A System Dynamics Study of a Commodity Plastics Industry

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Abstract

Faced with new challenges in managing the cyclical and volatile business environment, management at a Commodity Plastic (COM-P) Company agreed to apply System Dynamics (SD) to support strategy development. A SD model of COM-P industry was built by adapting the Pulp and Paper Model. The structure of COM-P Index Price creation was mapped and added to the generic model. The following were investigated: a) The effect of current delays in adjusting prices on phantom demand, on capacity utilization and shipment rates were tested; b) The phenomenon of Phantom demand or pre-buying when customers perceive that prices may be about to go up was modeled; c) By applying the model, the amount of margin lost or gained by the industry due to the price protection terms in the contracts was estimated; d) The risk in the top ten long term contracts under different supply and demand conditions and oil prices in order to support the sales organization with their negotiations; e) The model was applied to get guidance on capital investment timing and to assess the effect of different oil prices and supply & demand scenarios on the profitability of new investments. In many cases the results were counter-intuitive.

1. The Commodity Plastic Industry in North America

Commodity Plastic (COM-P) is a versatile plastic used widely in many applications ranging from food packaging, automotive, medical and textiles. Since its discovery this plastic grew at double digit rate, due to its breadth of performance and uses, ease of processing and most importantly the ready and cheap availability of its feedstock. Until 97, COM-P was a profitable business, with high margins, due to high prices and low feedstock (called monomer) prices. The situation changed from 98 onwards when new players attracted by the high margins and high growth rates entered the market and built excess capacity and margins collapsed. While the industry seems to accept cycles as a way of doing business, recently people have started to question increases in month-to-month volatility in demand and prices which indicates a different set of dynamics in the supply- chain practices.

2. Context of This Study

Two years ago during a strategy workshop, a group of managers at a COM-P company started to realize that their intuitive responses to today's problems were not effective and appeared to be open to new ways of handling pricing and demand volatility. At that moment, the term “System Dynamics” was introduced and a short explanation was given to the group. Though they did not seem to grasp fully the explanation, they agreed to commit to a two day workshop with 15 senior managers which in itself was the first major success.

The workshop was designed and facilitated by Dr. David Andersen and Dr. George Richardson from SUNY and supported by Lee Jones from Ventana Systems. On day one, the language of System Dynamics - Stocks, Flows, and Feedback Loops, was introduced with the help of a Concept model to illustrate how structure drives behavior. Then the boundary of COM-P micro-world was developed and historical industry data were reviewed to elicit structural hypotheses from participants. This helped participants identify key policy levers. The team was then invited to step into a Generic Commodity model to introduce them to commodity market dynamics. There was a high level of comfort and familiarity with commodity market dynamics and the key learning was that profitability emerges from “transient” strategies. At the end of day one, the team played the Beer Game and the insight, that structure of the system drives behavior, was brought home.

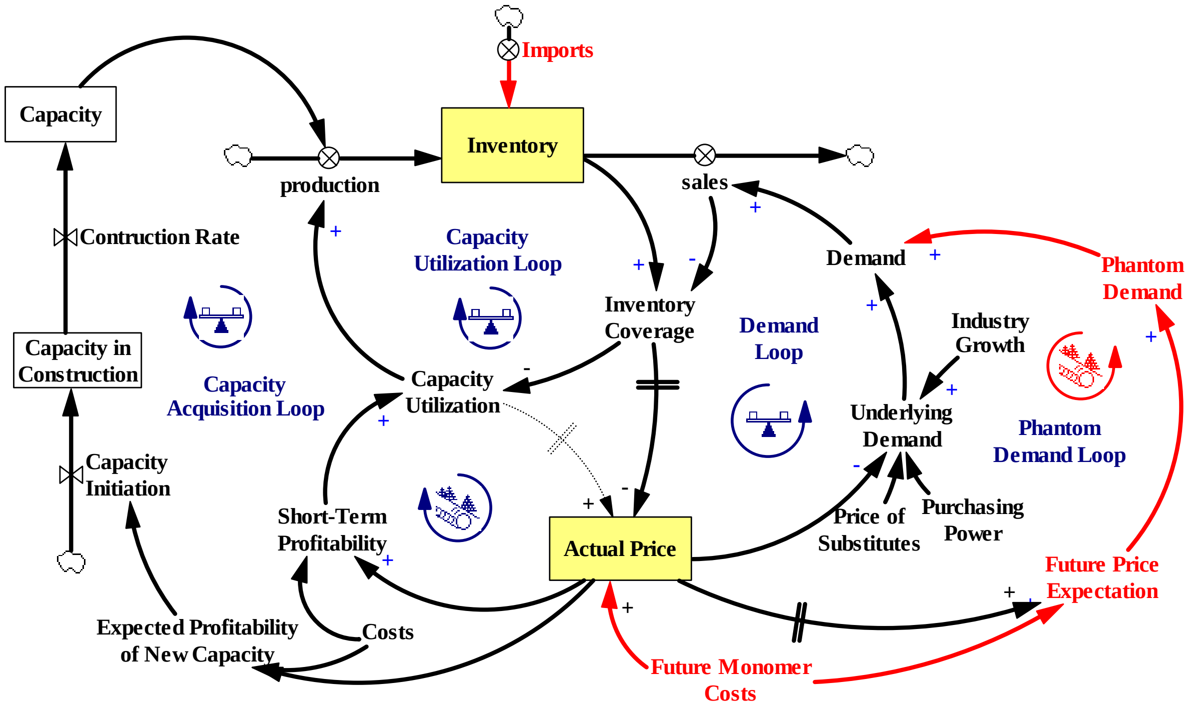
On day two, current industry practice for creating the index price was mapped. The process by which an independent consultant organization called ICO creates this index, via submission of “next months” prices or price changes from COM-P producers and COM-P buyers, was mapped using a causal loop diagram. Everyone agreed and identified with this map, however the conversation was very emotive with the group blaming the ICO index for the misalignment between ICO index price and “reality”.

3. COM-P Model Building

Following this event, a model of the North American COM-P industry using Vensim was built by adapting the Generic Commodity model from John Sterman's Industrial Dynamics book. Using the generic model as a guide, more conversations were held to elicit the time constants – the lags between the various steps in the diagram. This too was an important step in creating organizational learning from the senior to the junior members of the organization. Though initially Ventana was contracted to do the model building, internal expertise was developed by training Lester Burton through the WPI distance course on SD. This was another important step in building familiarity within the wider organization.

A high level representation of the COM-P model is shown in Fig. 1. The figure shows the three principal feedbacks which help equilibrate supply and demand. The stock and flow structure for Production and Inventory representing supply chain is at the top, the stock and flow for Capacity pipeline appears at the left of the figure and the Demand loop appears on the right. While these loops are the same as in the generic commodity model, three main changes were made to represent the structure of the COM-P industry.

Figure1. High-level COM-P model



On the demand side, as mentioned already COM-P demand grew historically due to its "value for money", wide applications and innovation. The Capacity Loop dynamics are the same as other commodities, high utilization rates and high prices lead to high expectations of future profitability which in turn drives new capacity decisions. However in the COM-P industry, the cumulative delays - information, perceptual, decision and construction delays - in the Capacity Loop are very long. Industry data on total available capacity figures are thought to be wrong - it is felt that suppliers under -report their total capacity. Approvals for investment could take on the average 1 year or longer as most players are a part of large oil companies where capital approvals have long internal pathways. Once funds are approved construction takes typically 3 years. In addition, scale being essential for low unit costs, COM-P plants need to be of world scale. New COM-P plant sizes have doubled in the past 7 years. This implies that capacity can only grow in very large slugs that take several years to be fully absorbed.

The Production and Inventory- or the capacity utilization loops in COM-P are also laden with delays – delays in reporting by industry bodies of inventory levels and delays in creating index prices and delays in announcing changes in prices. These lead to customers gaming the system and creating phantom demand. In short the main changes which were made to the generic commodity model are listed below.

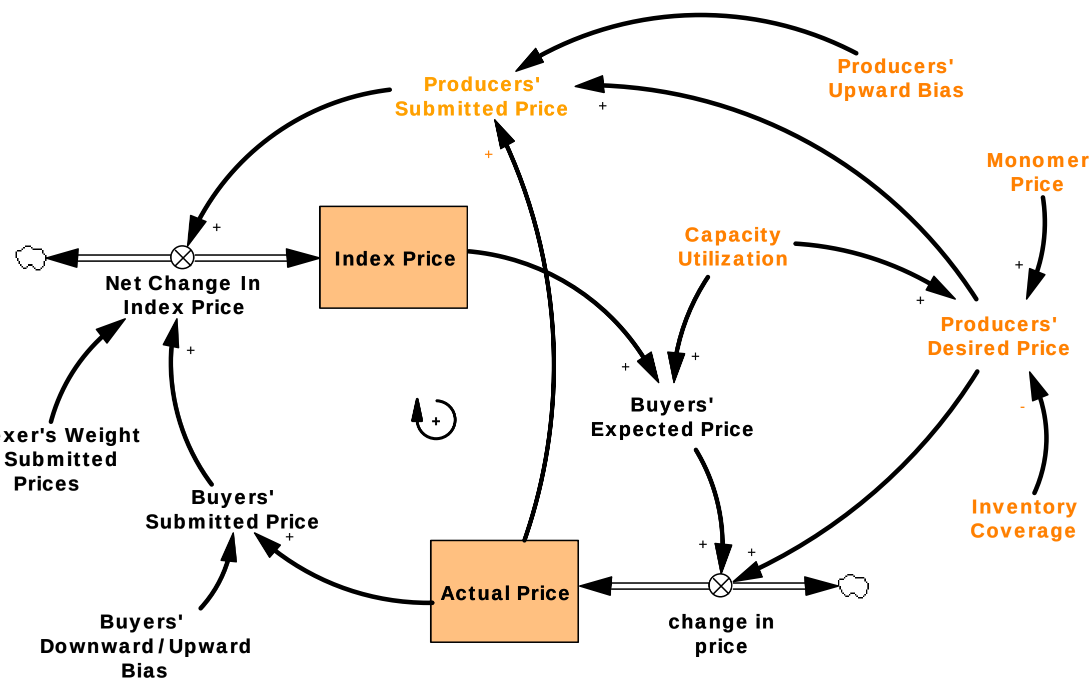
- **Index or posted price creation process followed by buyers discounting:** The mechanism for Index or posted price (e.g. ICO) creation via submission from buyers and producers and changes within this practice during the last decade were mapped and added. Buyers get bonuses based on the magnitude of the discounts they can show to their management versus the Index price. The behavior that results if the gap between the Index price and their realized price widens was mapped and added.

- **The phenomenon of Phantom demand** or pre-buying when customers perceive that prices may be about to go up.

- **Direct link to feedstock prices** – Feedstock which makes up 60% of the costs of COM-P prices are exogenously inputted into the model.

Index Price Structure: Fig. 2 shows the index or posted price creation process. In most commodities, there is a more-or-less transparent link between the commodity's posted price or index price and the supply/demand of the commodity and its major raw material prices. However, this is not the case for COM-P and other plastics even though they are considered to be commodities. The index prices are created by an independent body called here "ICO" – an acronym created to hide their identity. While many in the industry agree that these index prices are "wrong" in the sense that they are higher than they "should" be, due to lack of good alternatives, these index prices are widely used for setting worldwide contracts between producers and buyers. During the workshop much dissatisfaction was expressed about the current process for index price creation.

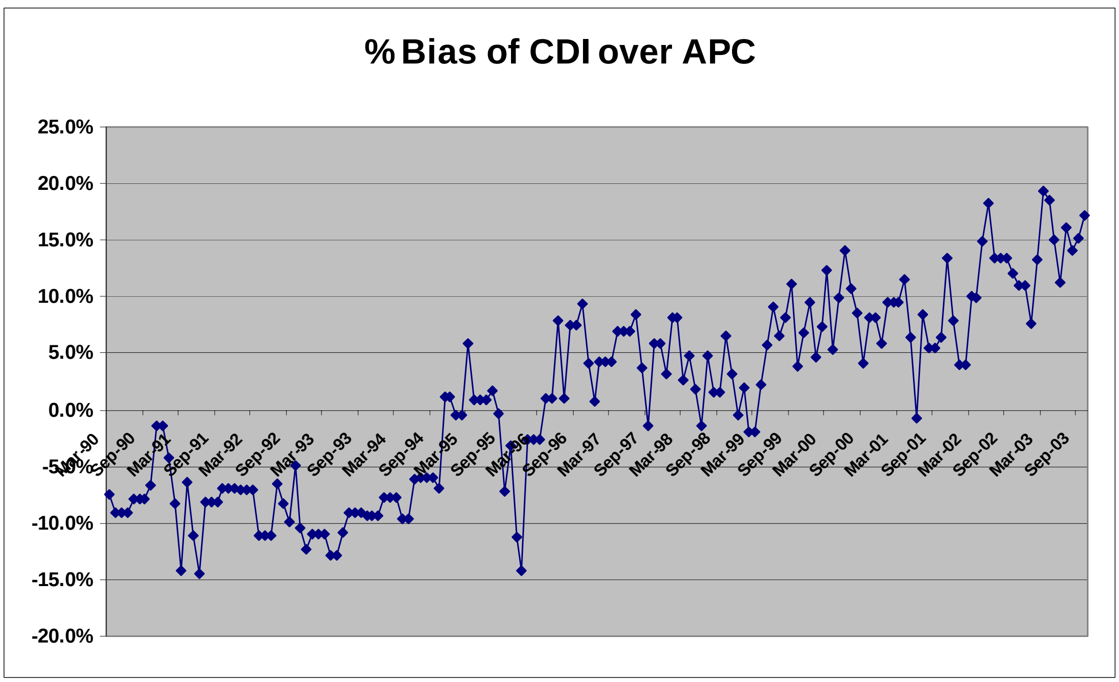
Figure 2: COM-P Index Price Creation Mechanism



The index price consultants (similar to ICO) use a process of polling each month all the producers and a large number of buyers by asking them for their position on the following month's price movement. This is shown in Fig 2. Producers, due to their natural bias for higher selling prices, report a higher price movement- the higher the index price, the higher the negotiated price and hence higher their submitted price. Until a few years ago, buyers used to have a downward bias when reporting prices, but increasingly they too want the index price to be as high as possible because their customers in turn are using index price in their contracts. For example, large buyers such as the Coca-Cola Company want their bottle prices to be set using the index prices (e.g. ICO) at which the bottle producers buy from the polymer producers. The cumulative effect is an upward drift of the reported prices by both the producers and the buyers. However, the consultant companies realize this issue and apply their correction or a weight to these submissions. What is not known, is how the consultants correct for this upward drift and what weight they put on the reported prices.

Fig. 3 shows that from 99 onwards Index prices were nearly 15% higher than those reported by APC – American Plastics Council, the industry body representing producers. APC collects the actual prices realized by the members at the end of each quarter. However APC data is only available to producers due to anti-trust reasons and as such it is not publicly available to the consultants who create the index prices.

Fig. 3 Increase of Index Price Over APC Prices



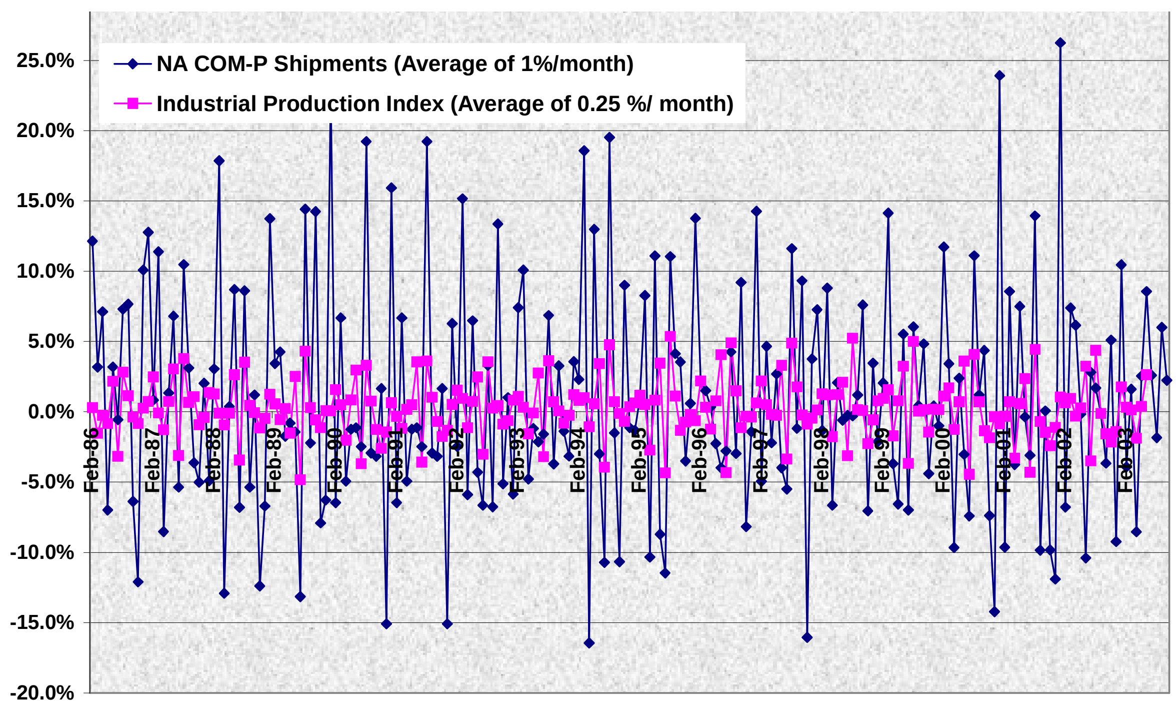
This situation has strong negative consequences for the industry e.g. in ’99 new entrant’s capacity was built based on the “inflated” Index prices since APC prices were not available to them.

Another negative consequence of the lack of transparency is the price discounting process. Buyers, after having applied an upward bias during the index price submission, start a tough process of negotiating discounts with the producers because their personal bonuses are based on how much of a discount they manage to get.

In terms of policy changes, the group wanted to test the effect of doing away with submissions and having an auditable index which would be linked to real price drivers (e.g. real time supply and demand and, inventory and raw material costs etc.).

Phantom demand: There was a general impression that the industry was experiencing increasing volatility in orders. Some blamed the economy and the cycles, but examining the historical demand for COM-P showed that there was more volatility in COM-P than in GDP or Industrial Production Index.

Figure 4: NA COM-P Shipments Vs IP % Change From Previous Month



This comparison posed the question of whether the volatility in COM-P orders could be due to reasons endogenous to the industry. We therefore added the mechanism by which Phantom demand or customers pre-buying could be created. The most widely accepted reason was due to customers' pre-buying or stocking when they perceive that COM-P prices or the feedstock prices are going to increase. The COM-P industry practices of announcing price increases one plus months ahead of the actual price increase implementation is one of the causes of the pre-buying. This in turn is due to the practice of giving price protection to customers of about 1-3 months.

4. Model Testing

We have replicated the historical pattern (over 10 years) of the COM-P prices (Fig 5) margins (Fig 6) and have gained confidence that the model is a good representation of the structure of the COM-P industry. The graph shows model output in red and real prices published by the American Plastics Council (APC) at the end of each quarter in blue. Other parameters such as inventory also correlated well.

Figure 5

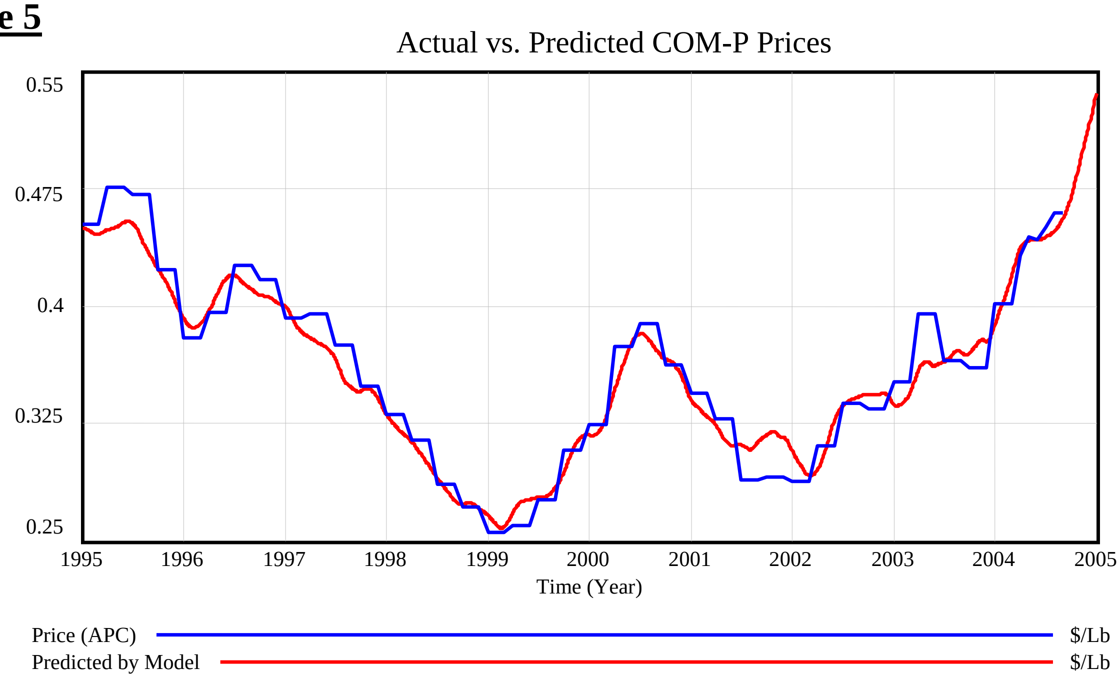
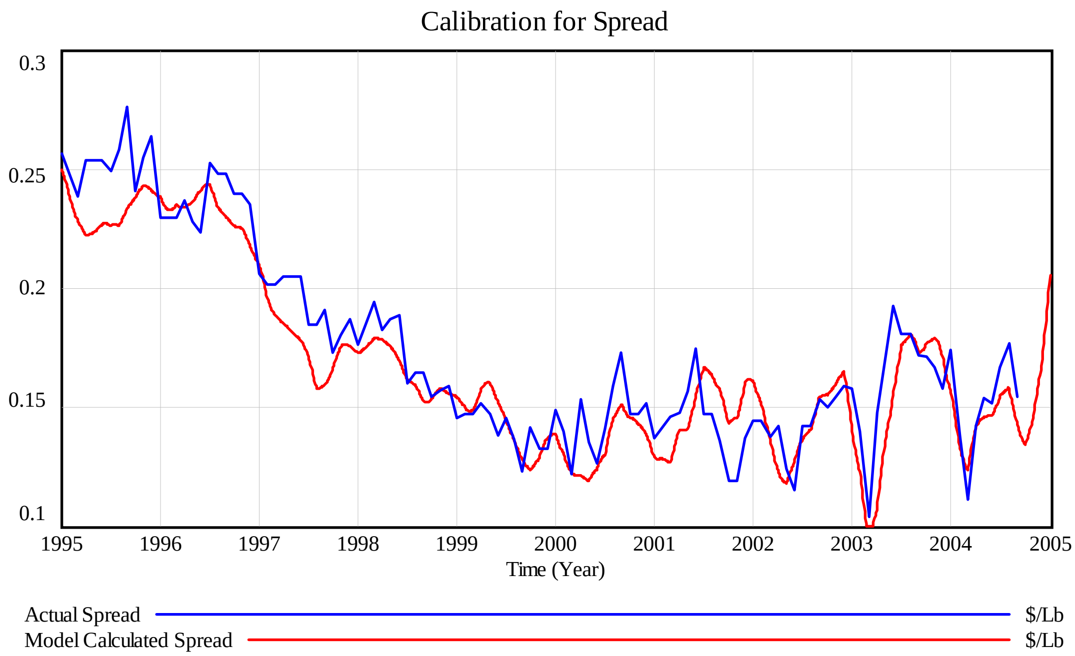


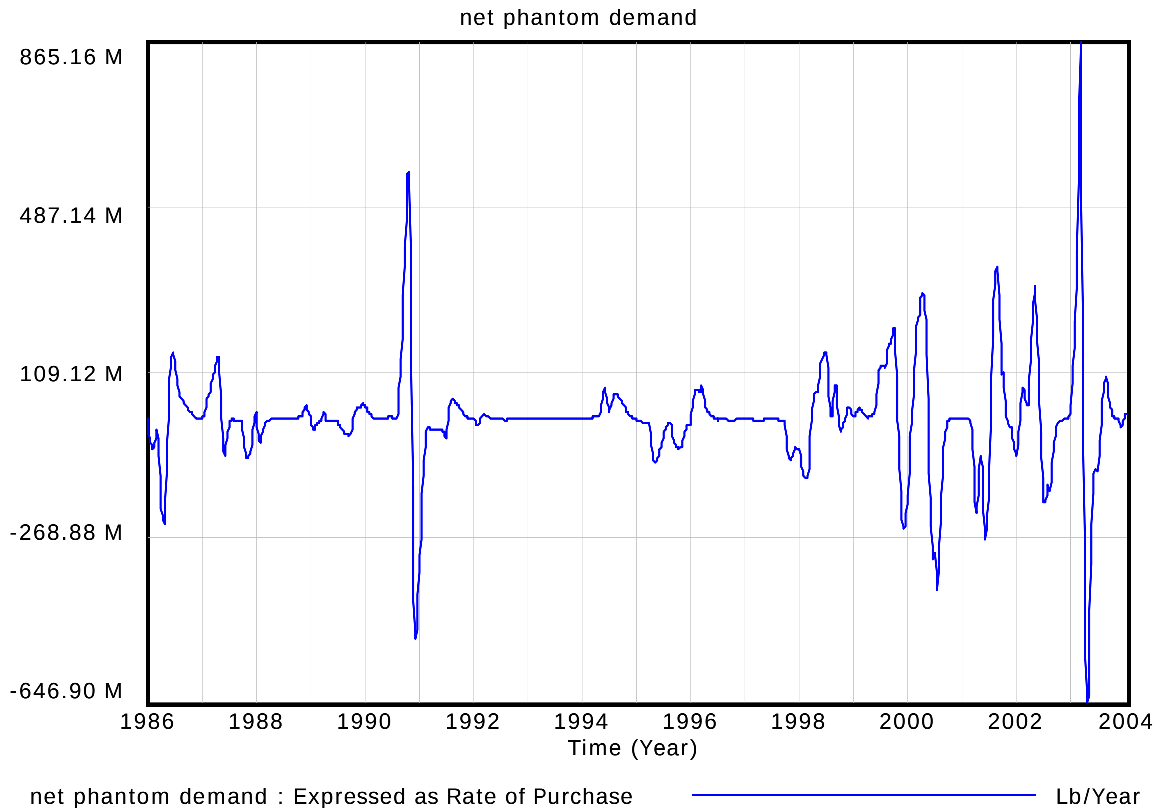
Figure 6



Testing of Phantom demand :

We wanted to test if the Phantom demand (pre-buying) predicted by the model was close to the actual spike in demand reported. The model indeed predicts quite accurately phantom demand. Our model also shows higher volatility of phantom demand over the past 5 years.

Figure 7- Phantom Demand (Customer Pre-Buying)



The phenomenon of phantom demand is a consequence of two industry practices. The first is the practice of giving customers terms that hold the prices constant when feedstock prices change. These terms range from 1 to 3 months of price protection built-in to contracts. This practice was intended to benefit COM-P suppliers from fast drop in COM-P prices if and when feedstock prices drop and likewise protect customers from increasing COM-P prices when feedstock prices increase. However, this led to an unintended consequence of customers and traders stocking and de-stocking prior to the price increase.

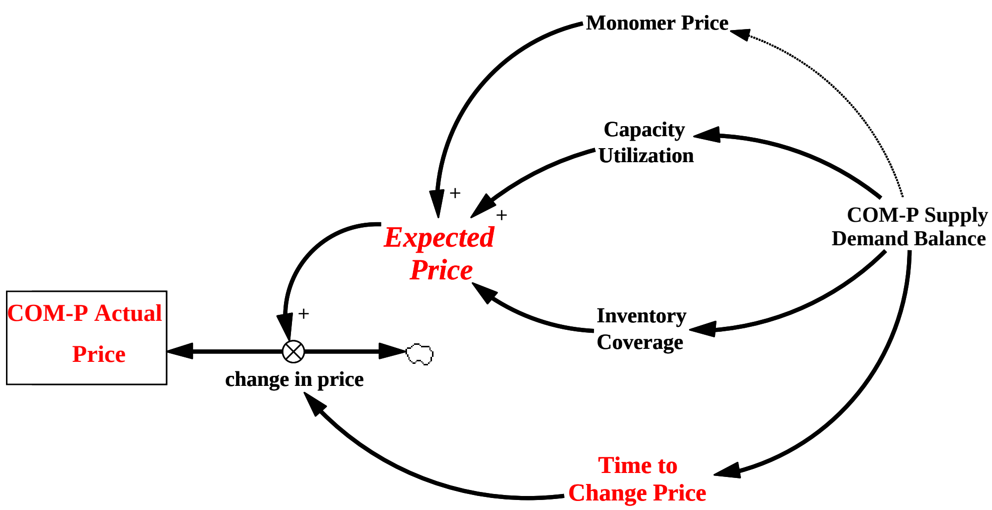
The second practice is that of announcing changes in prices 1 month in advanced of actual implementation. Speculators then gauge the readiness of the market to accept the attempted increases and buy spot in advance of the increase.

5. Model Applications

5.1 Testing the effect of reducing the time to change prices

We tested the impact of reducing the time to Change Prices in Fig. 8, which shows the three variables which drive the expected price- monomer or feedstock price, capacity utilization and inventory coverage.

Fig 8. Delay between the Expected Price and Actual Price



The policy to test the effect of reducing the time to change prices was done by setting the delay to 2 weeks - approaching the concept of a spot market. As the results below show, reducing the delays in adjusting prices reduces the volatility in capacity utilization (Fig 9) and shipment rates (Fig 10). This was counter intuitive in the sense that most people believe that contract is better than spot for reducing volatility.

Figure 9- Effect of Reducing Contract Delays on Capacity utilization

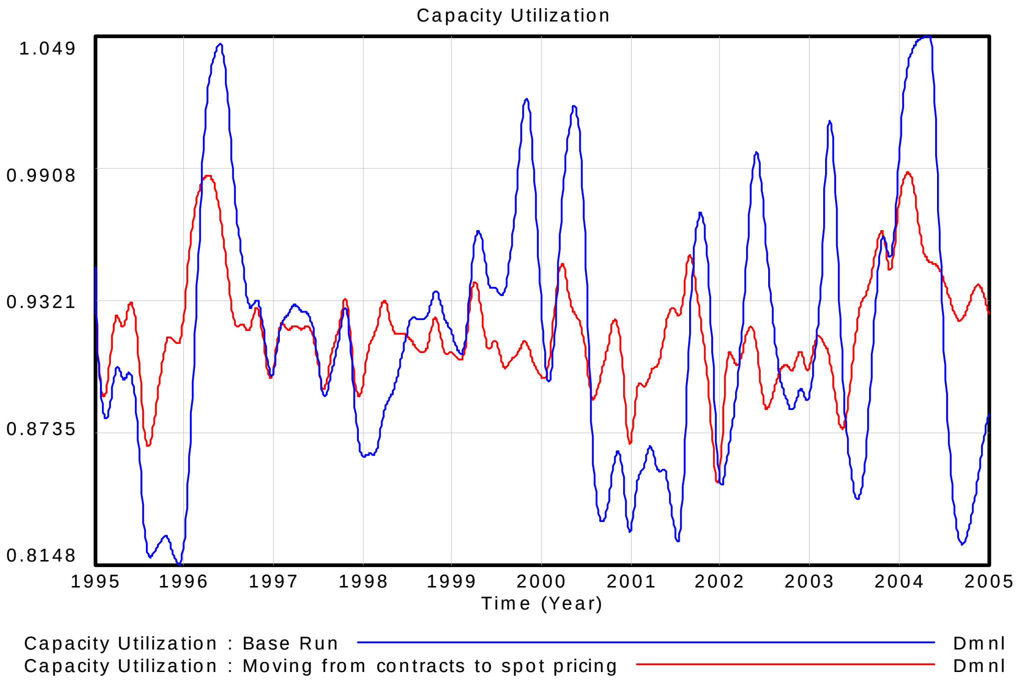
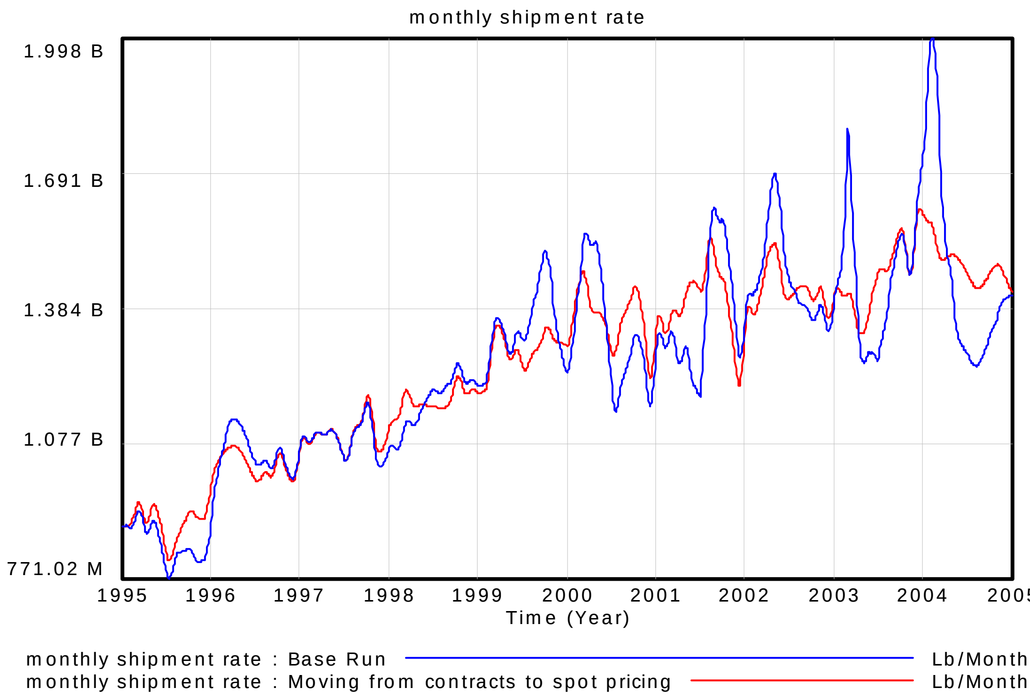


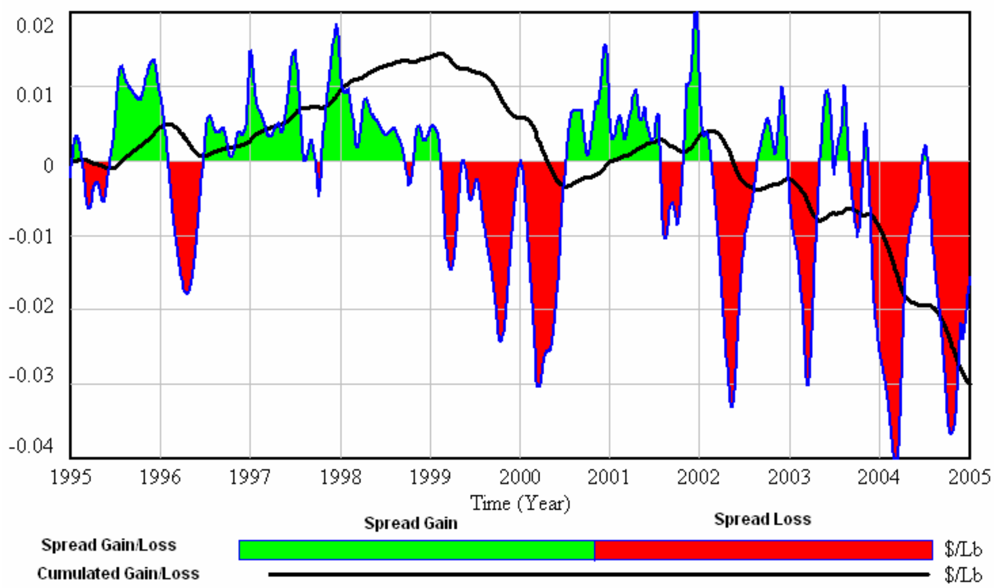
Figure 10- Effect of Reducing Contract Delays on Shipment Rates



5.2 Measuring the Financial Impact of Delays in Changing Prices on Margins:

We wanted to assess the financial impact of the delays in changing prices on margin loss or gain. Using the delays which the model generated we plotted the margin or spread losses and gains (Fig 11) . The spread loss shown in red indicates when the industry lost margins due to delays in passing on either feedstock price or utilization rates increase. Green areas indicate when industry benefited due to slowness in the fall of COM-P prices when feedstock prices or utilization rates decrease.

Fig 11. Spread Loss/ Gains from Delays in Changing Prices

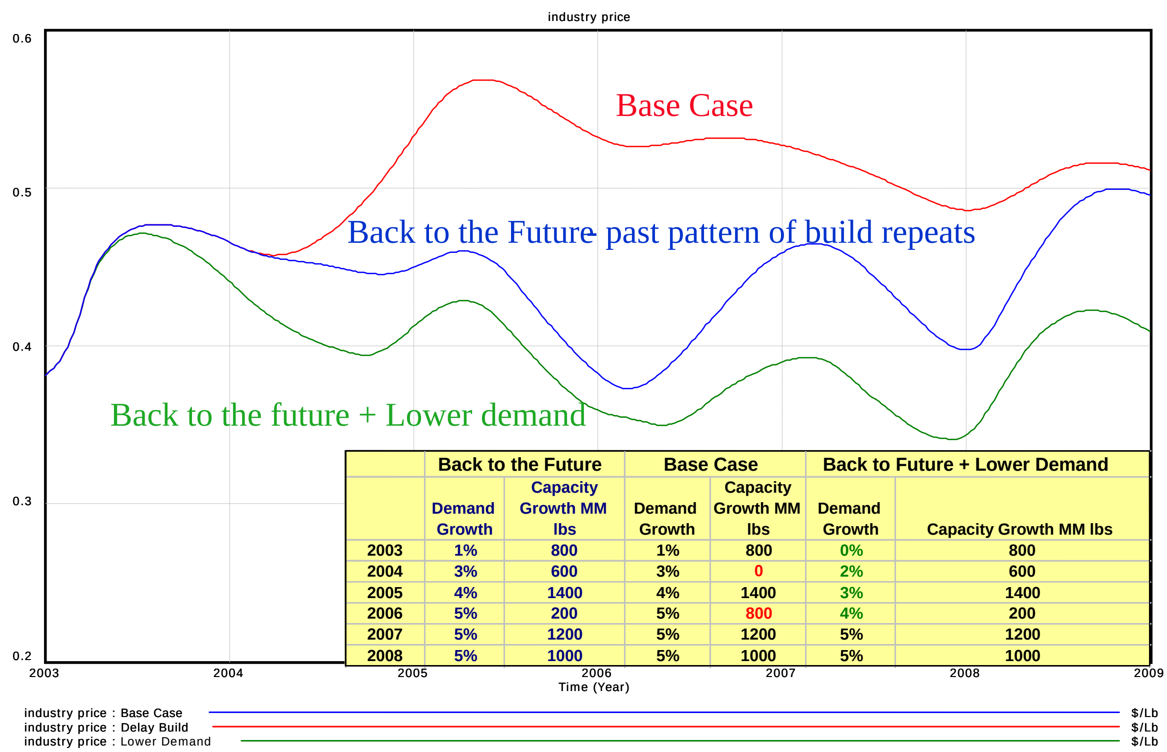


From Fig 11, we can see that the cumulative average spread loss through 2004 is about 3 cents per pound (cpp). Instantaneous spread losses have been as much as 4 cpp during the significant price increases in the first and third quarters of this year. These structural lags affect the industry roughly equally, though individual competitors may be better or worse than average.

5.3 Scenario Testing

Capital decisions in terms of when and how much to build are some of the most critical decisions in the industry. We have simulated a number of "what ifs" or scenarios to test the effect on prices and margins under different capacity and demand combinations. These were called "Back to the Future" – to tests the effect on margins if the industry repeated the historical pattern of capacity overshoot. Base Case represented our business plan assumptions and a third scenario of "back to the future" with lower demand was tested. As can be seen from Fig 12 price is extremely sensitive to supply/demand balances. Very modest changes in growth of capacity or demand radically affect pricing and profitability. This simulation raised much debate in the organization about investment timing and educating the industry.

Figure 12. Scenario Testing : Sensitivity of Price to Supply/Demand Scenarios



	Back to the Future		Base Case		Back to Future + Lower Demand	
	Demand Growth	Capacity Growth MM lbs	Demand Growth	Capacity Growth MM lbs	Demand Growth	Capacity Growth MM lbs
2003	1%	800	1%	800	0%	800
2004	3%	600	3%	0	2%	600
2005	4%	1400	4%	1400	3%	1400
2006	5%	200	5%	800	4%	200
2007	5%	1200	5%	1200	5%	1200
2008	5%	1000	5%	1000	5%	1000

5.4 Contract Support

During the last trough of 2000 when surplus capacity was brought on stream, industry entered into un-profitable contracts. However as time progressed and supply was tightening, they did not react swiftly and change the contract terms. We therefore undertook work to simulate profit potential for some of the major contracts under different supply and demand conditions and also feedstock or oil price scenarios. This work was intended to help the sales organization to do the following assessments.

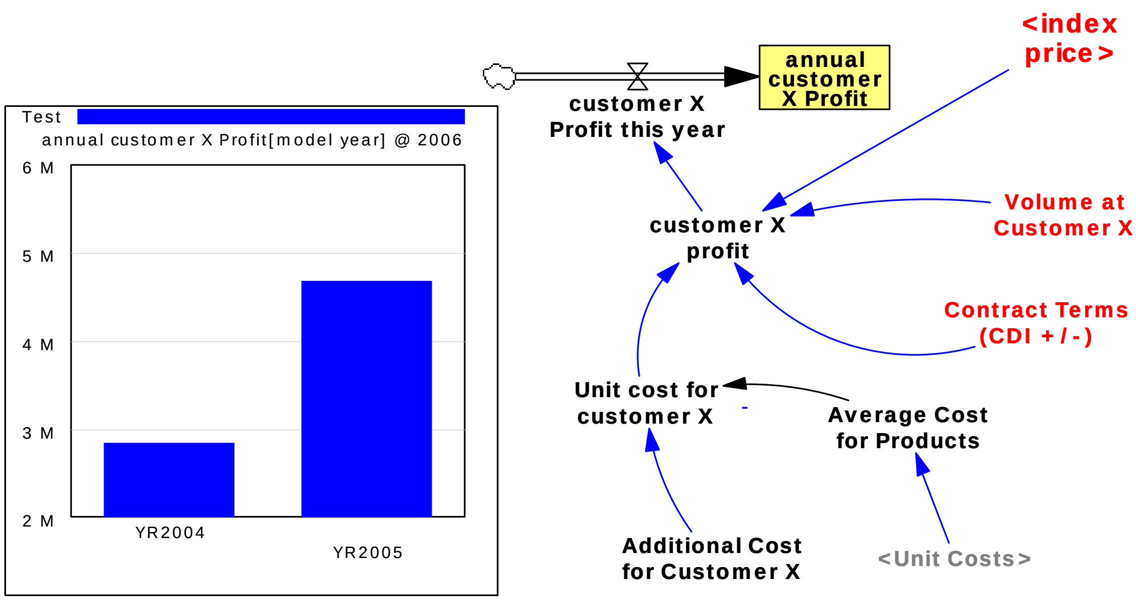
- Gauge the environment during a proposed contract period using business plan assumptions and deviations from these assumptions. The simulations calculate prices that the market will tolerate and help the sales person to decide when to be aggressive on price, when to forego volume etc.

- Calculate margins and profits for a specific contract, or group of related contracts, that are linked to an Index price or are market driven.

- Estimate risk associated with terms in existing and proposed contracts

To accomplish these objectives, the value of index-based contracts was estimated by taking the predicted Index Price from the model along with expected cost (variable model input) and calculating the value of a specific contract through a simple algorithm that contained the contract terms (discount rate from Index Price, price caps, payment terms and specific cost associated with servicing this particular customer – see figure 13). The profit or loss from the contract could be graphically presented based on current assumptions on supply/demand balance. The sensitivity/risk of profit to these assumptions can easily be modeled.

<u>Fig 13. Simulation of customer profitability under various contract terms</u>



6. Conclusions

It is difficult to point to a single big policy change as a direct result of this work. Senior managers realized that the strongest leverage is in making this work public and educate industry that cycles and volatility are due to endogenous reasons. However this policy was rejected by legal on anti-trust reasons. There have been several small changes. The sales organization applied the learning from the contract simulation in their negotiations with customers. During annual business planning process, the model is being applied to test margin sensitivity.

In terms of future extensions of this work feedstock dynamics need to be added to the COM-P model because COM-P is the largest derivative of the feedstock. Currently the feedstock prices are exogenously inputted. Secondly, the North American COM-P model can be extended to Global COM-P and it would be of interest to connect the model to other related plastics that effect demand via inter-material substitution.

Foot note: Seetha Coleman-Kammula, the author, initiated and led the modeling study. Lester Burton led the technical model building and calibration