussed in the first scenario. The major behavior and decision changes that were discussed were as follows:

1) Respondents said that this market would force them to form new relationships with other members of the supply chain. Many saw their firm consolidating or forming alliances with other members of the supply chain.
2) As there would be an opportunity for new markets, management decisions would change to facilitate these opportunities.
3) In order to provide segregation, new services, new products or institute other functions necessary to this market, respondents said that they would need to increase investments in some aspect of their business.

[11] Note that those who said that they were prepared or already preparing are included in the number of respondents who said that their behaviors and decisions would not change.

4) Respondents said that in this sort of structure, there would be a need to establish a better infrastructure throughout the supply chain.

Resulting Themes

There were three common themes to the results of this study of future agricultural market structure. The first, and most common, theme was explicit recognition of a much greater role for the consumer in the future. It is apparent that agricultural leaders believe that the future of biotechnology lies in the actions and reactions of the end consumer-to-government regulation, food safety beliefs and the environment. Every respondent interviewed discussed the consumer at some point during his or her interview.

The second common theme was that the future structural change in agriculture would require significant infrastructure change. There will be a need for more storage and facilities to segregate identity preserved and specialty products. A highly coordinated transportation and identification system will be needed to transfer the product and information that makes the product more valuable. Furthermore, the ultimate role of the farmer will be more like that of a manager in a competitive environment in which there is a need to differentiate oneself from others, more so than has been observed in the past.

The final common theme of the research was that relationships along the agricultural supply chain are changing quite rapidly. Respondents mentioned several different types of changing relationships. The most visible of these changes is the horizontal and vertical consolidation, as well as alliances among agricultural firms. These include biotech research and development firms, chemical and input suppliers, seed companies, food processors, Internet service providers and other supply-chain participants. Firms are cooperating to provide specialized products and services that may have been available before but are now being supplied more efficiently. Other changing relationships are those between the farmer and supply chain participants. Several respondents discussed farmer-input supplier and farmer-grain handler relationships changing because of the Internet and the options available in contracting and specialization.

Handling, Storage, and Logistical Implications

To this point, the commercial experience with biotech-driven enhancements in grain and oilseeds has been limited to the use of seed with agronomic traits such as herbicide tolerance or pest resistance. In the future, output trait enhancement will be focused to provide benefits to other value-chain participants, including grain handlers, processors, manufacturers, and consumers. In many cases, realizing the increased value from these traits will require segregated handling systems that will keep commodities with specific attributes until they reach the ultimate beneficiary of that trait.

To this point, financial investment has been focused on the development of genetics. It is becoming more obvious that to realize the benefits of these genetic advances, it will also be necessary to build new knowledge, business systems, and physical infrastructure in other parts of the value chain.

This section focuses on the issues around the timing and nature of developments in the transportation and handling infrastructure that will be needed in order to realize the value from biotech commodities[12]. Two major components comprise this section of the report. As noted in the prior two major sections of the report, advances in measurement technology capabilities and adoption of that enhanced technology will be a critical infrastructure issue. Therefore, the first part of this section focuses on measurement technology. The second major component will employ scenario analysis to examine the dynamics underlying investment in transportation and handling infrastructure relative to alternative futures for agricultural biotechnology.

Developments in Measurement Technology

As new products are developed which hold value and need to be separated from other products, the need increases for tests to detect that value and differentiate the product from the others. Here the focus is on seeds being tested for two purposes: to determine quality and composition or to detect genetic modification. The recent movement toward component pricing also has influenced the developments in measurement technology. Inherent characteristics such as oil content, protein, and isoflavones provide a measure of value different from the traditional pricing based just on moisture, damage, volume or weight.

Measurement technology appears to be poised to make significant advances for two reasons. On the "demand" side, issues associated with biotechnology and increasing customer interest in grain and oilseed components suggest that testing capabilities will be more valuable in the future. Second, computational and information technology forms the base for grain and oilseed measurement systems. Continual advances in these fundamental technologies promise that enhanced capabilities will continue to be available at reduced cost levels.

Given the market driven need for these technologies, measurement and testing may be conducted during several stages of the production and movement of an agricultural product through the supply chain. Recently, monitors detecting oil content have become available on combines on the farm; later in the chain, measurement and testing takes place all the way through to export. The need for measurement at several levels imposes certain operational requirements that could determine the diffusion and adoption of a technology. Vierling (1999) outlined some of these requirements that help validate testing methods:

1. Accuracy
2. Precision
3. Specificity
4. Limit of detection
5. Limit of quantification
6. Linearity
7. Ruggedness
8. Robustness

In conjunction with specified allowances in the case of GMO's and accurate definitions of characteristics in output traits, tests that have these properties could be useful in agricultural market systems. Additional factors that are important when designing, as well as choosing a test for use are cost, time required to complete the test, and the level of technical skill and knowledge

[12] For purposes of this initial discussion, it is assumed that public opposition will not stop the continued development of biotechnology enhanced grains.

to conduct the test. The next few paragraphs will describe measurement technologies currently in use.

Component Measurement

Measurement technologies can be divided into two major categories, conventional wet chemistry testing and rapid nondestructive measurement. Wet chemistry testing is conducted under laboratory conditions; grain samples are normally ground and evaluated to determine the amount of different components. Even components with low concentrations, about 1 percent, can be detected and measured. The process, however, is very time consuming, destructive, and costly and requires technically skilled operators. In general, using wet chemistry for evaluation is neither practical nor possible when operating under volatile and dynamic conditions such as those at harvest time.

Rapid measurement technologies help overcome many of these limitations. These include Nuclear Magnetic Resonance (NMR) and Near Infrared Reflectance (NIR) spectroscopic techniques. These technologies essentially study the absorption or reflectance of light by seeds. The basis for the analysis is that each chemical or component in a seed absorbs or reflects a certain amount of light at a given frequency. An NMR or NIR machine exposes ground or whole seed samples to light at different frequencies. Since NIR machines are cheaper and more rugged[13], NIR spectroscopy is more widely used. NIR machines are also very accurate and robust for larger components, like protein in wheat, and protein and oil in soybeans. USDA Federal Grain Inspection Service (FGIS) has made available standards of NIR analysis for wheat and soybeans. So far, these standards have been adopted only for wheat. Recent studies have demonstrated the robustness[14] of NIR techniques for measuring amino acids and fatty acids. However, there are serious concerns about the accuracy of NIR techniques for measuring very small components, for example, isoflavones in soybeans.

GMO Testing

Testing for genetically modified grain consists of detecting the novel DNA or novel protein that modifies the grain or oilseed. There are a variety of tests available commercially to test for genetic modification of seeds. These tests vary in their accuracy, cost, technical skills, and time required to complete the analysis. The most popular tests are Polymerase Chain Reaction (PCR), Immunoassay (ELISA) "Dipstick" and ELISA "Later Flow", and Electrophoresis-based tests.

PCR-based tests are extremely sensitive. The test process magnifies—one million times—the novel DNA present within a sample. The tests require a well-equipped laboratory and trained lab staff and take a minimum of 1 day. The test also is costly relative to the others.

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[13] Vierling defines "ruggedness" as the reproducibility of results obtained under varying conditions such as different laboratories, different days, different technicians, and different equipment.

[14] Vierling defines "robustness" as the ability to remain unaffected by small variations in the method parameters. This is measured by the ability to remain unaffected by small but deliberate variations in method parameters and provides an indication of its reliability during normal usage.

ELISA-based "Dipstick" tests can indicate positive or negative at a pre-set level of novel protein (e.g., 1 percent). They are similar to home pregnancy tests. A sample of grain is ground and added to a tube filled with liquid. The dipstick is then inserted in the tube and, within 5 minutes, a positive or negative result is indicated by a change of color. The ELISA-based "Lateral Flow" tests indicate the exact level of the novel protein. The ground grain sample is put into a test tube filled with liquid. After 30 minutes, a color change and match will indicate the percentage of novel DNA. The dipstick method is the cheapest and easiest method of testing available at this time.

Electrophoresis-based tests allow a large number of samples, up to 100 or more, to be tested simultaneously, using an electronic image analyzer. Although this method is quick and not as costly as a PCR test, it necessitates a higher level of technical skill and is not as reliable as the other methods.

With the exception of the Electrophoresis-based tests, the operator must know ahead of time the "GMO content" of the grain/ oilseeds and the variety (genetic event) that needs to be tested for. For example, an ELISA-based "dipstick" test designed to detect the presence of Liberty Link corn (Liberty brand herbicide tolerant) would not detect the presence of Roundup Ready corn (glyphosate tolerant corn). Two separate tests are required to test for these two genetic modifications. Electrophoresis-based tests allow testing of a large number of kernels at the same time and determine the trait(s) within each one of them simultaneously. Use of NIR techniques for GMO evaluation, which could offer rapid nondestructive testing, is under evaluation.

Characteristics of the Current Transportation and Handling Infrastructure

The current infrastructure has evolved over decades with a focus on moving high volumes of a few homogenous product streams as cheaply as possible. The result is a low-cost system that capitalizes on longstanding grain grade and quality standards. Like any established system, change to any single part of the system can throw other parts out of balance. The following outlines some of the characteristics of the current system that will constrain or facilitate future change.

Relatively Few Grade Factors

The factors used to establish grades are few and well established and regulated. Typical tests performed at various steps along the process are relatively inexpensive and take little time to complete. These grade factors also tend to be minimum standards that are the basis for a reduction in price if the standards are not met, but no premium is paid if the standard is exceeded. Biotech-driven quality enhancements will most likely be based on a payment schedule that rewards for higher component content.

High-Volume Throughput

The system has been driven to increase cost efficiencies by spreading fixed investment over larger volumes. Receiving facilities are designed to handle a constant throughput of trucks, typically elevating to a common storage bin. Each bin can be filled completely before moving to the next bin. Grain is then shipped to larger aggregation points by progressively larger modes of transportation. Optimal transportation between each stage will depend on the volume, the length of haul, and the transportation modes available. Table 7 provides a comparison of volume for the various types of transportation modes commonly used.

Table 7

How many of these units --> does it take to fill one of these units	Truck	Rail car	50 Car Unit Train	Barge	Handy Vessel	Panamax Vessel - 1 Hold	Panamax Vessel
Truck	1.0						
Rail Car	4.0	1.0					
50 Car Unit Train	198.4	50.0	1.0				
Barge	59.5	15.0	0.3	1.0			
Handy Vessel	1,312.3	330.7	6.6	22.0	1.0		
Panamax Vessel - 1 Hold	328.1	82.7	1.7	5.5	0.3	1.0	
Panamax Vessel	2,187.2	551.2	11.0	36.7	1.7	6.7	1.0

The volume of these various transportation modes becomes quite relevant when considering the difference between moving billions of bushels of commodity grain through homogeneous channels as compared to moving specialized grains through a number of channels in increments of a million or fewer bushels.

Many Grain Flow Configurations

The path that grain takes to get to the end user is highly variable and is a function of many factors. The basic flow is from the field to storage to the end user.

Producer's Field → Storage Facility → End User

At one extreme, the end user might be the producer who raises grain to feed to his/her own livestock. USDA figures indicate that on-farm feeding is decreasing. On-farm feed use accounted for 60 percent of domestic use in 1980 and only 44 percent by 1996. At the same time, many of the current enhanced quality grains have been developed for livestock feed (e.g., high oil corn or nutritionally dense corn). These trends are at odds with each other and require more coordination to get the desired grains to the livestock feeder than would be necessary if the livestock were fed on the same farm where the grain was raised.

At the other extreme, grain might be stored at multiple facilities and elevated multiple times prior to reaching the end user. Figure 6 indicates the vast number of permutations that might exist for producers at various locations across the country. For example, as illustrated at the bottom of this diagram, a producer might initially put the grain into on-farm storage and then sell to a country elevator, subterminal elevator, terminal elevator, or even directly to the end user. In the absence of on-farm storage, grain would be delivered to any of the elevator types or directly to the end user and then flow through the channel as needed.

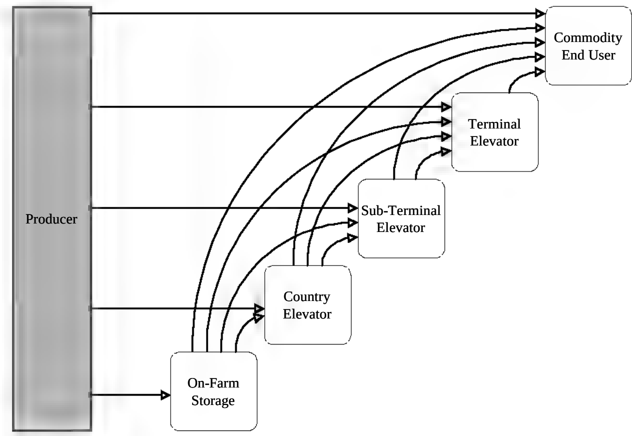

Figure 6

Generally, moving to the right on this illustration corresponds with larger lot sizes. In a commodity system, the end user accepts a high volume of generic products.

Typically, the flow from the producer tends to be directly to the smaller accumulation points to the bottom-left portion of as illustrated in figure 7. Note that there are no linkages between the producer and the end user in this version of the diagram. While there are a few cases where this might exist (e.g., a producer who sells directly to a livestock feeder), it is very rare that such linkages exist.

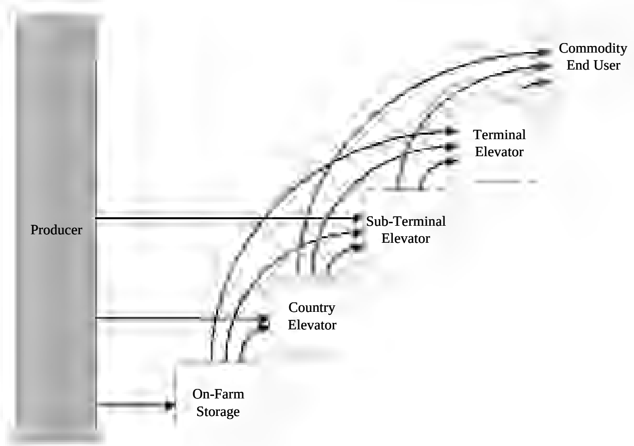

Figure 7

Relatively Few Localized Configuration Alternatives

There are many potential configurations between the producer and the end user when looking at the United States as a whole, but on a localized basis, the viable alternatives are much more limited. The grain movement from a producer in a given area is typically limited by the modes of transportation that serve that region. For example, it is not likely that grain grown near river terminals will be loaded on a train and shipped away from the river. Again, the evolution of the transportation infrastructure has been driven by the most efficient means of getting the grain to the end user. These localized constraints will play a key role in determining which areas are well suited for producing lower volumes of specialized crops and which will remain focused on high-volume commodity production.

Adversarial Market Environment

The current transportation and handling system is characterized by "cutthroat" competition. It is certainly not unusual to have a high level of competition between companies that are vying for the same customers. However, in the grain industry, the upstream and downstream players are often viewed in a competitive light as well. This is a result of the fact that everyone is dealing with commodities and there is no reward for providing added value.

Moving specialized commodities will require a fundamental shift in thinking. In the commodity system, value is derived from minimizing the differential between the minimum quality required by the applicable grade standards and maximizing volume. On the other hand, in an "attribute" system, value is derived by maximizing the absolute level of quality while maintaining a baseline level of volume. This will require participants of the value chain to start treating each other more like customers and suppliers as opposed to adversaries.

Dimensions of Biotech Market Channel Separation

Changes in the transportation infrastructure will be opportunity driven. That is, investment in infrastructure will be a function of the perceived opportunities that can be realized by building the components necessary to generate the added value. The new market channels will be unlike existing channels and will require the industry to consider a new set of dimensions in thinking about how and where value is created. The following section defines some of the dimensions that will be used to discuss alternative futures later in this paper.

Identity Preserved versus Segregated Systems

Different types of attributes will require different degrees of separation from commodity streams. Often, the terms, "identity-preserved"(IP) and "segregation," are used loosely to describe the same thing. For purposes of our discussion, these refer to two different types of channels.

IP involves establishing the identity of a particular quantity of grain that is retained up to the end user. The desired attribute can be measured or certified at harvest, and then the identity of the grain is maintained. An example of this in today's system would be organically grown crops or crops from a particular producer.

In segregated systems, crops with particular attributes are accumulated with like products but kept separate from other product streams throughout handling and transportation to avoid commingling. Unlike IP, crops from different sources will lose their identity once they have met the required threshold test and are accumulated with like products. Additional tests might be done at different points along the way to assure that the quality threshold is maintained.

Purity Requirements

Traditionally produced value-enhanced grains have moderately strict purity limits, which allow for some unintentional mixing. Discounts may apply when minor mixing occurs. For biotech crops, very strict purity limits may be imposed, making segregation more difficult to achieve. For example, industry experts have stated that a 1-percent threshold is nearly impossible to achieve in practice, while 5 percent would be manageable. This boils down to the simple fact that a 5-percent purity threshold can be achieved using the same equipment with attention to cleaning augers, trucks, etc., while a 1-percent purity threshold will require a totally separate handling system.

Geographic Concentration of Storage

As discussed earlier, one way to minimize the cost of IP or segregation is to localize production around an end user that utilizes the specialized crop. Depending on the volume of production, this raises a number of issues including risk of high losses in a drought year, reduction of alternatives for producers, etc.

Recent research by Agricultural Education and Consulting (AEC) suggests that producers across the Midwest are planning to increase on-farm storage and segregated handling capacity in the coming year. Figure 8 illustrates the ratio of bushels of on-farm storage capacity relative to the annual grain production across seven key grain-producing states. The ability to store and segregate crops on farms will have an important influence on the future production and marketing of biotech crops.

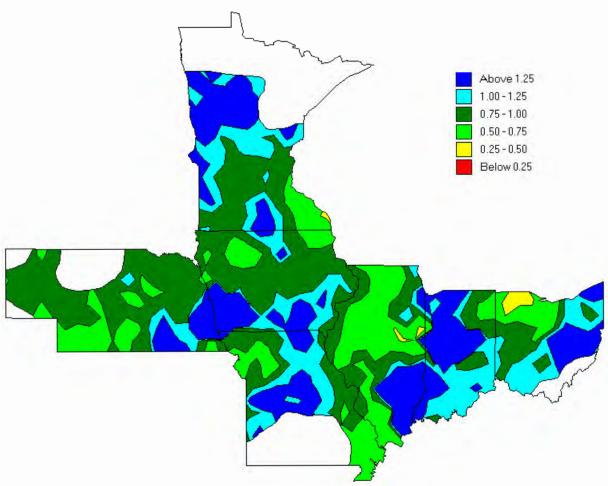

Figure 8. On-farm storage capacity to annual grain production for seven key grain-producing States (ratio of bushels to annual grain production)

Retooling of Processing Plants

Processing plants have been focused on high-volume processing of commodities. As the physical plant reaches maturity and requires replacement, decisions will need to be made about whether they continue to be a high-volume commodity processor or re-tool to be able to handle smaller lot sizes of specialized crops. The current age and condition of facilities across the country should be examined to get a better understanding of which facilities are candidates for re-tooling.

The Number of Segregated Configurations in a Given Area

Many country elevators and terminal markets currently have the capacity to handle a small volume of one or two segregated channels of grain. This is possible because they can use excess capacity and perhaps older equipment that is still in service (e.g., an older dump pit and grain leg that has lower volume).

However, expanding beyond one or two segregated channels becomes impossible without significant added investment. Conversations with originators suggest that many facilities are already utilizing this excess capacity in this manner but have little opportunity to add more channels or capacity without additional investment. Chapter 2 of the *1998-1999 VEC Quality Report* prepared for the U.S. Grains Council provides an overview of current segregation practices and capacities by elevators across the U.S.

Measurement Technologies

Because most attributes are not discernable by the naked eye, effective measurement technologies will be required to manage the flow of biotech grains through various marketing channels. The preceding part of this section provided an overview of developments in measurement technology. The evolution of these technologies will play a key role in determining the rate and structure of the biotech-driven market channels that emerge. Key factors include:

- Cost—The cost of testing will dictate the feasibility and frequency of testing as well as how the grain is handled after the test. For example, consider a trait that has a very high testing cost. Rather than test the grain at a number of points along the way, it may make more sense to test it once early in the process and then push the grain through an IP channel to avoid any commingling. On the other hand, if the test is very inexpensive, it may be possible to push it through a segregated channel and test more frequently.
- Speed—In traditional market channels, grain is tested at the time of delivery to determine conformance to grade standards. The process of performing these tests has evolved to be fairly efficient and can typically be done between the time that the load arrives and begins unloading. However, some of the new tests may be more sophisticated and require more time to perform. In extreme cases, the grain may need to be sent to a laboratory facility for accurate testing.
- Accuracy—Different attributes will require different degrees of accuracy depending on the variability and value of the attribute. Many times, the accuracy of a testing method is directly related to the cost and speed; that is, greater accuracy usually costs more and takes more time. The tradeoffs of speed, cost, and accuracy will be unique to each attribute being sought.

- Standardization—Industrywide standards have not yet been established for many of the new attributes. As various attributes become more prevalent, it will be necessary for standards to be developed to facilitate cost-effective trade.

It will be important to monitor developments in this area, as these factors will have significant impacts on the evolution of the transportation and handling infrastructure.

Process Certification

Process certification may become more relevant in the future as a way to augment or replace physical attribute testing. With process certification, producers (or other participants) provide assurance that the grain has been produced and/or handled in a particular way. Organically grown food is a good example of this. Because it is not possible to test the grain after harvest to determine if chemicals were used in the production process, the producer provides a "certification" that the grain was grown using certain practices. Other examples exist for specialty crops such as dry edible beans. Similar certification processes could be used for other biotech-driven attributes in the future.

Year-Round End Users

A seemingly fundamental fact is that most end users, whether food processors or livestock feeders, require a steady supply of grain throughout the year. This fact has shaped the current transportation and handling infrastructure for commodity grains. One of the main challenges of segregating into multiple channels is that each channel must flow simultaneously throughout the year.

To illustrate this challenge, consider a subterminal facility in today's environment that moves a 100-car unit train of commodity grain out each week to an end user. If they were to divide their flow into six channels, each week they would need to load 20 cars with grain type "A", 15 cars with grain type "B", 10 cars with grain type "C", and so on. And then the train would likely need to be split to get to multiple end-user locations. Obviously, this would create huge inefficiencies in the rail system that is designed for high volumes of homogenous product.

The most common model in today's environment is for an elevator to accumulate from producers directly out of the field or from on-farm storage facilities (figure 9). From there, the grain is hauled to the end user on an as-needed basis to supply the end user.

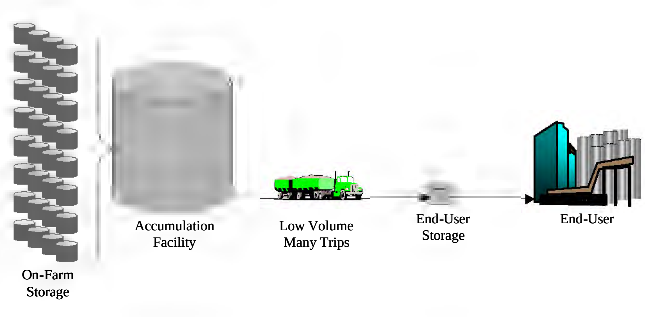

Figure 9

This approach will be viable as long as the accumulation facilities have the capacity to keep the multiple lines segregated and there is a transportation linkage of sufficient scale between them and the end user to facilitate a constant supply.

However, many facilities are not designed to accommodate segregation of many types of grain. In the future, a few models might evolve to meet these needs. One model would be for end users to increase their storage capacity to reduce the frequency of deliveries (figure 10).

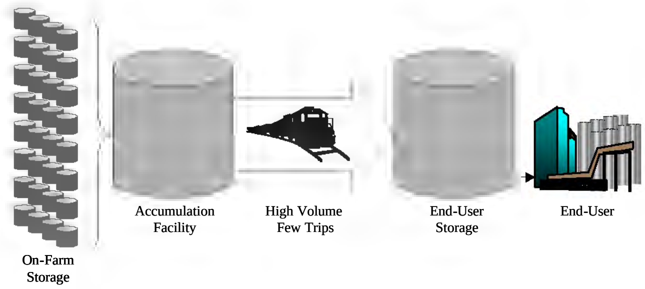

Figure 10

This structure allows the elevator to accumulate the grain from producers on demand (presumably from on-farm storage and not at harvest) and then send a few large-volume deliveries to the processor each year. The next week or month, the elevator could accumulate the second type of grain, ship it out, and so on.

Another model would be to maintain the steady flow directly from on-farm storage to the end user (figure 11). This is what has been done in the Midwest with food-grade corn.

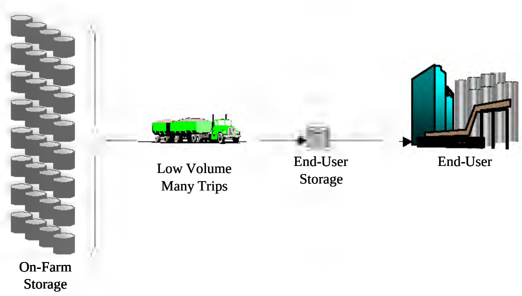

Figure 11

Other models undoubtedly will evolve, depending on the nature of the attribute being captured, the volume required, the existing storage and transportation types, and the geographic proximity of the production relative to the end user.

<u>Major Grain Flow Configurations</u>

The path that grain takes in its movement from the farm to the end user can take on many different configurations, depending on the region, the commodity, and the resources of the producer. To facilitate a discussion of future implications to grain handling and transportation, three basic grain flow configurations will be developed. Note that the diagrams are used to illustrate the primary flows of grain for each configuration. Some grain may flow through other paths but most likely in much smaller volumes.

High-Volume Configurations

The high-volume configuration (figure 12) will evolve to handle high-volume throughput, whether that is commodity grain or any other type of grain that moves in large volumes.

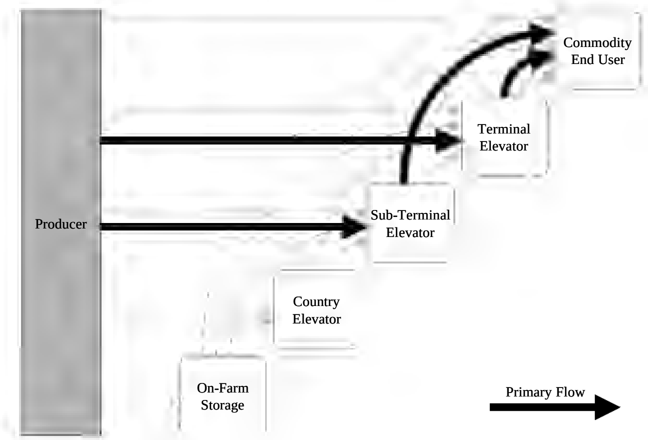

Figure 12

The primary flows will be from the producer to the subterminal and terminal elevators where high-volume flows are accumulated. This will leave the on-farm storage and country elevator storage facilities to handle smaller flow configurations. Note that while this configuration might be handling what would typically be considered "commodity," it is in essence segregated because it must be kept separate from the other flows of grain.

<u>*Implications*</u>

- Producers near these major collection sites will have an incentive to stick with high-volume commodity production.
- End users of specialty crops may locate away from these major collections sites to avoid having to compete for volume.

Medium-Volume Configurations

The medium-volume configuration (figure 13) will handle medium-volume flows that are typically considered segregated channels. Examples of this configuration in today's system are high oil corn or waxy corn.

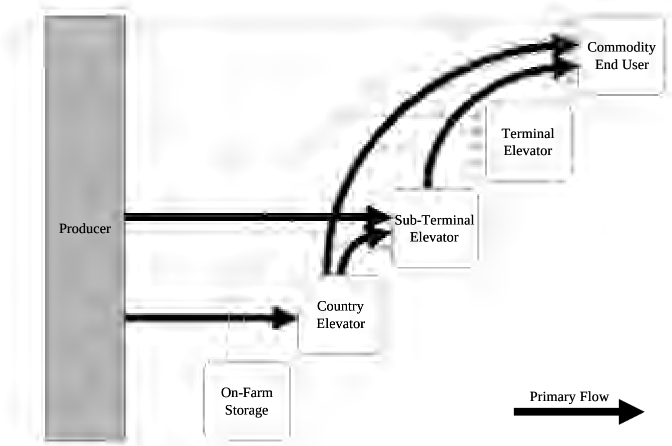

Figure 13

The primary movement from the producer will be to the country elevator and subterminal elevators, which are capable of handling moderate volumes of segregation.

<u>*Implications*</u>

- This will provide an opportunity for producers without on-farm storage to participate in specialty channels.
- Existing elevators will need to reconfigure in order to handle multiple channels.
- Because of limitations in the number of channels that can be handled by the elevators, production "zones" may evolve around elevators that focus on two or three specific types of grain.

Low-Volume Configurations

The low-volume configuration (figure 14) will handle low-volume segregated or IP flows of grain. Most grain flowing through these configurations will reside initially at on-farm storage and then proceed physically to the end user.

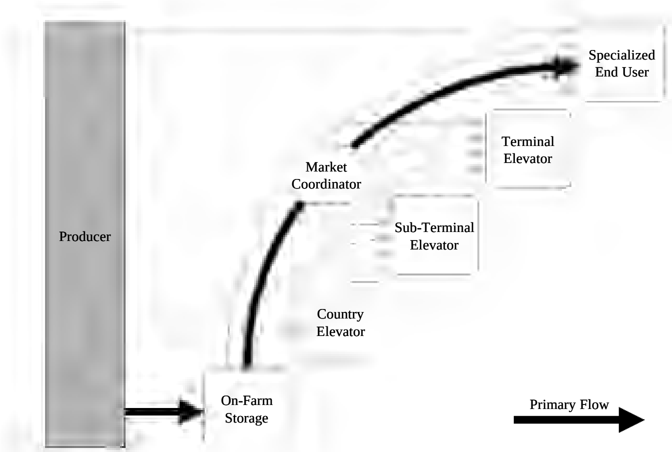

Figure 14

Note that an entity called "Market Coordinator" has been added to this diagram. The role of the party in this function is to coordinate the procurement and delivery of the grain between the producer and the end user. This is a function that is normally handled by the elevators but will need to be handled separately in cases when the producer will be delivering directly to the end user. This function will likely be managed as a business-to-business e-commerce activity.

The market coordination function may evolve at two levels. First is to coordinate physical delivery from the producer directly to the end user. Second is to coordinate the accumulation of grain through existing collection facilities (presumably small country elevators).

Implications

- Producers will generally be near the end user or near an accumulation facility.
- Specialized end users will build their plants (processing or livestock feeding) in areas where growers may be at a transportation disadvantage.

Applicable Transportation Types

In looking at high-, medium-, and low-volume configurations, it is possible to identify which types of transportation might best serve those markets. Table 8 provides some generalizations about how various transportation types might be used in each configuration.

Table 8

	Applicable Modes of Transportation			
Configuration	**Containers**	**Truck**	**Rail**	**Barge**
High Volume	No	Yes	Yes	Yes
Medium Volume	No	Yes	partial trains	limited
Low Volume	Yes	Yes	containers	No

High-volume configurations will likely continue to utilize truck, rail, and barge as their primary modes of transportation. However, geographies typically requiring long haul truck shipments may be some of the first to shift to production of grains that will flow through the medium- and small-volume configurations.

Medium-volume configurations will heavily favor trucks as their primary mode of transportation. In some situations, it may be possible to use partial unit trains to move moderate volumes from one location to the other depending on the storage capacities of the end user. As discussed earlier, even though the annual volume of a particular channel might be sufficient to fill a number of unit trains, the grain is typically required to be delivered in lower volumes to coincide with the storage capacities of the end user.

Low-volume configurations will rely largely on trucks. True IP channels will likely utilize containerized shipping. Depending on the distance of travel, containers could be shipped by truck or loaded onto rail. Export IP channels would likely use containers as well.

Handling and Transportation for Different Market Channels

The following summarizes the considerations for how grain from each market channel might flow in the future.

Vertical Integration: These would be relatively small-volume channels within a closed system.

Configuration Type—Low-volume, integrator serves as the market coordinator.
Storage—Either on-farm or at end user.
Transportation—Primarily truck and containerized.
Testing—Required to facilitate optimal processing as opposed to computing premiums or discounts.

Identity Preserved (IP): This market channel will be important in a future where traceability is important. This channel will likely be subdivided into multiple subchannels.

Configuration Type—Low-volume with market coordinator.
Storage—Primarily on-farm.
Transportation—Truck and containerized.
Testing—At harvest and spot-checked before processing. Very high degree of purity required.
Other—Concentrated production zones will likely emerge around specific end users or export shipping access points.

Specialty: Like many other channels, the handling will be dependent upon the number of subchannels that emerge.

Configuration Type—Hybrid of low/medium-volume simply due to the fact that some farm storage will be required to handle the overall volume if this channel is significant.
Storage—On-farm, country elevators, and subterminal elevators.
Transportation—Truck and rail.
Testing—At delivery and various accumulation/transfer points. Moderate to high degree of purity required.
Other—Assume that the on-farm storage is fully utilized by vertical integration and IP.

Super Commodity: This channel will look much like the specialty channel. Again, the number of subchannels will be the key in determining the handling and transport.

Configuration Type—Low/medium-volume.
Storage—Either on-farm or end user (who might typically be a livestock producer).
Transportation—Truck and rail.
Testing—At delivery. Moderate degree of purity required.
Other—Concentrated production zones will likely emerge around specific end users. Excess production or production that does not make the grade standard will flow into higher volume commodity channels.

Commodity: The configuration of this channel will depend on the gross volume. If it is a high-volume flow, then it will look much more like the traditional flows of commodity today but likely bypassing the smaller storage and origination facilities. On the other hand, if the volume of commodity is reduced to be no larger than some of the other channels, then it will be treated very much like a super commodity.

Configuration Type—Medium/high-volume
Storage—Subterminal and terminal elevators.
Transportation—Truck, rail, and barge if sufficient quantity.
Testing—At delivery and various accumulation/transfer points. Lowest degree of purity required.

While the characteristics of each of these channels are unique, the most important variable is still the relative volume of grain that will flow through each channel. The discussion of the two scenarios in the next section illustrates a range of possible outcomes.

Scenario Analysis

There are many factors pushing the grain and oilseed markets toward specific trait products, but there are many obstacles as well. Although the grain system will likely change in the future, predicting exactly how those changes will occur is nearly impossible. Instead it is useful to look at some potential scenarios of the future. The scenarios presented are not meant to be predictions of the future but, rather, illustrations to help stimulate thinking about the future of the grain industry and the implications of biotechnology.

Each of the scenarios is framed around the timeframes of 5, 10, and 20 years in the future (the years 2005, 2010, and 2020). For each scenario, the expected grain market structure is described for those timeframes as though they had actually occurred. Two future scenarios are explored:

Scenario 1—Dramatic shift caused by biotech traits and demand for traceability

Scenario 2—Gradual change over time through traditional traits

The scenarios fall into the “all versus nothing” approach to looking at the future of biotech. If biotechnology is accepted, it will be accepted broadly, and biotech traits will be used in many applications. If biotechnology is not accepted, public and regulatory pressure, as well as concerns about segmentation, will restrict it from nearly all applications. (As is typical in scenarios, this extreme specification is useful to frame the discussion. This does not mean that a “mixed” future is not possible.) Scenario 1 assumes biotech-enhanced crops will be widely accepted. If they are accepted, a rapid segmentation of the crop market into specific use traits is likely to occur. Scenario 2 assumes that biotech traits are not accepted. Under Scenario 2, gradual segmentation of the market continues with traditional trait development as it has in the past. Table 9 highlights the major background characteristics of the scenarios.

Table 9. Future scenario background summary

Characteristic	Scenario 1 dramatic shift through biotech	Scenario 2 gradual change without biotech
Biotech-enhanced traits	The number of traits explodes.	Developments cease.
Biotech acceptance	Broadly accepted, niches of resistance remain.	Not accepted
Demand for traceability	High, grows quickly	Moderate, grows slowly
Cost of segregation	Low	Moderate
Producer alignment with end users	High	Moderate
Relative value of specialty traits over commodity	High	Moderate

In Scenario 1, (figure 15) the benefits of biotechnology and the demands of the public will be the primary drives pushing the handling and transportation infrastructure to change as fast as possible. Assuming that the specialty and IP channels are further subdivided, this scenario will require radical change to the handling and transportation system.

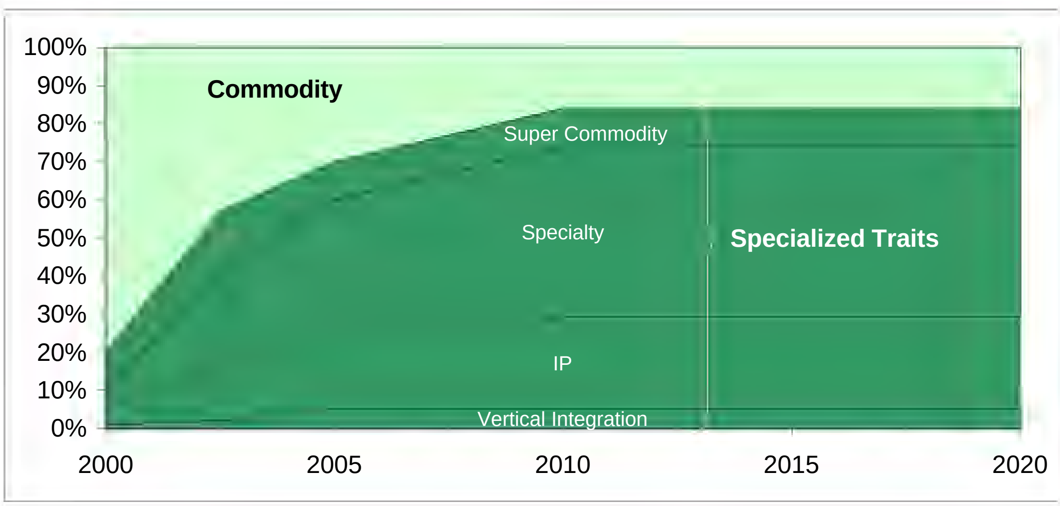

Figure 15. Scenario 1—Dramatic shift caused by biotech traits and demand for traceability

For this scenario to play out, the transportation and handling system will have to be changed dramatically from where it is today. Nearly every channel will push toward the utilization of small to medium grain flow configurations. Taken collectively, this suggests:

- No storage at terminal elevators
- High utilization of on-farm storage
- No barge utilization
- High utilization of trucks

- High utilization of testing
- Pressure to produce specialty grains near the respective end user

Thus, if market pressures (e.g., the value from biotech grains is sufficiently high) drive the industry in this direction, the handling and transportation infrastructure will need to change in the following ways:

- Terminal elevators will need to be able to segregate into at least a few different channels.
- On-farm storage will need to increase.
- Barge transportation must adapt to handle multiple channels, either through coordination (each barge hold has a separate product) or through the use of some type of containerization.
- Trucking capacity must increase.
- Testing methods must be developed that are accurate, fast, and economical and have the confidence of all parties involved.
- End users must strategically locate in areas where they can secure adequate amounts of the specialty grain that they need while having access to outbound transportation for their output.

Scenario 2 (figure 16) ends up at the same place as the first one in terms of the share of the market held by each channel. However, the pace at which the commodity channel is supplanted is considerably slower than in Scenario 1. Therefore, at the end of the period, one could expect similar implications with on-farm storage and truck transport increasing at the expense of large-scale, high-volume, commodity-oriented mechanisms.

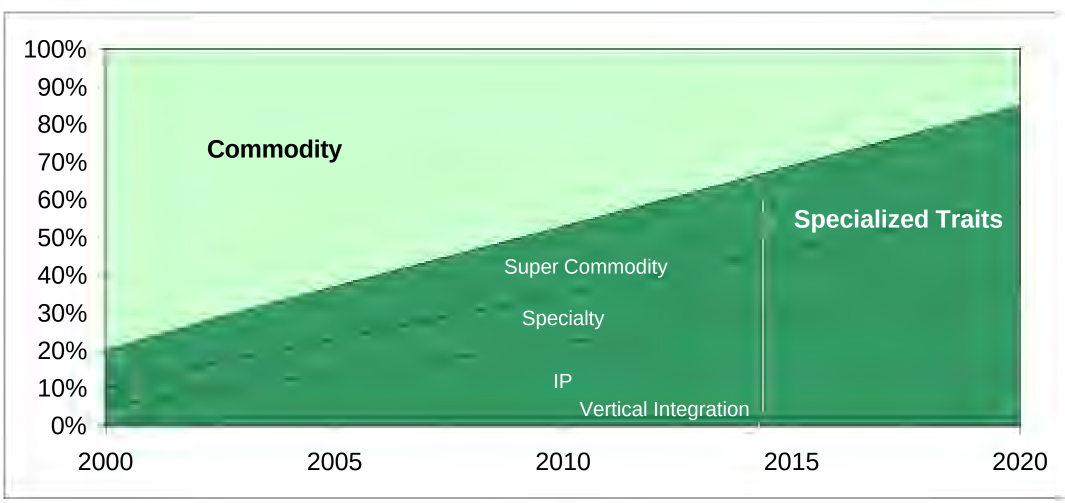

Figure 16. Scenario 2—Gradual change over time through traditional traits

Although transportation, handling, and logistical infrastructures will need to adjust, the speed of change can occur at a moderate pace. As the normal replacement of infrastructure occurs, in combination with advances in technology, systems that can accommodate the more precise requirements of IP, Specialty, and Super Commodity grains will evolve. Regionalized production will emerge around the locales where systems capabilities exist. In contrast with Scenario 1, where infrastructure retarded the pace of change, in Scenario 2, infrastructure investment will, at times, act to lead the evolution in channels.

Resulting Themes

Three key findings can be discerned from the preceding scenario analysis:

- Fundamentally, there is a mismatch between motivations and expectations between investing in biotechnology and investing in transportation, handling, and logistical infrastructure. Yet, if grains and oilseeds with differentiated output traits through biotechnology are to be effectively provided in the marketplace, investment in both activities is essential.

- To effectively produce and deliver grains and oilseeds with differentiated traits to customers, alternative mechanisms are needed which will extend the capabilities of today's commodity market channel. Building upon prior work, a typology of alternative market channels is specified in this report. These alternatives bracket the plausible range of expected needs. The alternative channels are categorized in terms of eight distinguishing characteristics deemed important to industry participants. At least at the conceptual level, it is important to emphasize that each of the alternatives is plausible. Although advances in measurement technology and scale efficiencies would alter the cost effectiveness of the alternatives, each of the five could be implemented today. Therefore, mechanisms do exist (or could be expected to rapidly emerge) by which a whole range of differentiated output could be marketed.

- Because of the uncertainty and turbulence surrounding agricultural biotechnology, scenario analysis was employed to explore the dynamics of potential futures. Results of two scenarios are of particular interest. In Scenario 1, advances in biotechnology drive relatively rapid and substantial change. In Scenario 2, the system moves to the same ultimate endpoint in terms of differentiated output, but the pace of change is relatively slow as biotechnology is presumed not to be a driving force. The dynamics of change are very different in the two settings.

  In Scenario 1, the pressure for a rapid shift to alternative market channels conflicts with investment patterns in transportation, handling, and logistical infrastructure. The presence of existing infrastructure, which is economically viable but not well suited to differentiated output traits, acts to slow the rate of change. One expected result of this conflict would be considerable pressure for biotech stakeholders to establish dedicated vertically coordinated systems outside the existing organizational structures. To optimize these new structures, production of the products with differentiated output are likely to be regionally localized. Therefore, advances in measurement technology may be less of an impediment to change as organizational structures partially substitute for the need for measurement capabilities.

  Conversely the slower pace of change in Scenario 2 allows transportation, handling, and logistical infrastructure to evolve at a rate that is more consistent with the latter entities' normal investment patterns. Indeed investment in transportation, handling, and logistical infrastructure in a particular region may be a force that leads to greater differentiated trait production in that region. The rate at which measurement technology advances will be a larger determinant of the rate of change in this setting, as it will facilitate low-cost transactions in less tightly controlled vertical systems

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