Problems and Opportunities in the Supply Chains of Fresh Agricultural Products

J. Rene Villalobos, Octavio Sanchez, Nicholas Mason, Omar Ahumada

International Logistics and Productivity Improvement Laboratory (ILPIL)

School of Computing, Informatics and Decision Systems Engineering

Arizona State University

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http://ilpil.asu.edu/

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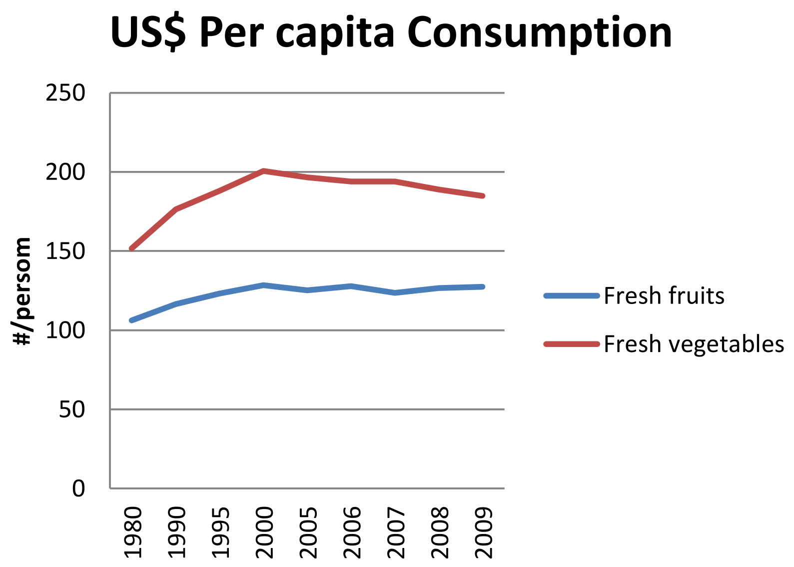
Agenda

- Background
- Trends in the supply chain of fresh fruits and vegetables
- Strategic Planning
- Tactical Planning
- Operational Planning
- Conclusions

Background

- Per capita consumption of fresh produce has increased over 60% in the last 30 years.
- Demand is driven by demographic changes and health concerns (Let's move, farm to school programs).

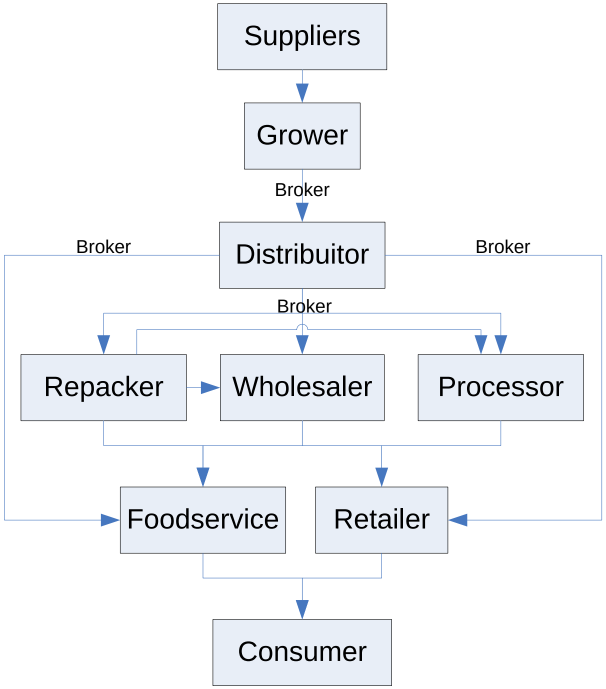
- From Harvard School of Public Health: "...average American gets a total of just three servings of fruits and vegetables a day. The latest dietary guidelines call for five to thirteen servings of fruits and vegetables a day (2½ to 6½ cups per day)"



Source: US Census Bureau

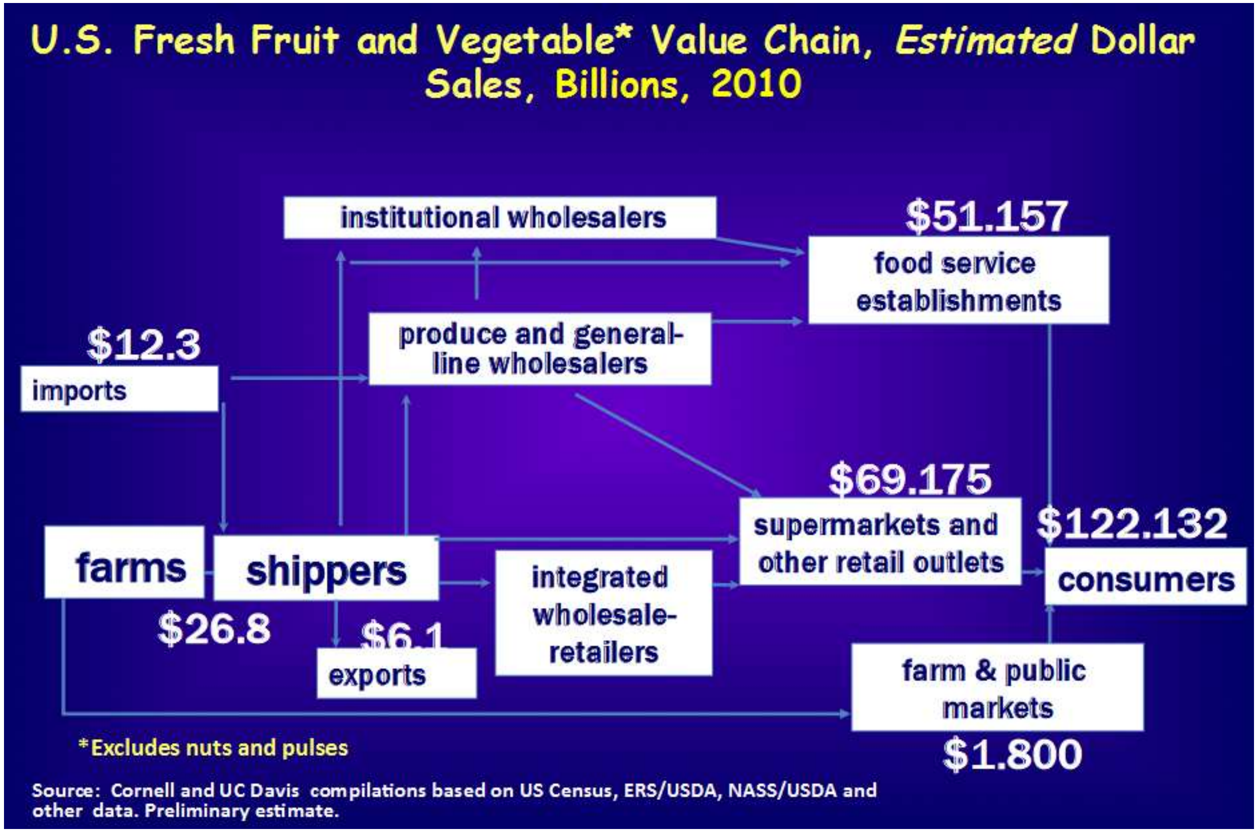
How to deal with fresh supply chain issues?

- Long cycle times, perishability, high variability and other special conditions (temperature controlled, compatibility, marketing practices) make the fresh supply chain very complex→ up to 50% of the product is lost when the product reaches the consumer



- There are many players in the fresh produce SC
- This increases costs and lead time, and reduces flexibility
- The grower has narrow profit margins even though the complete chain doesn't

Supply Chain Value in Year 2010



Taken from: http://agecon.ucdavis.edu/people/faculty/roberta-cook/docs/Articles/ValueChainProduce2010.pdf

The global environment

- Tendencies in the supply chain:
  - **Europe**
    - Greater power of supermarket chains
    - Emphasis on private labels
    - Strategies based on a supply chain collaboration model
  - **Spain**
    - Farmers consolidation through cooperative levels
  - **Holland**
    - Different model, vertically integrated with distributed power
    - Production, marketing and distribution cooperatives play a key role
  - **Chile**
    - Offer consolidation through "exporters"

Trends in the USA

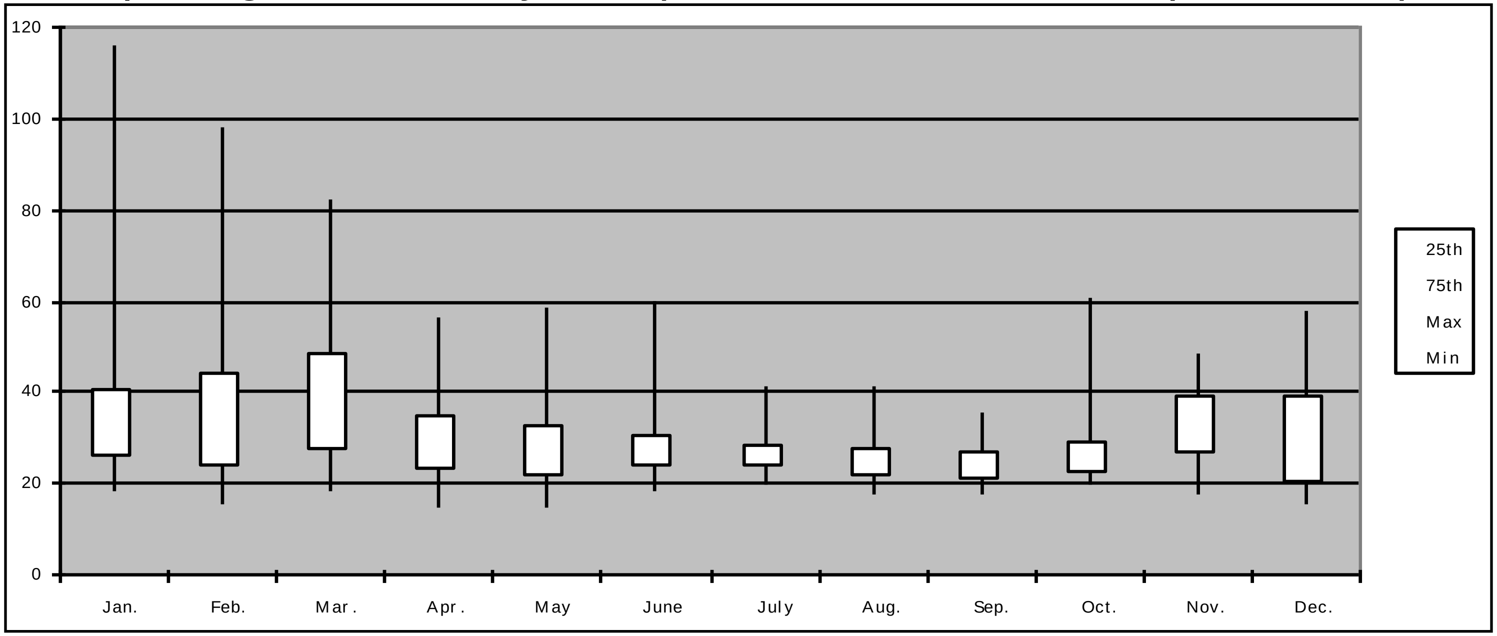
- More direct relationships between the retailers and growers based on year-round supply of products based on contracts
- Integrated grower-retailer planning
- Greater control of the distribution chain by the retailers.
- Elimination of non-added value inefficient intermediaries to better control de cost, quality and traceability of the product
- About to experience some of the trends already experienced in Europe.

The case of Mexico

- Main exporter of fresh agricultural products to the USA
- Main supplier of winter produce to the USA
- Competes directly with Florida in winter tomatoes
- A lot of individual growers that mostly sell their product FOB at the border at reduced market prices
- They withstand most of the variability of the prices, with limited reward to compensate for the additional risk

Tomato prices

Tomato pricing data for 25 years (Min, Max, 25th and 75th percentiles)



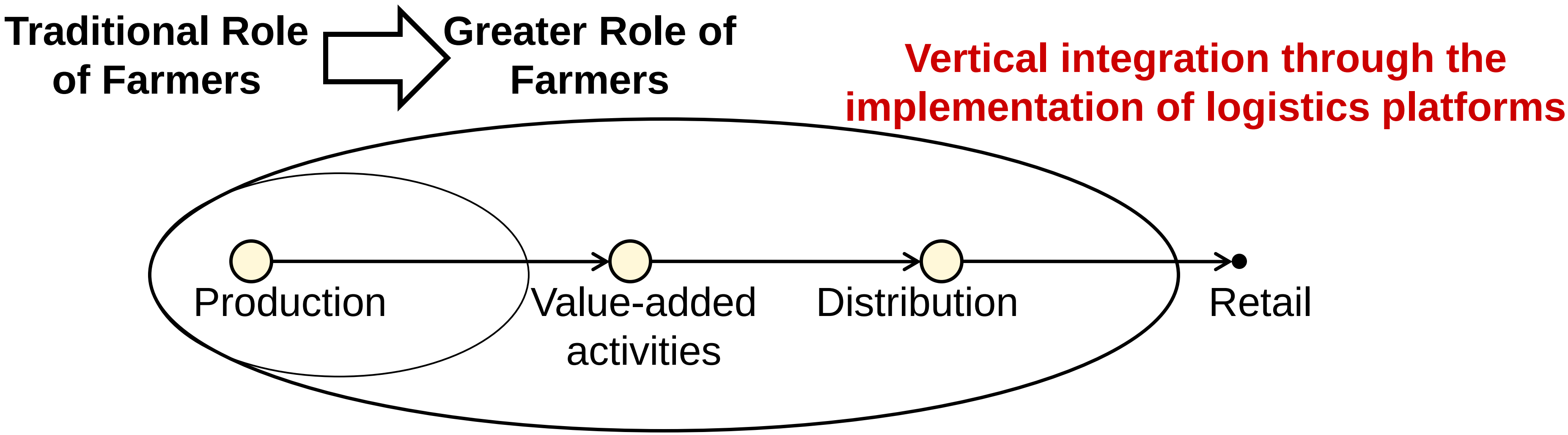
Slide seems a bit out of place

<u>What we have available to make decisions</u>

- Historical distribution of prices (per week)
- Historical distribution of yields (per week)
- Historical and contracted demand from customers

Current FV Market Dynamics and Trends

- Product Value Chain



Strategy:

- Get closer to the end consumer through a **vertical integration**
- **Continuous operations** of value-added and distribution activities

Requirements:

- **High levels of investment** in infrastructure for value-added and distribution operations
- **Market Intelligence**

Description of the Problem

Fresh agricultural planning:

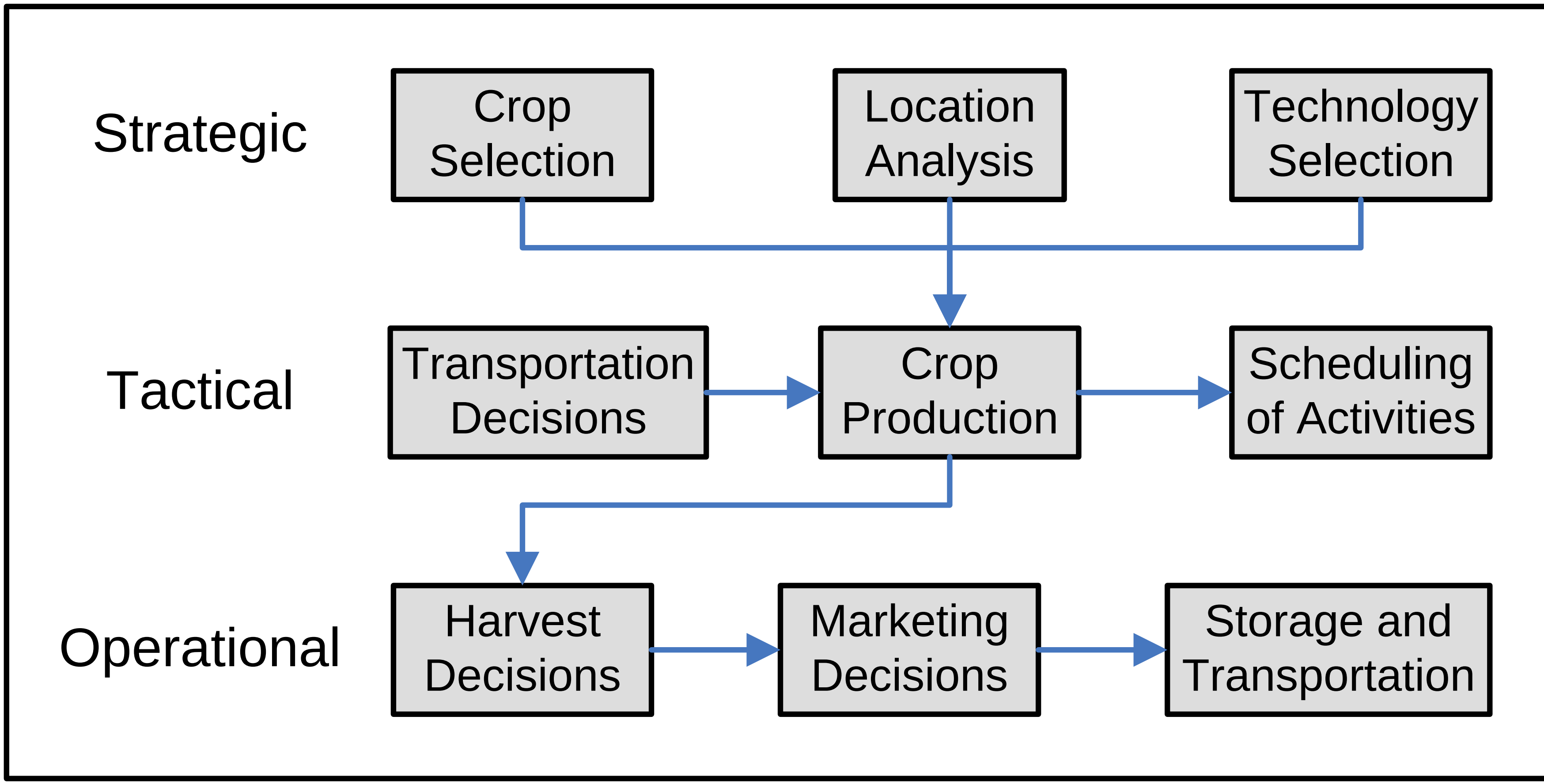
- High production costs
- High labor requirements
- Uncertain yields and demand
- Limited shelf life
- Risky Market
  - Highly variable Price
  - Variable demand
- Decisions are taken before any knowledge of the demand, price and production
- Increased concerns about food safety
- Is there something that we can do to improve the state of the industry? → planning tools

The need to engage in planning

For farmers to advance in the value chain it is necessary to have the infrastructure and underlying planning systems vital for providing services to end customers.

Planning tools are needed at different levels to make the production, consolidation, distribution and marketing of fresh agricultural products more efficient.

Levels of Planning



Projects related to Fresh Supply Chain

Works completed and in Progress

Completed

- Omar Ahumada: Ph.D. Dissertation
- Octavio Sanchez: MS. Thesis
- Hector Flores: MS Thesis
- Liangjie Xue: Ph.D. Dissertation

In Progress:

- Nicholas Mason, Ph.D. student.
- Christopher Wishon, Ph.D. student.
- Hector Flores, Ph.D. student.

Papers to be used in today's discussion

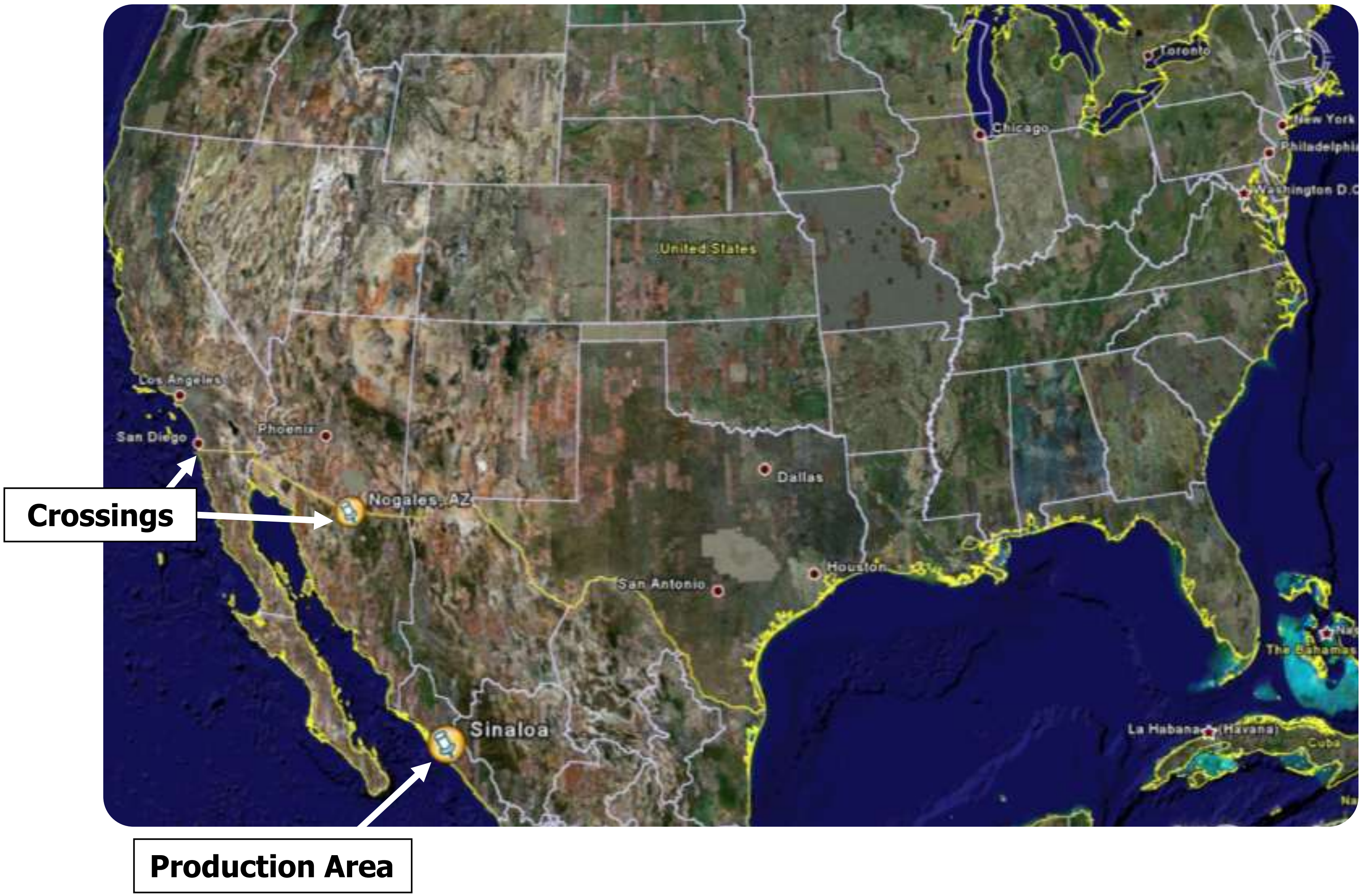
- Ahumada, O., J. Rene Villalobos, "Operational model for planning the harvest and distribution of perishable agricultural products," *International Journal of Production Economics*, Vol. 133,pp. 677–687, 2011.
- Ahumada, O. and J.R. Villalobos, "A Tactical Model for Planning the Production and Distribution of Fresh Produce," *Annals of Operations Research*, DOI: 10.1007/s10479-009-0614-4, Vol. 191, Issue 1, pp. 339–358, 2011.
- Ahumada, O., J.R. Villalobos and A. Mason, "Tactical Planning of the Production and Distribution of Fresh Agricultural Products under Uncertainty," *Agricultural Systems*, Volume 112, pp. 17-26, 2012.
- Flores H. and JR Villalobos, "Using market intelligence for the Opportunistic shipping of Fresh Produce," *Int. J. Production Economics*, Vol. 142, pp. 89–97, 2013.
- Sanchez, O. (2007). *Strategic design of a logistics platform for fresh produce*. Master of Science Thesis, Arizona State University, accessible through http://ilpil.asu.edu

Strategic Planning

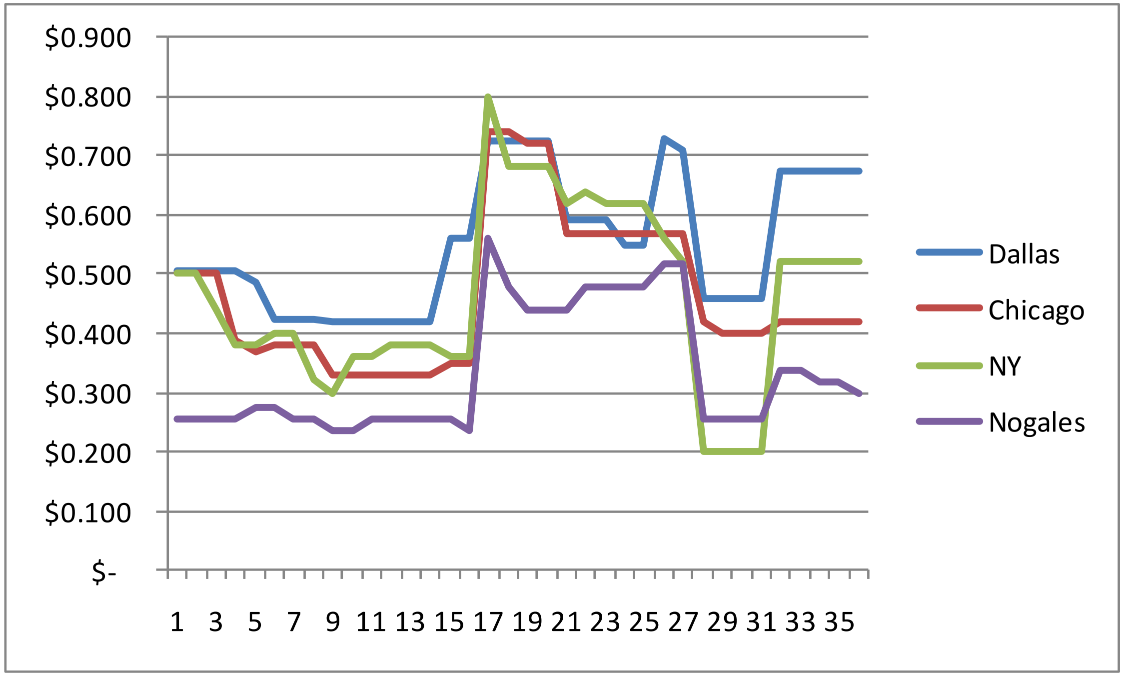
Background and objective

- Around 50% of all fresh tomatoes consumed in the US during the winter are produced in Mexico, in particular in the state of Sinaloa
- Usually the farmers from Sinaloa sell their fresh produce FOB at the border and brokers sell and distribute their product in the US. This practice has been very beneficial for them, but over time they have seen their profit margins reduced.
- Objective: develop strategies for this farmers to take greater control of their distribution/Value Chain
- Main strategy: develop logistics platforms in strategic points of the US to reach the most attractive markets

Map of the area



Wholesale prices comparison



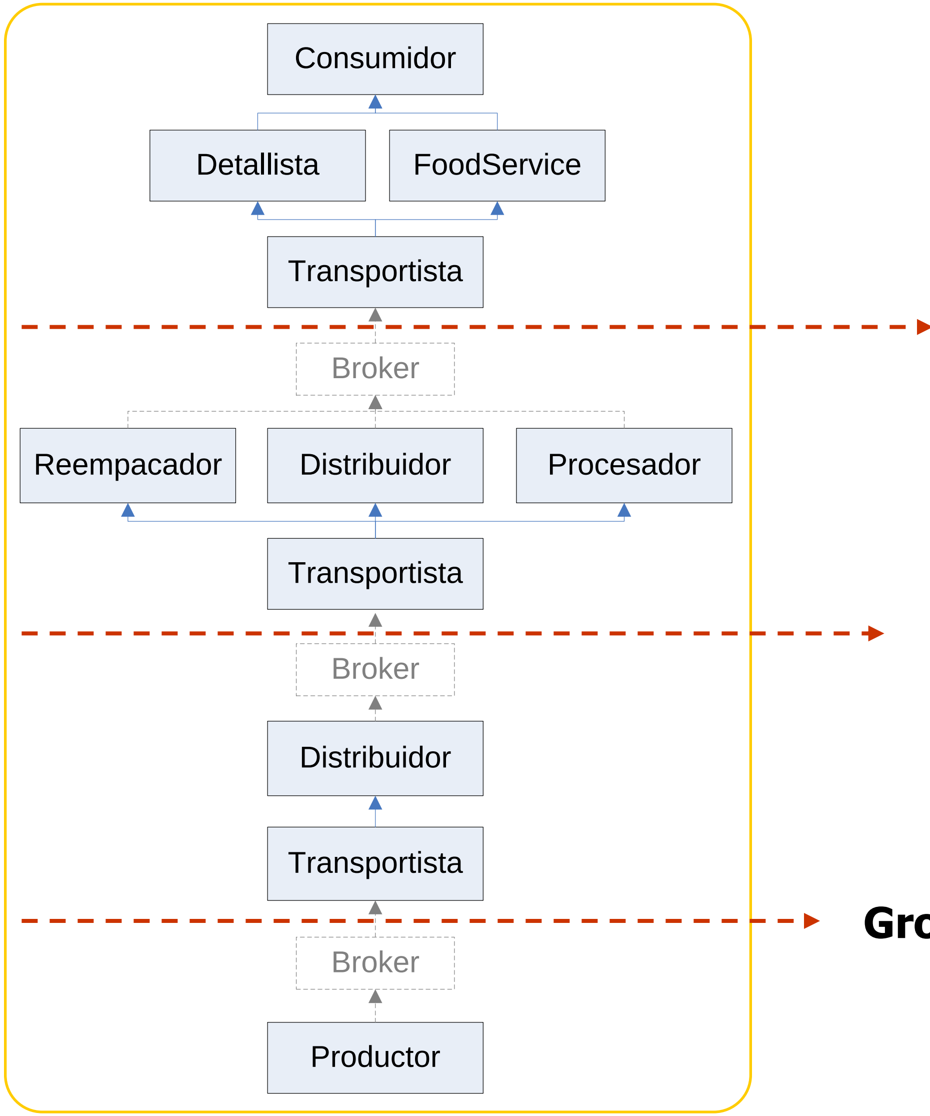
	Dallas	Chicago	NY	Nogales
Average wholesale prices(2009)	0.64	0.54	0.57	0.38
Std. Dev.	0.16	0.15	0.15	0.15
Variation Prices	0.24	0.28	0.26	0.39
Distribution Prices	0.41	0.30	0.33	0
% of destination price	0.59	0.70	0.67	1

Price analysis: Tomato, plum type

Florida					
City	**25 lb Profit**	**53' Truck $**	**Freight**	**Tot Profit**	**Margin**
Los Angeles	$1.60	$3,075.12	$4,792.55	($1,717.43)	-6.45%
Dallas	$3.63	$6,960.51	$2,503.44	$4,457.07	16.74%
Atlanta	$4.38	$8,419.16	$1,488.24	$6,930.93	26.03%
Chicago	$4.45	$8,551.35	$2,579.41	$5,971.94	22.43%
New York	$2.65	$5,086.29	$3,061.76	$2,024.52	7.60%

Nogales					
City	**25 lb Profit**	**53' Truck $**	**Freight**	**Tot Profit**	**Margin**
Los Angeles	$3.73	$7,159.46	$966.43	$6,193.03	27.21%
Dallas	$5.65	$10,840.05	$2,093.00	$8,747.05	**38.44%**
Atlanta	$6.29	$12,074.57	$3,710.00	$8,364.57	36.76%
Chicago	$6.36	$12,207.19	$3,321.00	$8,886.19	**39.05%**
New York	$4.75	$9,126.68	$4,882.14	$4,244.54	18.65%

Example: Level of integration

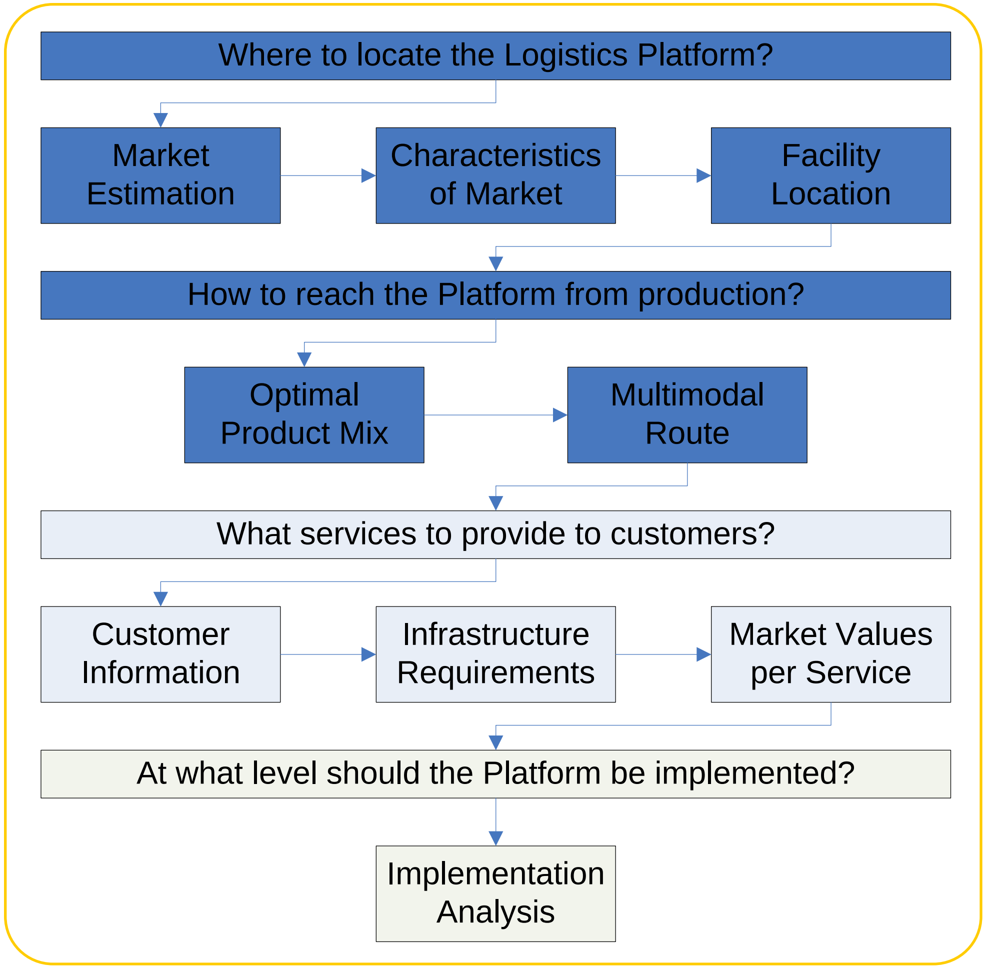


Logistics Platform~ $59.1b
$ - - b

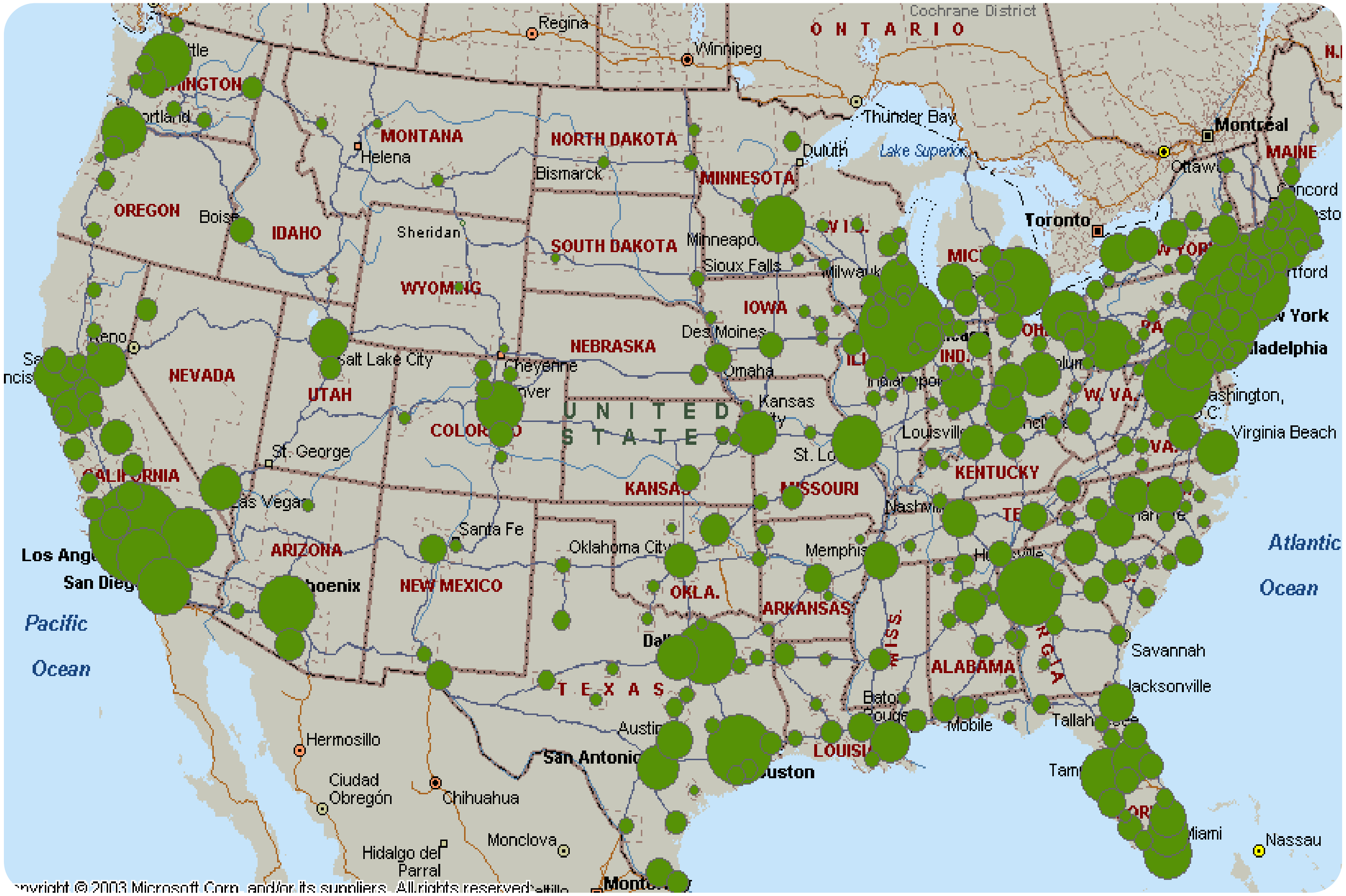
Selling to Distributors~ $28.1b
(-$31.0b)

Growers ~ $20.5b
(-$38.6b)

Methodology



Population Distribution

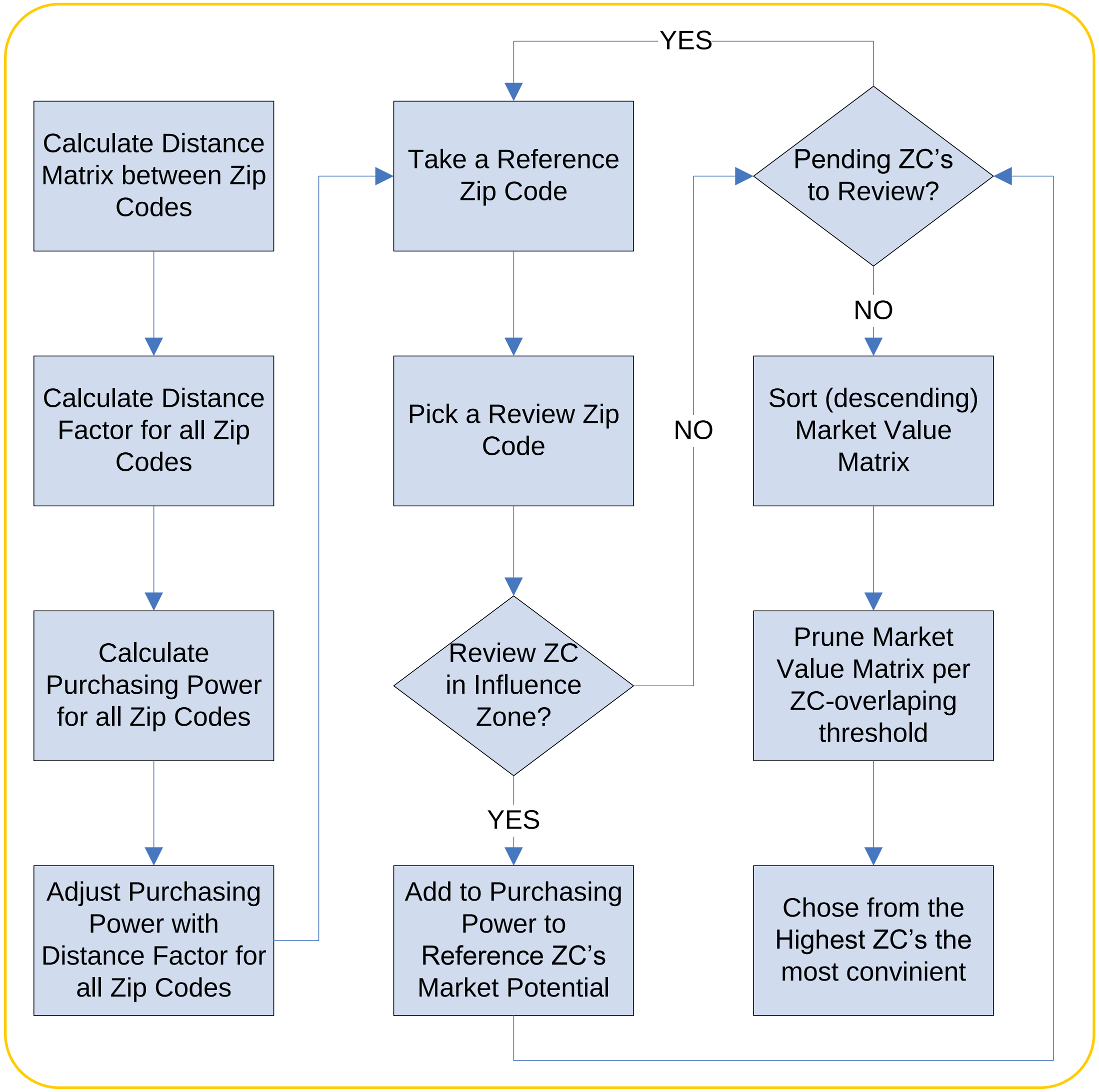


Data Used in Segmentation Analysis

- 3 digit zip codes
- Coordinates:
  - Longitude
  - Latitude
- Population
- Income per capita
- Distance Factor:
  - Percentage difference between Nogales and Miami with any zip code in the USA
- **Market Potential:**
  - **Population x Income per capita x Distance factor x Consumption**

* US Census Bureau

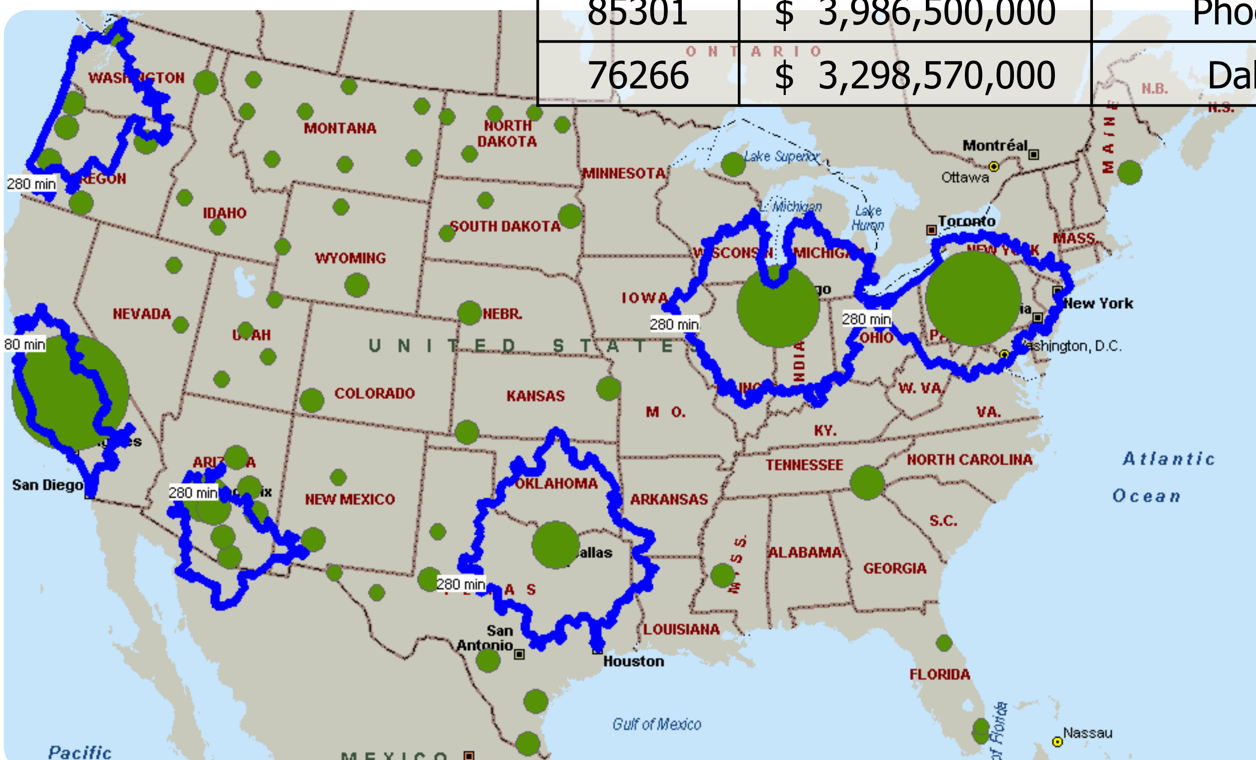
Market Estimation



- Maximal Coverage
  - Maximize Market Potential
- Analysis based on 3dZCs
  - Use Census Information
  - Estimate Market Potential
  - Estimate Influence Zone Size

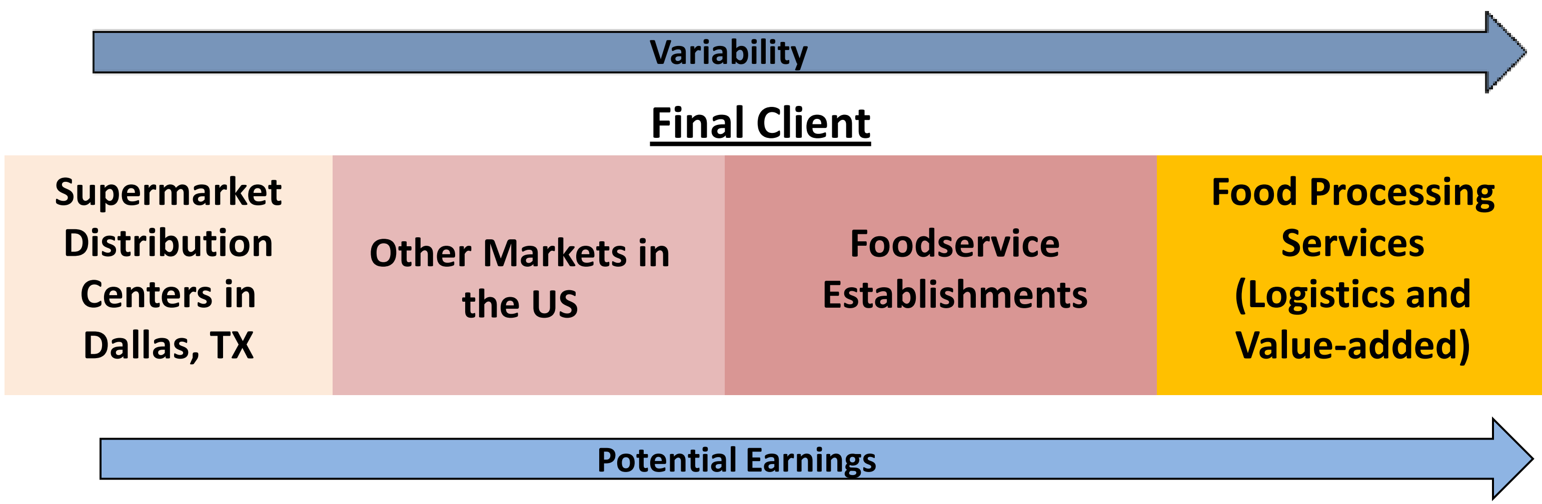
Results: Objective Market

Zip Code	Market Potential	Nearest Metropolis	City, State
93270	$ 8,220,680,000	Los Angeles, CA	Terra Bella, CA
16859	$ 7,102,020,000	New York, NY	Moshannon, PA
46368	$ 5,329,280,000	Chicago, IL	Portage, IN
85301	$ 3,986,500,000	Phoenix, AZ	Glendale, AZ
76266	$ 3,298,570,000	Dallas, TX	Sanger, TX



Logistic Integration

- Implementation sequence of logistics platform



Logistic Integration (MX-Dallas)

Summary or results

- Various implementation strategies were developed based on different platform's integration levels
  - Level of capital investment required for each segment was estimated in terms of infrastructure, service capabilities, and operations size
  - Financial tools were utilized to determine the economic opportunities for each commercialization level
- An implementation sequence plan was developed based on these factors

- How to provide the level of service required by the final market? → year-around production, basket of products, right timing and volume of production ➔ Planning tools

Tactical Planning

Problem

Objective:

Provide vertically integrated producers of perishable products with the planning tools that will allow them to maximize their profits by selling directly to final distributors.

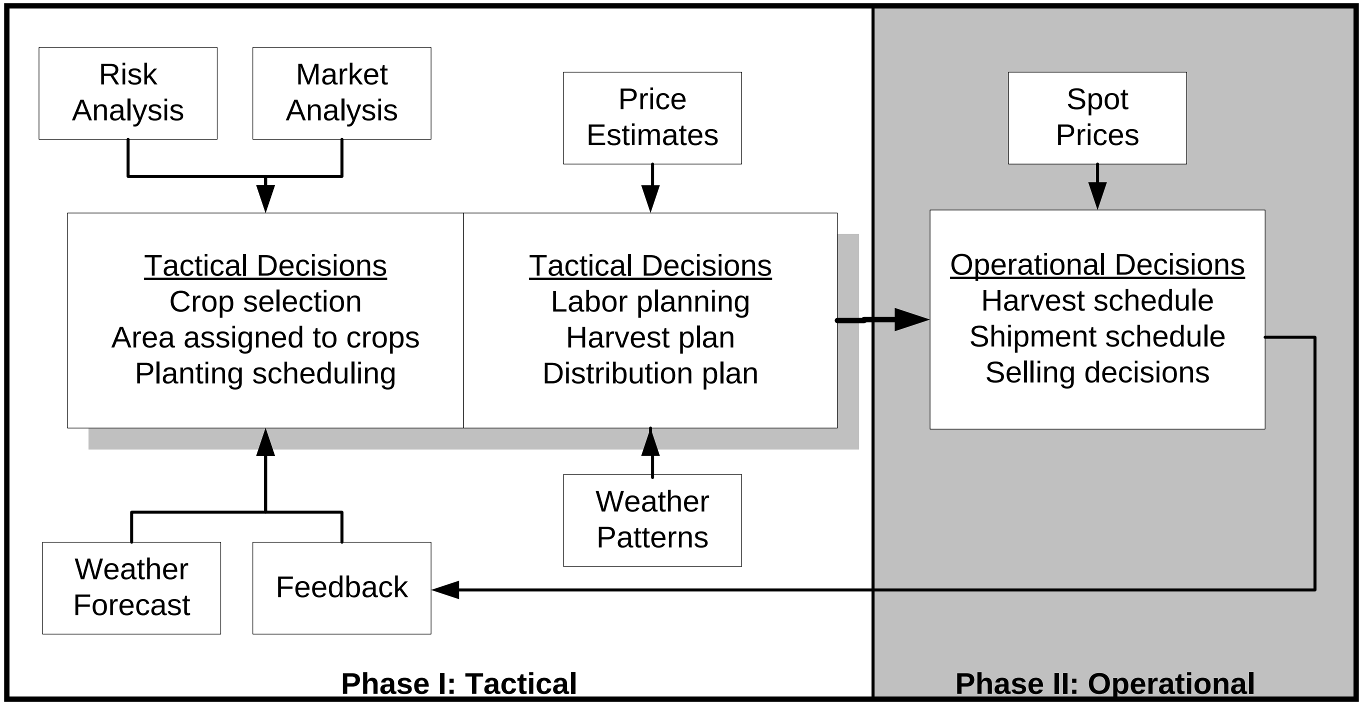
Models Developed

Tactical Model

- How much and when to plant
- Land assigned to each crop
- When to harvest and sale
- Transportation decisions

Operational Model

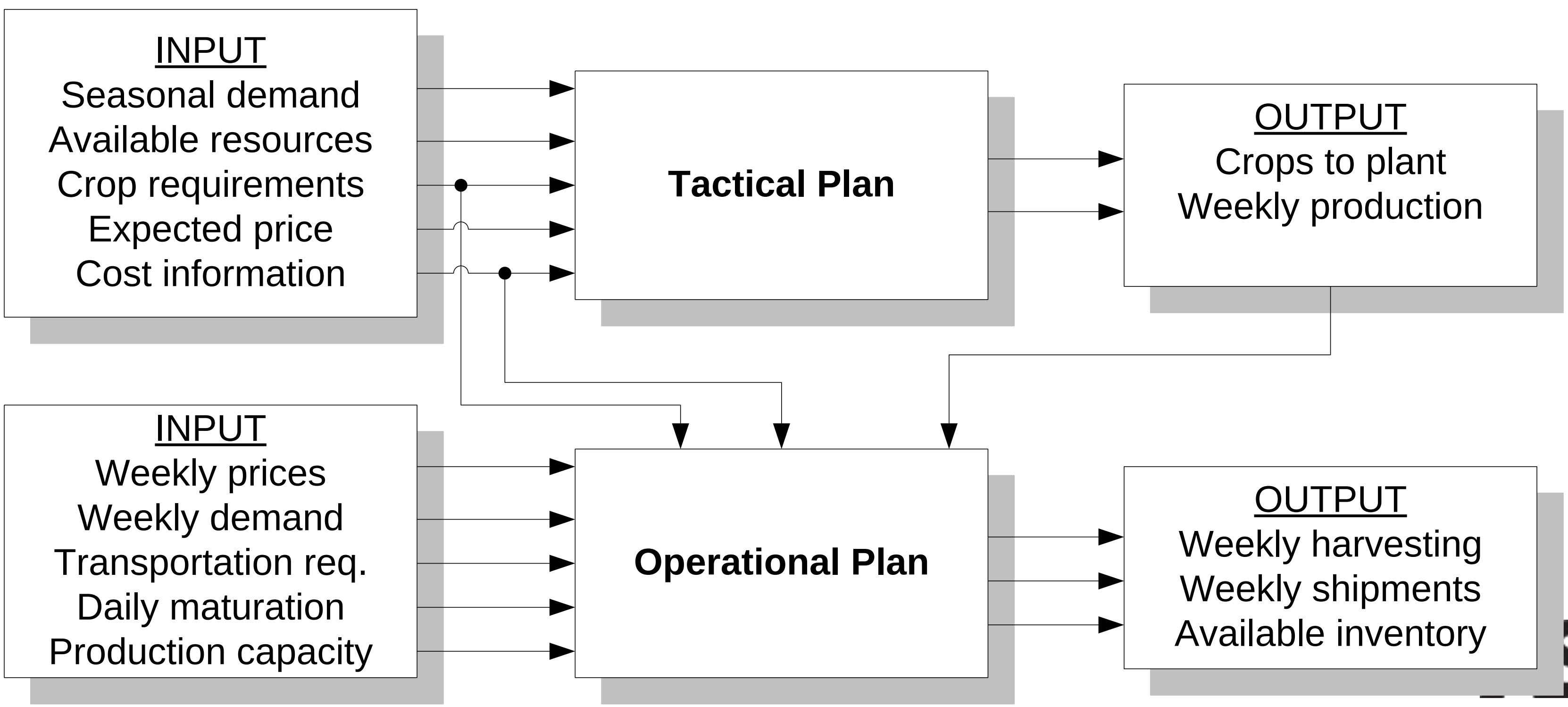
- Harvest schedule
- Schedule of shipments
- Storage and selling decisions
- Transportation decisions



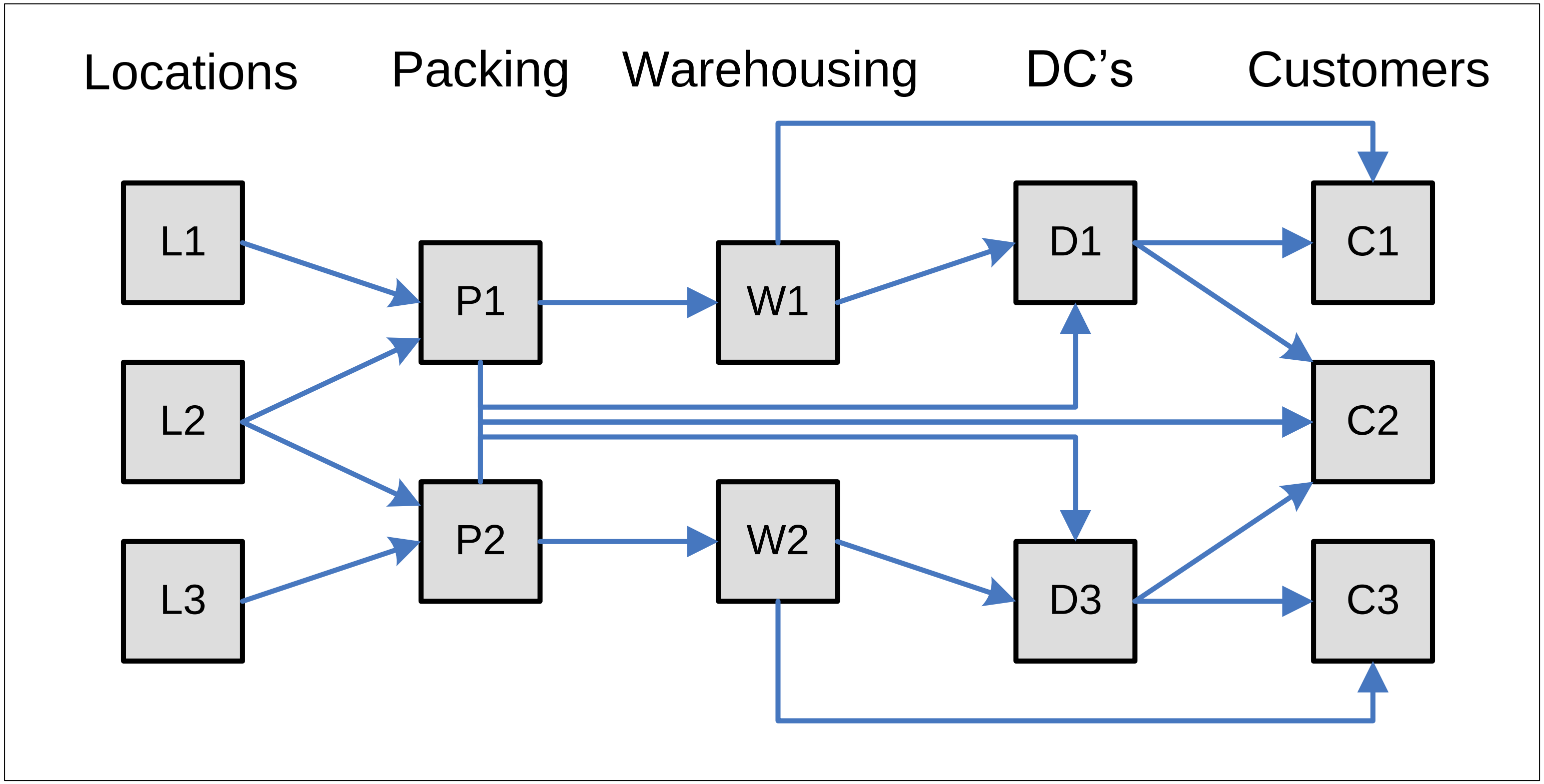
Models Developed

Model interaction

- Use tactical model a few times in the season (multiple planting dates).
- Use the operational model every week during the season harvesting season.
- Use estimated costs of harvest and transportation from operational model in tactical planning



Tactical Model



Sets

$l \in L$	Locations available for planting
$t \in T$	Planning periods (weeks)
$j \in J$	Potential crops and/or varieties to plant
$p \in TP(j, l) \subseteq T$	Feasible planting weeks for crop j in location l
$h \in TH(j, l) \subseteq T$	Feasible harvesting weeks for j in location l
$k \in K(j)$	Products obtained from crop j
$q \in Q$	Quality of crop at harvest (color)
$w \in W$	Warehouses available for storage
$i \in I$	Customers
$d \in D$	Distribution centers
$f \in PF$	Packaging facilities
$r \in TM$	Transportation mode

Sample of Decision Variables

- Area to plant of crop *j*, in period *p* at location *l* (in hectares)
- Harvest (pounds) of crop *j* in period *h* and planted in period *p* at location *l*
- Quantity of product *k* with color *q* packed at facility *f* in period *h* (in boxes)
- Seasonal laborers required at location *l* and time *t* (men-week)
- Operator hours allocated at facility *f* and harvest time *h*
- Number of workers hired at period *t* in location *l*
- Number of workers terminated at period *t* in location *l*
- Number of temporal laborers hired at period *t* in location *l* (menweek)
- Pounds of crop *j* to ship from location *l* to facility *f* in period *h*

Sample of Parameters

- Water required per acre of crop *j* in cubic meters
- Land available at location *l* (in hectares)
- Capacity of facilities *w* (in pallets)
- Shelf life of product *k* (in weeks)
- Required lead time by customer *i* (in weeks)
- Workers required at period *t* for cultivating/harvesting crop *j* planted at period *p* (men-week/Ha)
- Man-hours required for packing a box of product *k*
- Yield of crop *j* planted in location *l* at time *p* and harvested in week *h* (percentage of total)
- Total production of crop *j* planted in location *l* at time *p* (pounds per hectare)
- *Prodphjk* Percentage of product *k* from crop planted in location *l* at time *p*

Description of the Problem

		Harvest by week																																
		November				December				January				February				March				April				May				June				
Date of Plant	Production	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	%
15-Aug	1,662			5	5	10	10	10	10	9	9	8	8	8	8																			100
30-Aug	1,828					5	5	10	10	10	10	9	9	8	8	8	8																	100
14-Sep	2,373					5	5	6	10	10	10	10	10	9	9	8	8																	100
29-Sep	2,564							5	5	10	10	10	10	9	9	8	8	8	8															100
14-Oct	2,698									5	5	10	10	10	10	9	9	8	8	8	8													100
29-Oct	2,684											5	5	10	10	10	10	9	9	8	8	8	8											100
13-Nov	2,896													5	5	10	10	10	10	9	9	8	8	8	8									100
28-Nov	2,837															5	5	10	10	10	10	9	9	8	8	8	8							100
13-Dec	2,337															5	5	10	10	10	10	9	9	8	8	8	8							100
28-Dec	2,183																	5	6	10	20	22	10	8	7	6	6							100
12-Jan	1,794																			4	5	10	15	22	10	9	9	8	8					100
27-Jan	1,385																					7	7	13	13	18	18	9	9	4	2			100
11-Feb	1,200																					7	7	21	21	15	15	5	4	3	2			100
26-Feb	948																							6	6	16	17	12	12	8	8	8	7	100

Model Objective and Variables

Objective:

$$Max = \sum_{tki}(\sum_{f} SC_{tkfir} + \sum_{h}\sum_{w} SW_{htkwir} + \sum_{h}\sum_{d} SD_{htkdir}) \cdot price_{tki} + \sum_{hj} SK_{hj} Psalv_{j}$$ **Revenue**

$$- \sum_{pjl} Plant_{pjl} Cplant_{jl} - \sum_{pjl} Opl_{tl} \cdot CLabor - \sum_{tl} Hire_{tl} \cdot Chire - \sum_{tl} Opt_{tl} \cdot Ctemp$$

$$- \sum_{tf} Opf_{tf} Chire - \sum_{tkw} Z_{tkw} \cdot Pavg_{tk} - \sum_{fhk} Pack_{hfk}(Ccase_{k} + Coper_{k})$$ **Production**

$$- \sum_{tkw} Invw_{tkw} Chw_{kw} - \sum_{tkd} Invd_{tkd} Chd_{kd}$$ **Holding**

$$- \sum_{tkqfir} SC_{tkqfir} CT_{fir} - \sum_{htkqwir} SW_{htkqwir} CTW_{wir} - \sum_{htkqdir} SD_{htkqdir} CTD_{dir}$$

$$- \sum_{htkqfdr} SPD_{htkqfdr} CTPD_{fdr} - \sum_{htkqwdr} SWD_{htkqwdr} CTWD_{wdr} - \sum_{htkqfwr} SPW_{htkqfwr} CTPW_{fwr}$$ **Transportation**

$$- \sum_{tkqfir} SC_{tkqfir} price_{tki} Time_{fir} / SL_{k} - \sum_{htkqwir} SW_{htkqwir} price_{tki} TimeW_{wir} / SL_{k}$$ **Perishable**

Decision Variables:

$Plant_{pjl}$ **: Area to plant of crop *j*, in period *p* at location *l***

SW_{htkwi}**: Qty of product *k* in period *h* shipped from warehouse *w* to customer *i* in period *t***

SC_{tkfi} **: Quantity of product *k* to ship directly to customer *i* from facility *f* in period *t***

SD_{htkdi} **: Quantity of product *k* in period *h* to ship to DC *d* from facility *f* in period *t***

Model Constraints

Production Subproblem:

$$\sum_j \sum_p Plant_{pjl} \le LA_l$$

$$Min_j \cdot Y_{jp} \le Plant_{pjl} \le Max_j \cdot Y_{jp}$$

Minimum and maximum to plant

$$Hire_{tl} + Fire_{tl} = Opl_{tl} - Opl_{t-1l}$$

$$Hire_{t_m l} + Opl_{t_m - 1l} \ge Opl_{tl}$$

$$Opl_{tl} + Opt_{tl} \ge \sum_{pj} Plant_{pjl} \cdot LabP_{ptj} + \sum_{pjl} Harvest_{phjl} \cdot LabH_{phj}$$

Labor planning

$$Harvest_{phjl} = Plant_{pjl} \cdot Yield_{phjl} \cdot Total_{pjl}$$

$$Pack_{hkqf} = Col_{hkq} \sum_{phjk} Harvest_{phjlf}(1 - Salv_{phjl}) \cdot Pod_{phjk} / Weight_k$$

Expected yield

Distribution Subproblem:

$$Pack_{hkqf} = \sum_i SC_{t_1kqfir} + \sum_d SPD_{ht_2kqfdr} + \sum_w SPW_{ht_3kqfwr}$$

$$\sum_f SC_{tkqfir} + \sum_h \sum_w SW_{htkqwir} + \sum_h \sum_d SD_{htkqdir} = Dem_{tki}$$

all t,k,i, where $t \le h \le t - SL_k$ and $q \le Q\max_i$

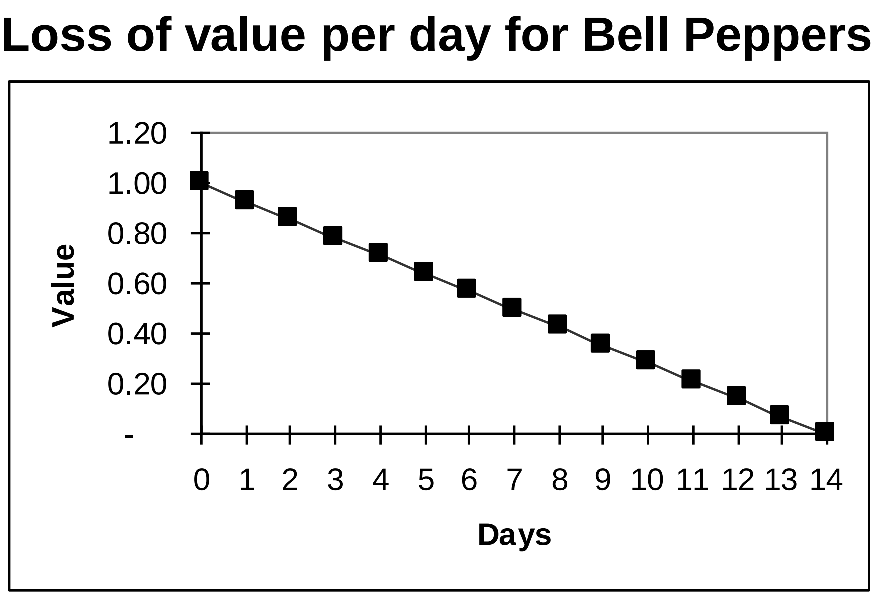
Meeting demand and quality conditions

Case study

Transportation Assumptions:

- There are 3 modes of transportation available: Truck Rail and Air
- The value of the product decays linearly with the elapsed transportation time.
- The cost of transportation increases linearly with the boxes of product shipped

FAC	CUST	TRANS	Time	T1	CT
P1	CH	TM1	0.71	1	$2.30
P1	CH	TM2	0.14	-	$35.42
P1	CH	TM3	1.00	1	$1.25
P1	CN	TM1	0.17	-	$3.12
P1	CN	TM2	0.14	-	$36.70
P1	CN	TM3	0.43	-	$1.75
P1	CL	TM1	0.43	-	1.07604
P1	CL	TM2	0.14	-	25.5208
P1	CL	TM3	0.57	1	0.809
P2	CH	TM1	0.71	1	$2.30
P2	CH	TM2	0.14	-	$35.42
P2	CH	TM3	1.00	1	$1.25
P2	CN	TM1	0.29	-	$3.12
P2	CN	TM2	0.14	-	$36.70
P2	CN	TM3	0.43	-	$1.75
P2	CL	TM1	0.43	-	1.07604
P2	CL	TM2	0.14	-	25.5208
P2	CL	TM3	0.57	1	0.809



Data for Case Study

	Yield per Week											
Crop	1	2	3	4	5	6	7	8	9	10	11	Total
A	0.01	0.07	0.17	0.17	0.20	0.04	0.10	0.05	0.07	0.04	0.08	1.00
B	0.02	0.10	0.21	0.07	0.14	0.09	0.11	0.03	0.05	0.05	0.12	1.00
C	0.01	0.06	0.18	0.13	0.13	0.08	0.14	0.04	0.05	0.12	0.08	1.00
D	0.01	0.05	0.13	0.20	0.13	0.06	0.10	0.04	0.04	0.13	0.11	1.00

	Boxes of Tomato Harvested								
Crop	4X4	4X5	5X5	5X6	6X6	6X7	Total	2nd Class	Salvage
A	1,201	1,840	815	571	86	29	4,542	3,959	503
B	767	1,400	1,639	1,504	223	44	5,577	4,300	654
C	723	1,389	1,722	1,790	347	66	6,037	3,457	654
D	130	683	1,454	2,754	1,050	360	6,431	2,834	602

Year	TA4X4	TA4X5	TA5X5	TA5X6
1998	9.86	9.87	8.49	7.59
1999	7.71	7.71	6.59	5.93
2000	7.87	7.87	6.82	6.36
2001	9.54	9.54	7.59	6.73
2002	10.85	10.85	8.78	7.74
2003	10.01	9.93	8.40	7.71
2004	11.05	11.05	9.58	8.54
2005	13.40	13.40	11.55	10.61
Average	10.01	10.00	8.45	7.62

Labor Planning

Personnel:

- The model requires the maximum amount of personnel available.
- For the case study two types of laborers are assumed: Seasonal and Temporal.
- Seasonal laborers are hired until the end of the season.
- Temporal laborers are hired according to the needs of the growers, one day at a time.
- Seasonal laborers require housing and a minimum of work assured (hours per day).

Week	Seasonal	Temporal	Total
1	78	4	82
2	78	0	78
3	242	0	242
4	249	61	310
5	249	86	335
6	249	0	249
7	268	109	377
8	268	59	327
9	268	27	295
10	268	0	268
11	418	0	418
12	440	36	476
13	440	0	440
14	441	0	441
15	716	0	716
16	800	2	802
17	800	126	926
18	800	200	1000
19	800	200	1000
20	800	171	971
21	800	200	1000
22	800	65	865
23	800	0	800
24	800	172	972
25	800	200	1000
26	800	58	858
27	800	27	827

Computational Results

J	T	TP	TH	I	Row	Col	Non	Binary	Trans Mode	Abs	Time
8	30	8	15	3	64,106	71,242	233,055	12,304	Y	0.00%	42
8	30	8	16	100	22,134	123,088	311,129	39,776	Y	0.01%	58
8	40	18	26	3	9,639	40,384	124,379	15,424	N	0.01%	73
8	40	18	26	3	112,173	124,766	420,393	20,304	Y	0.01%	970
8	40	18	26	100	29,016	136,682	359,299	60,407	N	1.70%	3,600
8	40	18	26	100	29,016	136,682	359,299	60,405	N	0.01%	2,625
35	40	18	26	3	126,497	145,912	590,888	20,790	Y	3.30%	3,600
35	40	18	26	3	25,222	77,162	319,583	19,510	N	2.80%	3,600
35	40	18	26	3	25,222	77,162	319,583	19,510	N	1.10%	3,600
35	40	18	26	100	44,271	184,814	561,660	60,893	N	0.01%	3,299

Results

Planting schedule:

	Deterministic	
Week	Peppers	Tomato
1	28.02	-
2	-	-
3	-	113.66
4	-	20.00
5	-	-
6	-	28.84
7	21.67	24.15
8	-	-
9	-	-
10	-	-
11	-	84.64
12	23.45	-
13	-	46.63
14	-	-
15	-	-
16	20.00	-
17	-	-
18	-	88.95
	93.14	406.86

Results of Tactical Model

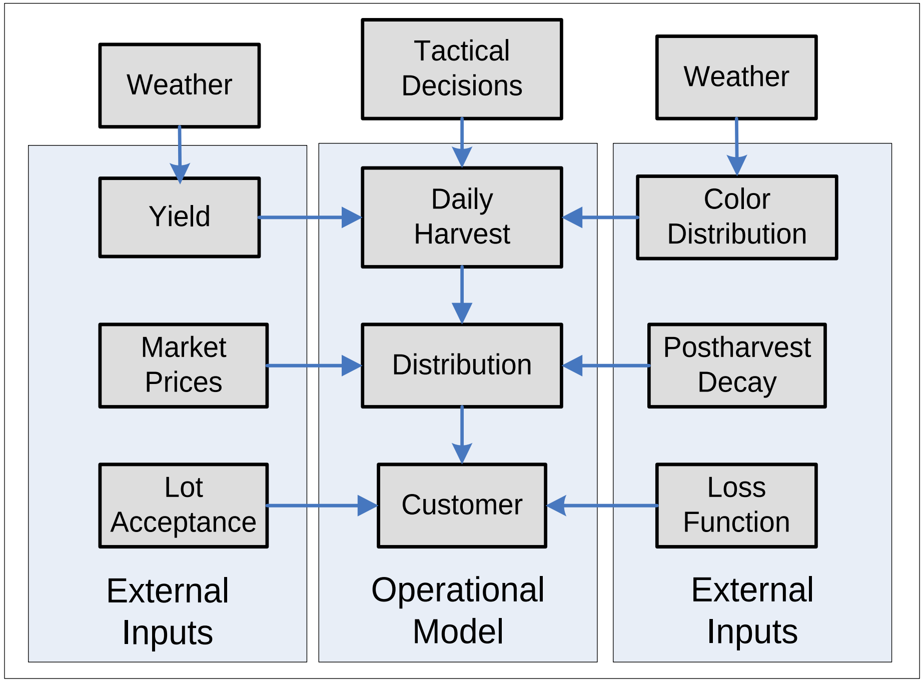
- Using the model just for planning production without considering direct distribution of crops the profits increase by 6%. This comes mainly from increased estimated revenues.
- If on the other hand the proposed direct delivery of products to the terminal markets is implemented, then there is a 25% increase in profits.
- The proposed model could be used by grower-shippers that have contracted sales of product (Volume and/or price) for the whole season.

Operational Planning

Operational Model

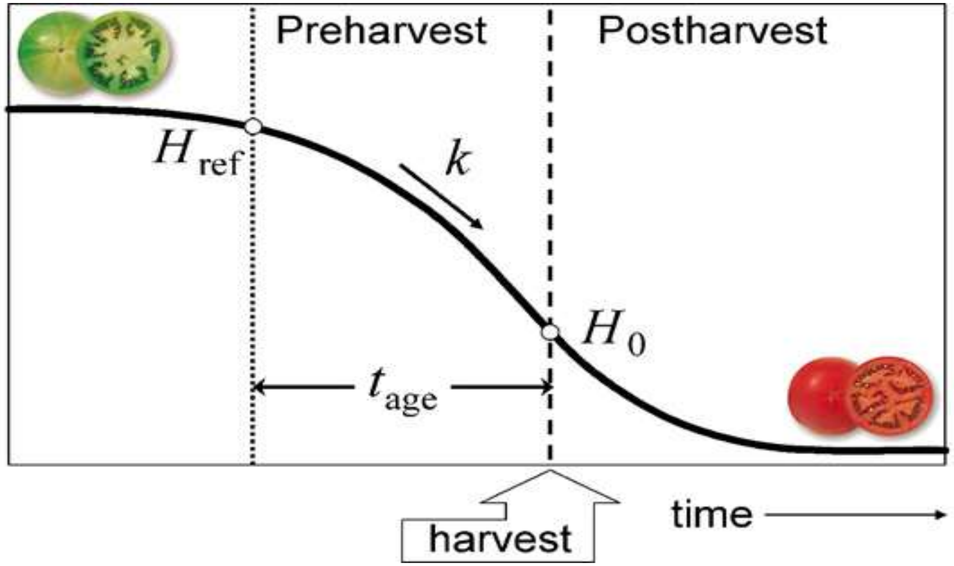
- YTiming and quantity of crops is already defined.
- Quantity of laborers available for harvest and production is also known.
- The capacity at the packing plants, warehouses and DC's and the costs of transportation are also known.

- Using all this information it is possible to determine the harvesting policies for the coming weeks.
- Based in the data and remaining shelf life, determine the best way to ship and distribute the harvested products.



Tomato Maturity

- The operational model uses a tomato color function developed by Hertog (2002).
- This function is used to estimate the maturity of preharvest and postharvest tomato fruit:

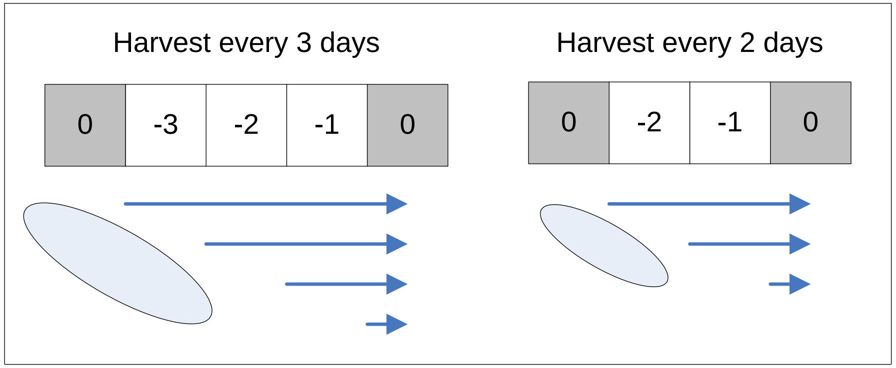


k: Rate of change (Temp).
t: Time (days)
Ho: Initial color of tomatoes
H(t): Expected color at day t.
Hmax: Maximum color achieved at maturity
Hmin: Minimum color at mature green stage

$$H(t) = Hmax + \frac{Hmin - Hmax}{1 + \frac{e^{kt(Hmin-Hmax)}(Hmin - Ho)}{(Ho - Hmax)}}$$

Tomato Maturity

- Expected distribution of tomato colors at different harvesting patterns.
- This table presents two examples of expected color distribution for different harvesting patterns (1-4 days). At two different weeks during the harvest season.



1a January 20°C

Day	Crop	Color	%
1	TA	2	1.00
1	TA	3	0.00
1	TA	4	0.00
1	TA	5	0.00
2	TA	2	0.57
2	TA	3	0.43
2	TA	4	0.00
2	TA	5	0.00
3	TA	2	0.39
3	TA	3	0.39
3	TA	4	0.21
3	TA	5	0.00
4	TA	2	0.33
4	TA	3	0.33
4	TA	4	0.33
4	TA	5	0.02

1a March 22°C

Day	Crop	Color	%
1	TA	2	0.77
1	TA	3	0.23
1	TA	4	0.00
1	TA	5	0.00
2	TA	2	0.41
2	TA	3	0.41
2	TA	4	0.18
2	TA	5	0.00
3	TA	2	0.32
3	TA	3	0.32
3	TA	4	0.32
3	TA	5	0.05
4	TA	2	0.28
4	TA	3	0.28
4	TA	4	0.28
4	TA	5	0.17

Operational Model

	Day											
	1	2	3	4	5	6	7	8	9	10	11	12
Pattern	Mo	Tu	We	Th	Fr	Sa	Mo	Tu	We	Th	Fr	Sa
I	1	1	1	1	1	1	1	1	1	1	1	1
II	1	0	1	0	1	0	1	0	1	0	1	0
III	1	0	0	1	0	0	1	0	0	1	0	0
IV	1	0	0	0	1	0	0	0	1	0	0	0

- These are the current harvesting patterns followed by the growers for Peppers and Tomatoes.
- The planning horizon is two weeks. This simplifies the patterns and is consistent with short term planning.
- The patterns can be selected for individual plots, so the selection of the patterns provide harvest plans with detailed information for each day.

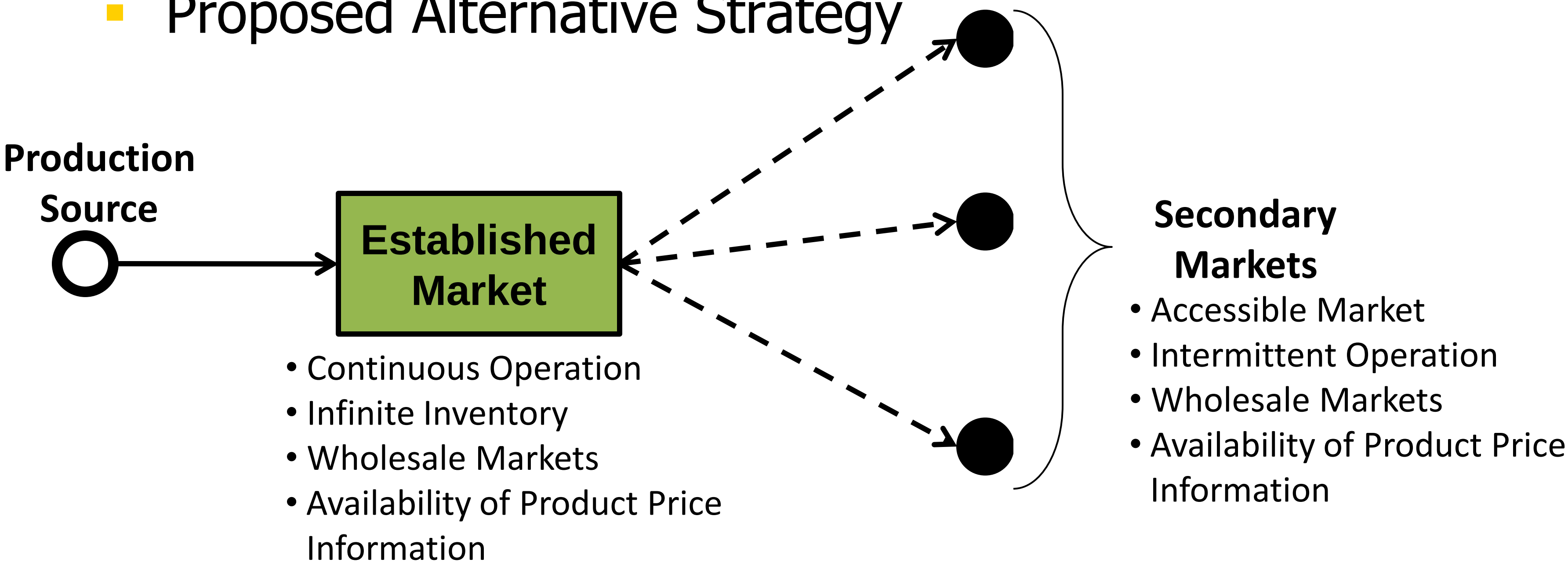
Conclusions

- The research presented is only the start of a plan to develop better planning tools for the supply chain of fresh agricultural products.
- We have already developed stochastic planning models and market analytics operational models
- We have also modified the models for the tactical planning of H2A visas.
- Other topics: incorporation of biological models, application of models to biomass/energy production, farms to school production, food hubs strategy design, food deserts, market analytics.

Other Research Projects

Market Intelligence and Arbitrage

- Proposed Alternative Strategy



<u>Strategy:</u>

- Use the **volatility** of the fresh produce markets **as an advantage**
- **Intermittent shipments** from base to secondary market whenever an **arbitrage opportunity** is identified

<u>Requirements:</u>

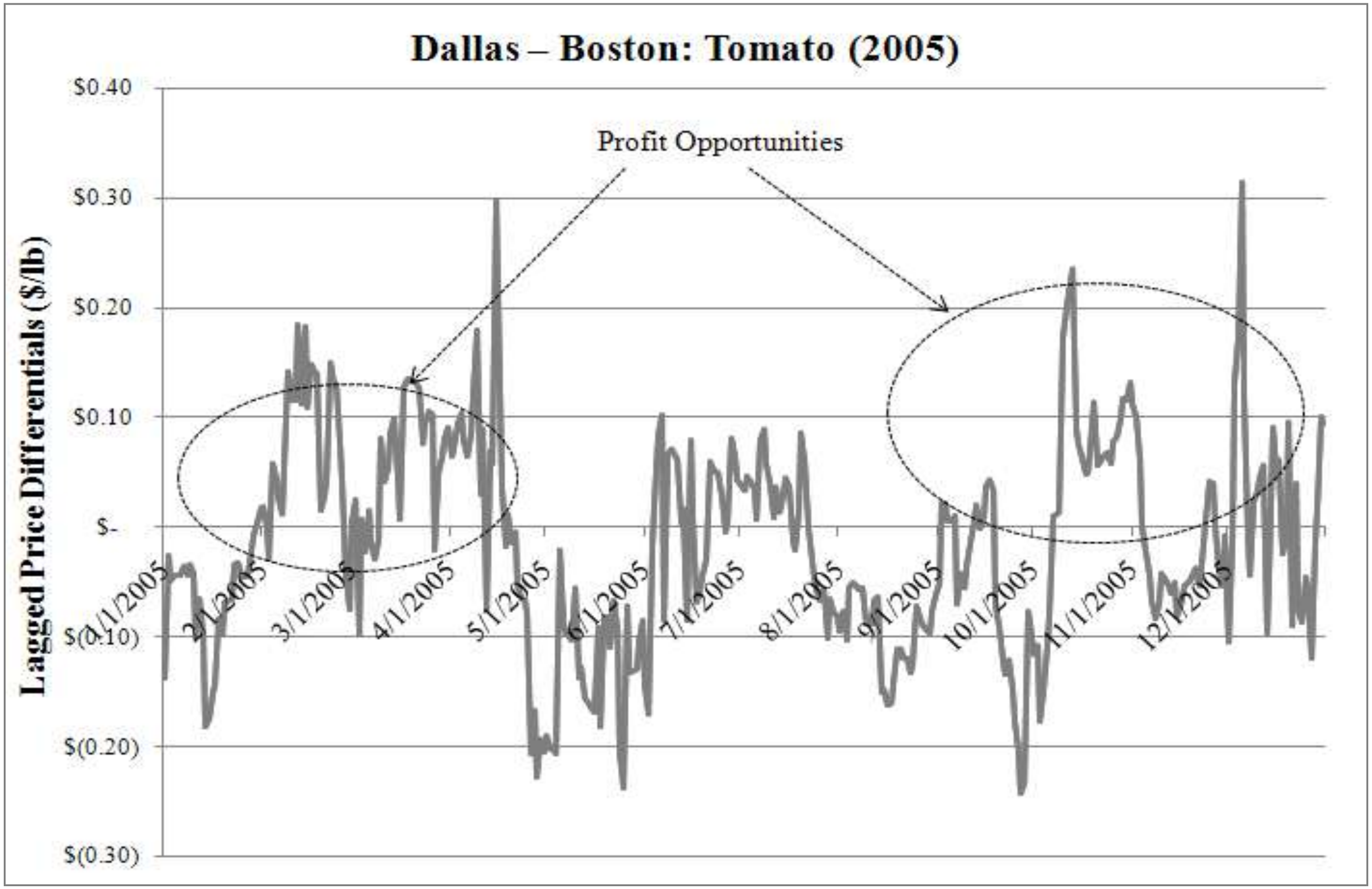
- **Low levels of investment** in infrastructure for value-added and distribution operations
- **Market Intelligence**

Mexican Farmer Case Study

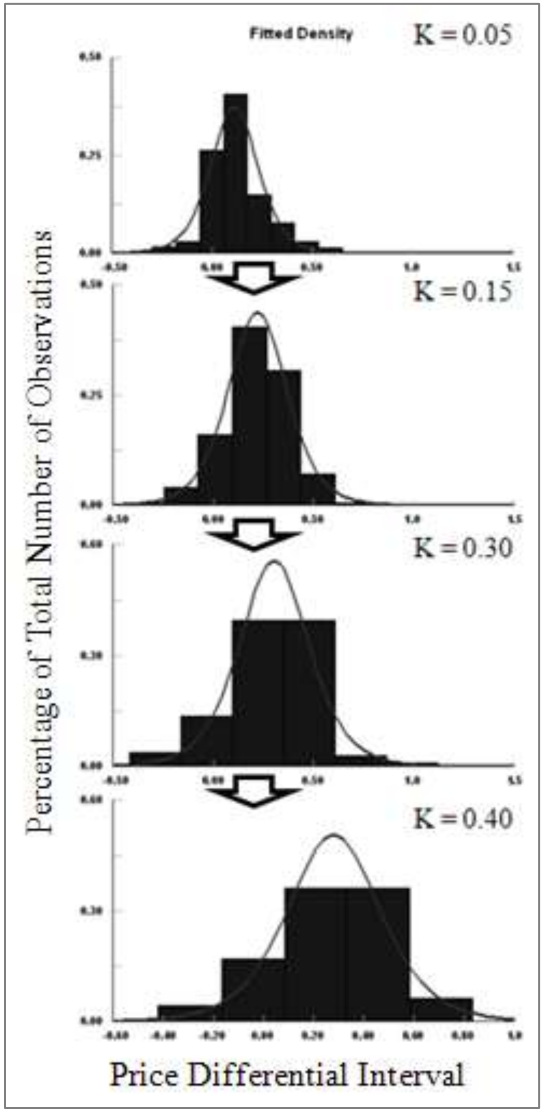
- Observation Period
  - January 2000 – December 2009 (Daily prices)
- Product Basket
  - Tomato (Plum Type)
  - Cucumber
  - Eggplant
  - Squash
  - Bell Pepper
- Transportation Mode
  - Truck

	Dallas	Boston	Atlanta	Chicago	DC	NYC
Tomato	$0.70	$0.76	$0.70	$0.71	$0.72	$0.66
Squash	$0.58	$0.46	$0.49	$0.50	$0.53	$0.46
Eggplant	$0.94	$0.86	$0.57	$0.83	$0.55	$0.77
Cucumber	$0.39	$0.37	$0.33	$0.39	$0.31	$0.36
Bell Pepper	$1.07	$0.67	$0.99	$0.97	$1.01	$0.84

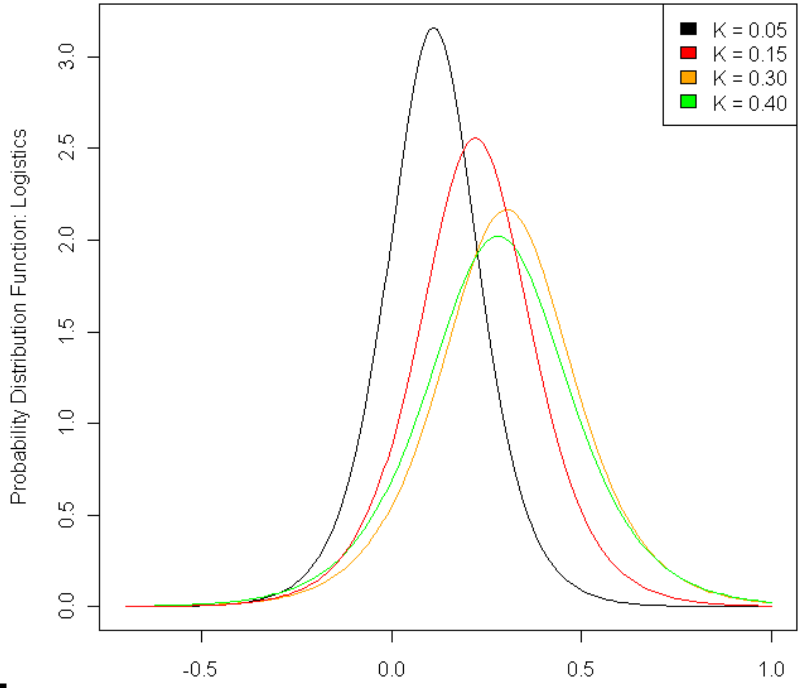
Potential Market Opportunities



Shipment Policy (Pragmatic)

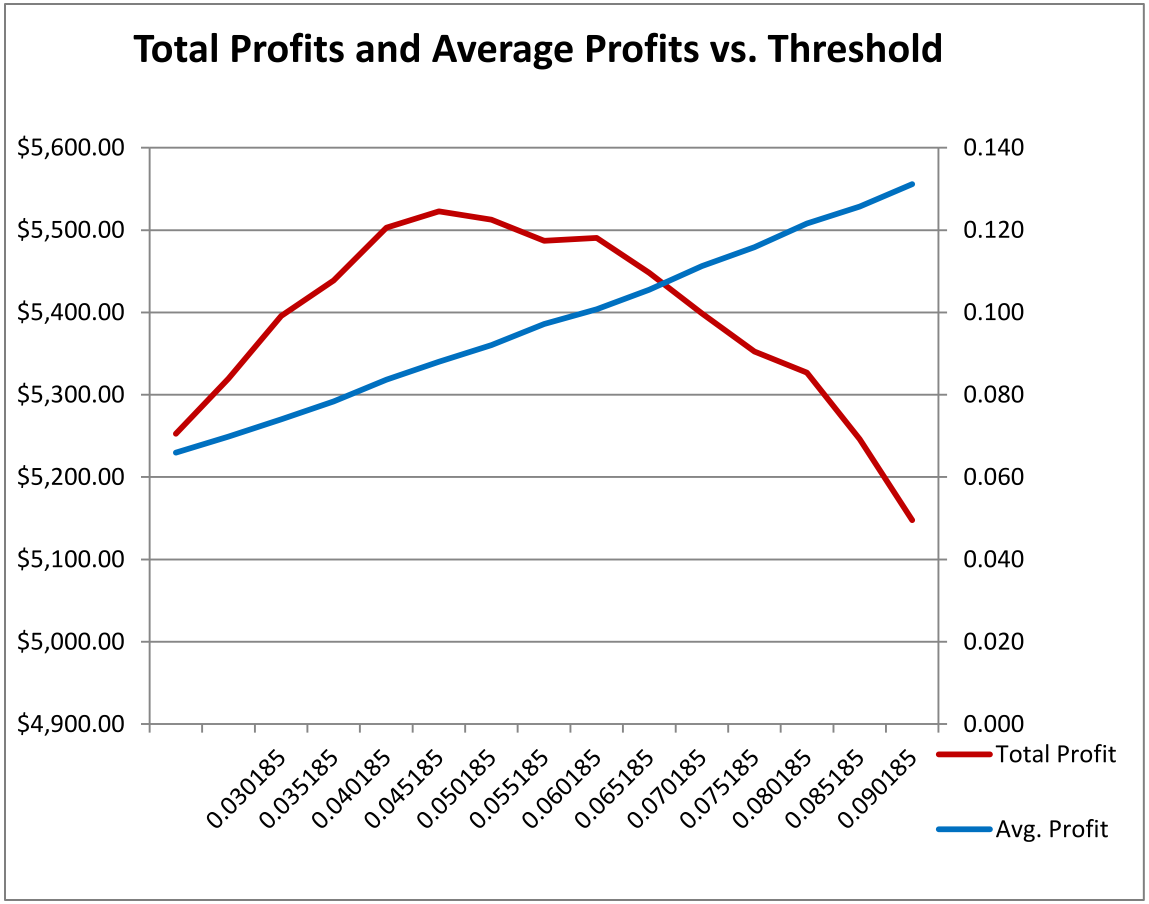


- Dallas – Boston (10 years) iterative summary of historical profits under varying values of threshold



μ and σ per threshold value is equal to the mean profit and standard deviation per pound of product shipped

Shipment Policy (Theoretical)



Threshold + Cij	Total Profit (thousand $)	Avg. Profit
0.0302	5252.632	0.0659
0.0352	5319.384	0.0698
0.0402	5395.584	0.0740
0.0452	5438.908	0.0784
0.0502	5502.928	0.0836
0.0552	5522.660	0.0880
0.0602	5512.480	0.0921
0.0652	5487.104	0.0972
0.0702	5490.544	0.1008
0.0752	5448.264	0.1055
0.0802	5398.912	0.1113
0.0852	5352.424	0.1159
0.0902	5326.720	0.1216
0.0952	5246.104	0.1257
0.1002	5147.668	0.1312

0.0502<K<0.0602

Conclusions

- The operational decision-making tool can be used to evaluate present arbitrage opportunities and estimate the chance of a gain based on historical behavior of the prices
- IT Develops a shipment configuration tool that reduces the profit variability on a two-market transaction

General model for stochastic planning

- Uses recourse variable ***y***, which will take a value depending on the values of the second stage random varible $\boldsymbol{\omega}$

- General SP formulation:

$$\boldsymbol{min\, z = c^T x + E_\xi \left[\min q(\omega)^T y(\omega)\right]}$$
$$\textbf{st: } \boldsymbol{Ax = b}$$
$$\boldsymbol{T(\omega)x + Wy(\omega) = h(\omega)}$$
$$\boldsymbol{x \geq 0,\ \ y(\omega) \geq 0}$$

General model for stochastic planning

- Uses recourse variable ***y***, which will take a value depending on the values of the second stage random varible ω

- General SP formulation:

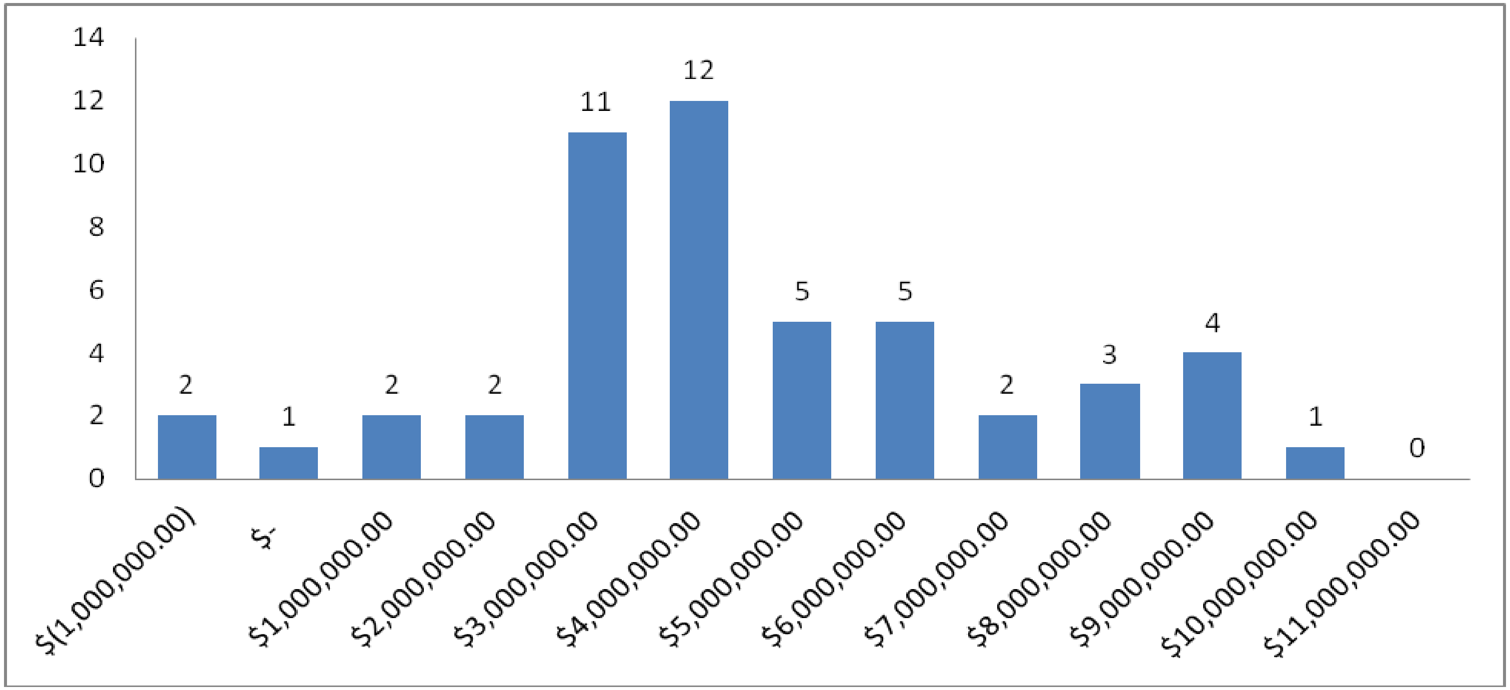
$$Max\{cx + E_p Q\{x, \xi(w)\} | Ax = b, x \geq 0\}$$

- Where:

$$Q\{x, \xi(w)\} = Max\{q(w)y | Wy = h(w) - T(w)x, y \geq 0\}$$

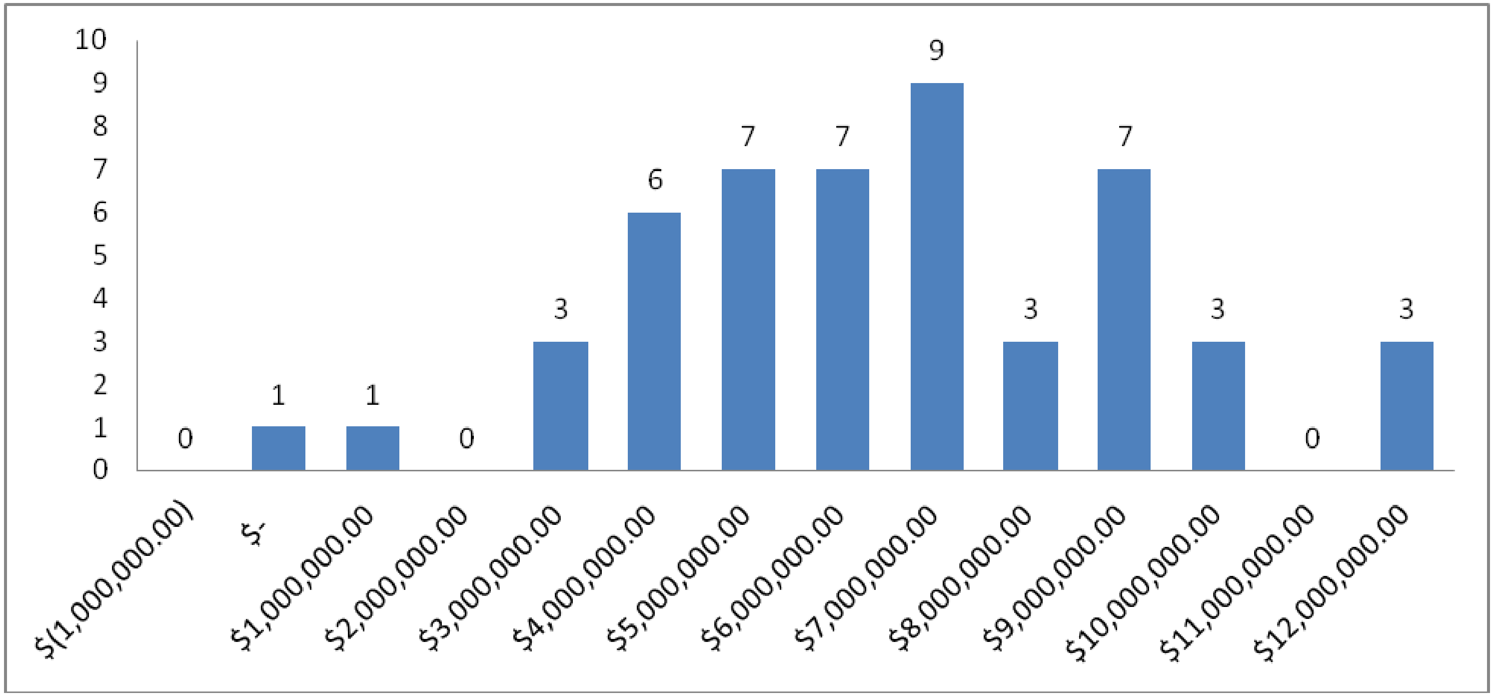
Deterministic solution

- Simulated cost for realization of random parameters
- Profit varies for the different scenarios considered



Stochastic (risk neutral) solution

- Significant performance improvement over deterministic solution



Comparison of expected values

- Deterministic vs risk neutral and risk averse solutions

Model	λ	Profit	Costs	ROI	Worst	CPU/s
Deterministic	0	$3,255,643	$14,439,900	22.5%	- $37,598,000	197.54
Stochastic	0	$5,621,200	$14,427,100	38.9%	-$174,526	1325.41
Stochastic	1	$5,619,360	$14,434,100	38.9%	-$138,500	1350.15
Stochastic	10	$5,510,680	$14,434,500	38.1%	$153,871	1485.52

Variance analysis

- Deterministic vs risk neutral and risk averse solutions

λ	Scen	Mean	Std. Dev.	Worst	Best
Deterministic	1	$3,978,744	$2,500,621	-$1,741,163	$9,139,454
0	50	$6,070,825	$2,615,054	-$268,011	$11,523,316
1	50	$6,194,092	$2,781,673	-$223,124	$12,203,016
10	50	$6,119,366	$2,648,494	-$221,385	$12,038,200
Perfect information	-	$8,321,542	$3,320,269	$3,005,492	$21,148,775

Downside risk

- Deterministic vs risk neutral and risk averse solutions

λ	Scen	Mean	Std. Dev.	Worst	Best
Deterministic	1	$3,978,744	$2,500,621	-$1,741,163	$9,139,454
0	50	$6,070,825	$2,615,054	-$268,011	$11,523,316
1	50	$6,194,092	$2,781,673	-$223,124	$12,203,016
10	50	$6,119,366	$2,648,494	-$221,385	$12,038,200
Perfect information	-	$8,321,542	$3,320,269	$3,005,492	$21,148,775

Bringing it all together

Our Vision

- Tackle the issues of agricultural supply chains using industrial engineering tools
  - Optimization tools
  - Statistical analysis and inference
  - Risk management
- Identify opportunities with large impact (Farm to School, foreign labor force, climate change)
  - Design a suite of decision support tools
  - Form partnership with farmers to refine tools and implement results

Questions?

ASU

Arizona State University