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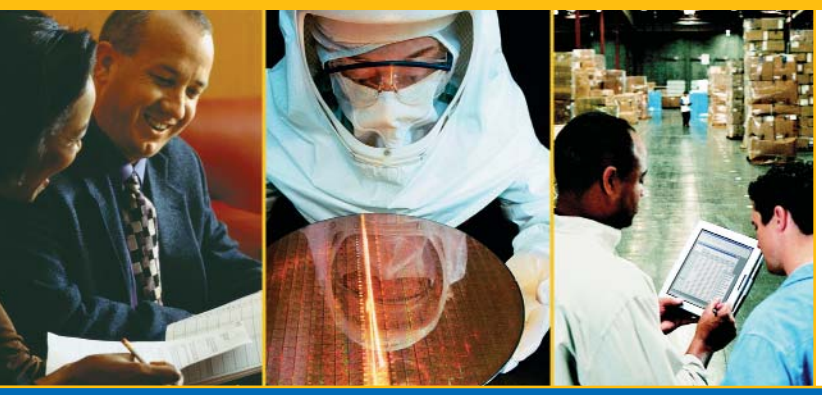

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Managing Uncertainty in Planning and Forecasting

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Managing Uncertainty in Planning and Forecasting

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Index words: planning, forecasting, product transition, product introduction

ABSTRACT

Orchestrating product transitions is a challenging yet vital function across Intel's organization. "Demand Generation" research, sponsored by Intel's Customer Fulfillment, Planning, and Logistics Group, has probed historical and present-day transitions to learn how the organization plans, forecasts, and executes transitions and how we might be able to improve in the future. Completing case studies of real Intel® products led to the development of models to comprehend observed dynamics and to the development of new methods to address common challenges across the phases of product lifecycle management.

The paper covers key findings and outcomes from the research, describing observed problems and detailing solutions that have been identified or developed from 2002 to 2005. The solutions focus specifically on the functions of planning and forecasting, highlighting the need to integrate a broad base of information into a stack that includes not only hard data but also strategies, assessments, uncertainties, risks, and contingency plans. The overall solution stack is comprised of a planning system linking business strategies and assessments to a playbook of risks and contingency strategies. Use of these methods helps the organization plan for uncertainty and improves agility by mapping out tactics in response to potential risks. Forecasts also benefit from the use of repeatable, systematic methods and the integration of uncertainty.

Initial findings from pilots with two business groups validate the approaches, but integrating new methods into broadly used tools and processes is not without challenges. Research continues on both the proliferation of these methods and an exciting new capability, the use of market mechanisms to resolve ongoing challenges associated with traditional hierarchical planning and forecasting. Potential applications and advantages of market-based systems are discussed.

INTRODUCTION

Intel's business is one of transitions. The steady stream of technological innovation driven by Moore's Law requires one product and manufacturing process transition after another, each bringing a new generation of capability and computing power to the market. While transitions are ultimately beneficial, delivering value to consumers and shareholders, they also introduce uncertainty and risk to Intel's product management across all demand and supply functions.

Our research into planning and forecasting through periods of product transition was spurred by specific cases where transitions did not turn out as well as they might have. We set out to study the transition management process from a systems perspective. Each team involved in phasing in one generation of product and phasing out another uses processes (in the form of policies, strategies, or models) to manage data (input and output) and interfaces with other functional teams, each driven by various indicators of operational and strategic success. Using hard and soft data we studied these aspects for several products, seeking to identify sources of uncertainty and their adverse impacts on the bottom line. We then developed concepts and methods that would help the business navigate transitions with greater success.

An early lesson of the research was that in high-volume markets the stakes of a product transition are high, and numerous factors can compromise transition success. A substantial miscalculation of the timing of market demand or a technological glitch impairing supply can cost the company $500M in a market segment worth over $10B in annual revenue.

Through the case studies we classified four sources of uncertainty: *market*, which includes economic, business, and seasonal cycles; *product changes*, those of Intel, competitors, and complementors; *marketing actions*, which include pricing, promotions, and advertising; and

systems, the methods by which we forecast, plan, execute, measure, and monitor our business.

We developed two methods, each intended to be a part of the *systems* used to manage product transitions, to help assess and account for the uncertainties stemming from market, product, and marketing factors. The first method, the Product Transition Index, divides a transition into eight vectors and calculates the energy in each vector, driving the transition's pace and ultimate success. The second is the application of an idea that came out of research at Stanford and Hewlett Packard, i.e., Transition Playbooks. These are designed to coordinate organizational response to risks. Other methods we have considered in our research include range forecasting and the use of market mechanisms. In this paper, we touch on each of these methods, describing our experiences with them to date and considering how the collection of ideas addresses the overall challenge of transition management.

SOURCES OF UNCERTAINTY IN TRANSITION MANAGEMENT

Case studies of past product transitions at Intel and other companies have revealed many failure modes [1]. Among the more common are the following:

- Weaker than expected demand for a new product, causing a surplus of new product and a shortage of old product.
- Stronger than expected demand for a new product, causing a shortage of new product and a surplus of old product.
- Delayed supply for a new product, causing a shortage of old product and potentially depleting inventories of any product to sell.
- Weaker demand for the old product in anticipation of the new product, causing a surplus of old product. If the new product is then delayed, it is known as the "Osborne Effect" and can drive a company out of business for lack of product to sell [2].

Three factors are at work in these scenarios: market risks, which are the demand for old and new product; technology risks, which are the supply of the old and new product; and the alignment of demand and supply. Although weak demand or supply can be damaging, we have observed that a large gap between demand and supply tends to be the most damaging outcome.

Another way to slice the uncertainties in transition planning is a four-layer model consisting of market, product changes, marketing actions, and systems. A description of each layer and key findings from our case studies follows.

Market

The best understood and most documented uncertainties in forecasting are market forces. For that reason this layer is the least interesting in the model from a research perspective. Planning supply hinges on demand, which hinges on many market forces from macroeconomic cycles to industry specific cycles to seasonality. Since these forces are essentially outside of a company's control, the best response is modeling ranges of likely results and comprehending potential outcomes in the planning processes. The solutions we present later comprehend market uncertainty but demonstrate that it is only one of many drivers in transition planning.

Product Changes

Whenever a product changes within a given market, uncertainty results. Sometimes the product is the company's own. Other times it belongs to competitors or complementors. Product roadmaps and tactical plans should be mindful of competitive forces, and the impact of complementary products on a company's own are a key element of planning. However, the most dominant factor in transitions–one that is completely under the company's own control–is changes made to one's own products. The technology and feature gap between two generations of products and across market segments (e.g., high end, mainstream, and value products) is fundamental to sales. Numerous examples within and outside Intel demonstrate that product sales can soar or plummet due solely to competition among a company's own products.

Marketing Actions

Products cannot be brought to market without consideration of pricing and promotion, but interestingly the impact of these policies on demand is not deterministic. Due to the many factors that drive demand, predicting the exact result of a price move or an advertising campaign is improbable at best. Still, product sales can be modeled most simply as a function of capability and price, with the ratio of the two determining customer value. Our critical finding is that price is both a powerful and overused lever. We therefore looked to solutions that encourage the use of other product and marketing levers and considered the lasting repercussions of the levers that are used to manage a transition.

Systems

The most interesting source of uncertainty in transition planning turned out to be the very processes and tools used to manage the business. Forecasts proliferating through our sales and marketing and business planning functions are judged four or more times between customers and the supply network. Each layer of judgment

hinges on local knowledge, local policies, and local indicators and incentives. We observed that the propagation of these datasets at best involves lag, judgment, and some loss of context–the strategy and uncertainty behind the data–and at worst may include clear bias and gaming. To clarify, any given team routinely judges forecasts up or down, always based on experience and available information, because the incoming information is deemed too high or low, or because the outgoing forecasts are expected to be judged up or down by a subsequent owner.

Another key finding is that the forecasting systems tend to be noisy. One fundamental cause seems to be the use of point estimates for sales by product SKU, family, or manufacturing start. We observed that a series of updated point estimates conveys uncertainty through the volatility of the signal over time. In this method quantifying the uncertainty requires tracking information over time, which is too broad a view for the busy planner. Instead, planners tend to chase the dominant data point in the forecast, something we call "change from prior." The critical information in an updated forecast is not the actual forecast (typically unit sales) but rather the delta or "change from prior" since the last forecast. The phenomenon of each new forecast or supply network plan reacting to the change from prior propagates noise through the system. Instead of ignoring insignificant volatility, planners often transmit it.

Looking across these sources of uncertainty led to the discovery of an additional source, actions implemented by the organization (product, marketing, or supply changes) intended to manage the transition. We found that actions taken in different groups across the organization were not always planned and executed in synch, so the net impact of these actions sometimes manifested itself in the form of unexpected results.

As our research team entered the solution space we considered methods, some developed internally, some discovered or recommended to us along the way, that we believed would help manage or even reduce the uncertainties affecting our product transitions.

SOLUTIONS TO AID TRANSITION PLANNING AND FORECASTING

The following principles were developed out of the case study work to guide our general approach to improving planning and forecasting.

- Global strategies should drive local actions that support global optimization. Local policies and incentives should be flexible, shifting with global strategy.
- Forecasts should convey a contextual layer above the numbers. Each forecast handoff subjects data to loss of context and a new round of judgment. Context–strategy and uncertainty–should be communicated across internal and external interfaces.
- Processes should be designed to identify and attenuate noise. "Over-nervous" planning reacts too strongly to short-term trends and aggressively closes gaps, sometimes leading to oscillation and amplification.
- Organizational processes should systematically manage uncertainty. Contingency planning, scenario planning, and range forecasting improve positioning and reaction speed.
- Market assessment and response (strategic and tactical) should be as systematic and repeatable as possible, codifying tribal knowledge and enabling new types of analysis. It should capture the past and present sufficiently well to help predict and manage the future.

Product Transition Index

Based on these principles, we developed a planning approach consisting of three methods, each used to encourage collaboration and coordination among functional teams across the organization. The first, Product Transition Index (PTI), is an assessment tool used to gather information about the product transition. PTI is a model containing eight vectors that dictate the pace and success of a transition. A total of 65 factors identified in our research are scored to complete the PTI, and the scoring process requires integrating the knowledge of teams across sales, marketing, planning, manufacturing, and engineering. Table 1 lists the vectors in PTI and provides a brief summary of key factors within each vector.

Table 1: PTI vectors and summary of key factors

PTI Vector	Summary of Factors
Product Capability	performance, features, usability, compatibility; anticipated product longevity, quality, reliability
Product/ Platform Pricing	cost of the product itself, the platform that uses the product, the process of adopting, manufacturing, or integrating the product; historical and expected price stability; costs of competitive products
Timing	time since last product introduction, anticipated time to next product introductions, age of the installed base, timing of competitive introductions
Marketing Indicators	product alignment to market segments, breadth of product applications, potential market size, timing and aggressiveness of promotion, end customer impression of product
Environment	economic conditions, customer demand trends; health of own company, value chain partners, competitors
Competition	performance, features, market perception of competing products, competitors' manufacturing capability and capacity, and alignment between competitors and value chain
Value Chain Alignment	cost and complexity facing value chain, reliance on new standards/technology, reliance on suppliers to deliver, perception of product attractiveness, balance of customer pull versus own push
Internal Execution	manufacturing risks such as design readiness, capacity, process health; clearance of regulatory hurdles, sourcing risk for materials

A scored PTI shows the relative energy imparted to the transition by each vector. Scores range from cold to hot with the center of the range aligned to the typical past transition in that product family. If all vectors are scored down the middle, the product transition should be expected to unfold at a rate on par with the average of past transitions. Hotter scores predict a faster transition, colder scores a slower transition. A faster or slower transition is not necessarily better or worse. Rather, the PTI should be assessed for the overall balance of demand and supply for the old and new generations of product. A scenario of slow demand and slow supply is easier to manage than one of fast demand and slow supply or vice versa. The scoring process should therefore be used to identify risk factors in demand, supply, and demand-supply alignment that could derail the transition.

Transition Playbook

The second method in our planning solution is Transition Playbook, an idea developed in research at Stanford and Hewlett Packard [3]. The intent of the playbook is to enable strategists and managers to map out the tactics the organization will use to respond to risks that might impact the transition. Sports teams develop plays so that in the stress and time constraints of a game tactics can be invoked without delay and the team players can perform with nearly perfect synchronization. A playbook in business likewise encourages advance planning and analysis so that the business functions can respond quickly and in concert to keep the transition on track.

Playbooks (see Figure 1) consist of a primary transition strategy, transition risks, and contingency transition strategies. The primary strategy is formulated based on the output of the PTI process and the market strategies for the product. We observed that market strategies for new products commonly have a blend of three objectives: profit, market segment share (unit sales), and market or technological leadership. The most critical step in developing the playbook is to understand the weighting of these (and perhaps other) objectives and to understand which results will constitute a successful transition. The PTI results shed light on how readily these objectives will be achieved and identify the risk factors that could prevent a successful transition. The primary strategy implicitly includes both tactics that lead to success and preventive strategies aimed at avoiding the more threatening risks.

Transition risks generally fall into four categories: new product demand greater than or less than supply and old product demand greater than or less than supply. We have found that the mapping of risks identified in the PTI scoring process to these categories is straightforward. It is impractical to account for all risks in a transition, so risks must be prioritized. We relied on a standard Intel definition of risk (probability x severity) to guide prioritization.

Contingency strategies are comprised of both preventive and mitigation strategies. If a risk is seen on the horizon as the transition unfolds, it can potentially be circumvented. But if the risk is already imminent, then the remaining option is to minimize its impact. Some contingency strategies are specific to risks while others are targeted at category of risk. So, the risk of a certain technical glitch likely requires a direct response to the glitch. The risk of demand exceeding expectations for a generation of product could trigger any number of tactics designed to speed product delivery or perhaps shift demand to another product (ideally not the competitor's).

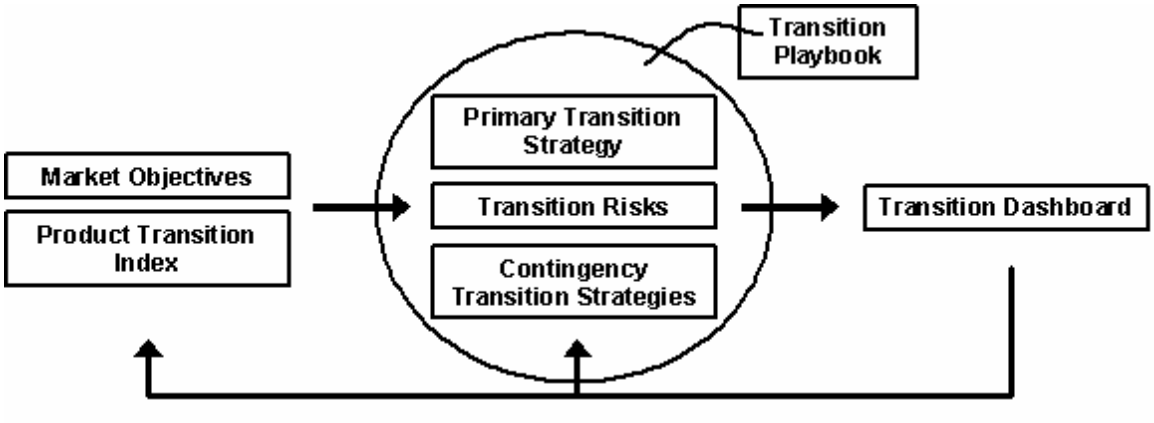

Figure 1:Transition playbook planning system

Defining primary and contingency strategies involves choosing from many potential tactics. As the business develops strategies it is helpful to refer back to the PTI model for guidance. While two of the PTI vectors, environment and competition, are largely outside of the company's control, the remaining vectors contain a number of levers that can be used to influence the transition. Table 2 lists a matrix of control by vector that guides application of levers.

Table 2: Transition control by PTI vector

PTI Vector	Complete	Long Term	Indirect	None
Product Capability	✓	✓		
Product/Platform Pricing	✓			
Introduction Timing	✓	✓		
Marketing Indicators		✓	✓	
Environment			✓	✓
Competition			✓	✓
Value Chain Alignment		✓	✓	
Internal Execution	✓	✓		

Transition Dashboard

The third method in our solution is the Transition Dashboard, which is intended to monitor the risks identified in the playbook. The dashboard tracks the key risks to demand, supply, and demand-supply alignment for both the new and old products and should be used to trigger execution of the playbook. An ideal dashboard is tied to execution of increasingly aggressive tactics within the contingency strategies as the transition moves farther off-track. It also indicates when the existing playbook is no longer able to satisfy the success criteria for the transition. In such a case, it may be necessary to revisit the market objectives or the PTI assessment for the product and then revise the playbook.

One of the clearest benefits of a transition playbook is the definition of measured responses. We observed that Intel employees are highly adept at closing gaps, so adept that in transition management gaps are sometimes closed so far as to open an inverse gap. Within a fairly short span of time inventory shortages can turn into surpluses and vice versa. Using a dashboard with well-defined triggers to invoke appropriate and measured contingency strategies can help keep the supply network out of a state of oscillation or even bullwhip.

Integration with Other Solutions

The research team developed a new approach to forecasting by integrating the PTI scoring system with diffusion modeling. Our research partner, Paulo Goncalves at the University of Miami, developed system dynamics models based on the equations from epidemiology applied to product and technology diffusion by Frank Bass [4]. The first step of this method involves fitting past transitions in similar product families to the diffusion models. The set of parameters (market size, coefficient of innovation, and coefficient of imitation) from past products provides a range of likely parameters for the new product. A range of potential diffusion curves can be calculated directly using the system dynamics model. However, each product transition is unique, having characteristics that make it behave differently from past product transitions. We capture these differences using the results of the PTI assessment for the current product (which implicitly compares the current product to past products). The scores from PTI are used in the model to calculate the attractiveness of the new product relative to the company's old product and to competitive products. The attractiveness is then used to modulate the diffusion curves, and the sensitivities of unit sales to various factors

in the model can be tested using Monte Carlo techniques. While this technique holds promise, the lack of readily available price data for historical products has been an obstacle preventing precise calculation of attractiveness as a function of price. Nonetheless, the concept holds promise for future application.

The playbook method is a natural bridge to range forecasting. It was noted earlier that Intel's traditional forecasting systems are based on point estimates (from a statistical perspective the estimates are most analogous to expected value). Playbooks can be thought of not only as planning maps but also as decision trees. With each risk comes a probability of occurrence and a range of potential impact on sales. Similarly, each contingency strategy has a probability of being invoked and an expected range of efficacy. A playbook analysis might reveal that a transition faces an aggregate risk of 60-80% that new product sales will come in below expectations, and a 45-65% chance that supply will come in below expectations. Numbers can also be expressed in pure units. So, the playbook might reveal a 50% probability that Q2 sales of the new product will fall within 6.0m and 8.5m units. Such range forecasts can be used broadly, and a team of demand and supply planners at Intel has begun integrating range planning into some of our systems in the past year.

The benefits of range planning are threefold. First, the organizational mindset is moved from artificial certainty to uncertainty. Rather than building to hit an expected value outcome and then chasing that outcome as it changes, the supply network can build to cover a range of outcomes. The focus of planning shifts from guessing and optimizing the expected outcome to analyzing financial and operational performance across a range of outcomes. The final decision on which parts of the range of outcomes to cover becomes a largely strategic decision based on the results of these analyses. Second, the amount of noise in the forecasts is reduced because the range forecasts can absorb some degree of volatility period to period without adjustment. Less energy is devoted to processing noise. Third, range forecasting encourages portfolio management of capacity and materials. The blend of fixed (lowest cost, dedicated use), fungible (higher cost, use across product lines), and flexible (higher cost, shorter lead time) capacity and materials helps to cover different outcomes with varying degrees of cost and risk.

Another area we have researched for the past few years has involved the use of market mechanisms as substitutes or complements to traditional hierarchical forecasting systems. As PTI and playbook are intended to aggregate and coordinate information from across the organization, market mechanisms may also be used to aggregate knowledge and provide better insight on demand trends. We are preparing to launch a series of market experiments to assist planning for product families that have proved challenging for our traditional forecasting processes. The market forecasts will be evaluated based on their accuracy, volatility, and the speed with which they react to market significant events. Much of our learning in the area of markets has come from the University of Iowa Electronic Markets [5] and the forecasting experiments performed at Hewlett Packard in conjunction with the California Institute of Technology [6].

RESULTS OF INITIAL PILOTS

Application of PTI began in 2004, a few months prior to the release of a new generation of product. Intel's central marketing and planning organization, the team most directly responsible for managing demand and supply alignment, used PTI as a process through which to collect information about the new product and the transition. We organized sessions with several teams from our sales and product marketing organizations, having each team score and provide comments on the factors for which team members had information.

The assessment process revealed several interesting insights. First and foremost, the two marketing teams representing key components of the new platform each felt that the other team's component would be the one to drive sales of the platform. We interpreted that as a bad sign because each team felt that their own product would not be the main driver. Second, the prevailing wisdom expressed both outside and even inside these sessions about product strengths and weaknesses did not match up to factor by factor analysis within PTI. A few areas that were widely considered strengths could not be justified as strengths based on hard data. Third, sales representatives alleviated fears that technical issues or manufacturing challenges might slow adoption of the product, but they had insight that the overall cost of the new product platform might impede sales within certain market channels.

The resulting PTI scores showed the vectors driving the speed of the transition to be environment (hot economic and recent sales trends), internal execution (product ready for moderately fast ramp), and marketing indicators (solid alignment to some market segments). Product capability and competitive factors were also somewhat positive, while timing was neutral. Vectors inhibiting the rate of transition included value chain alignment (typically strong support from some customers but rather weak support from others) and, to a lesser degree, price (platform cost).

Based on the PTI assessment and a comparison to actual sales results from a product released the year prior in the same family, we determined that the consensus forecast was optimistic. If we define the best whisper forecast

among central planners for sales over the next two quarters as x, the official forecast being published and used to drive supply was about 1.2x. The estimates coming in from the sales organization were fairly volatile from month to month but ranged from 0.65x to 0.9x. Based on the sales organization's past forecasting patterns, the central planning group felt that these figures were pessimistic. After completing the PTI assessment, we published a report about six weeks prior to launch stating that sales were unlikely to exceed 0.93x and would probably come in lower. Given all available information, we stated that only an improbably large second quarter after release could result in a higher sales total. Within about six weeks after launch the official forecast dropped to approximately 0.9x and continued to decline. By the beginning of the second quarter after launch the forecast accurately called the final result of 0.79x.

In hindsight, the PTI assessment enabled the pilot team to identify the strongest drivers and inhibitors of the transition. Considering all factors affecting the transition and comparing it to a recent transition in the same product family we were able to generate a prediction that was accurate enough to benefit the bottom line through better allocation of factory capacity and sound inventory planning. The participants in the process from the central planning team felt that in comparison to past transitions the PTI process brought better insight and enabled better forecasting. As work on this transition began to slow, the team promptly began discussing application of the method for the next major transition.

In 2005, we began applying the playbook method with a different Intel business unit. The senior management team of this unit requested an assessment of the product and technology roadmap against the direction of the overall market and the strategies being employed by competitors. To tackle this problem we combined the playbook approach with a scenario planning process that has been applied at Intel for the past five years. Scenario planning considers long-term business strategies and product roadmaps against potential future states of the market. Representatives from across functional teams work together to envision potential future market states, which are then used to script possible story lines for Intel's businesses. We felt that combining this approach with the playbook approach would bring a complete vision of how the entire business fits together. A product roadmap is a series of transitions, and analyzing each transition as a standalone event and as part of a five-year business plan seemed a sensible approach. The scenario planning piece helped define market objectives, primary strategies, and risks for individual transition playbooks. In return, the playbook enabled more actionable output from the scenario planning process. Indicators of important market shifts can be included in the dashboard and used to trigger contingency plans within the playbook.

The output of the scenario planning process emphasized the importance of the upcoming product transition in the greater context of the business. Everyone left the room with a clearer definition of success for the overall business and for the product transition. A playbook for the upcoming transition is now in development. We have analysis covering eight dimensions in the playbook, including the impacts of these factors: qualifying various SKUs for production and sale, design wins with various customers, timing of product launch, and manufacturing process health. The best and worst potential outcomes (in unit sales for the new product) have a ratio of 4:1, which at face value makes for difficult supply network planning. But, within that range the business now understands the influence critical drivers will have on demand and supply and can begin pulling levers months to quarters ahead of product launch to drive a successful transition and keep demand and supply aligned.

CHALLENGES

The greatest challenge to developing and proliferating new planning and forecasting methods is getting the methods piloted in an operating and bandwidth constrained organization. Everyone involved in operational planning has a full workload and is already using a suite of applications and processes to do their job. We encourage grass roots participation and work our way to organization-level pilots by starting within the organization and working up to senior management. Our partners in business groups take the methods to their own managers as potential solutions to recognized problems, encouraging employees to participate and fit R&D into their otherwise operationally focused schedule. Finding organizations willing to partner on a pilot takes time and quite a bit of selling, but an initial success in one pilot starts to open other doors.

As we near the piloting of market solutions we face more specific challenges. A participant base of at least 20-30 individuals is required for good results. Recruiting these participants, who will be expected to remain involved for more than six months, requires a blend of marketing and incentives. We will then need to demonstrate the exact benefits of their participation to the company in order to retain interest.

Another challenge is identifying suitable metrics for testing solutions. Obvious choices include operational metrics such as inventory levels and return on invested capital, but it is difficult to isolate the effects of the new methods among all the other factors in the environment. We are also looking at forecast signals to see improvements in accuracy, volatility, and timeliness

(response to events). Direct feedback from partners and participants is highly valuable. If they state that using the process brought higher confidence, enabled better judgment, enabled anticipation of risks and responses, or reduced the workload to produce a forecast, then a clear benefit has been achieved even if it is not purely quantitative. The ultimate indicator of benefit is whether we achieve successful transitions and whether we keep transitions on track using the methods, and we will certainly be tracking that indicator through all future activities.

A final challenge is porting new concepts, methods, and processes to next-generation tools. Research in information technology has a limitation in that product and application roadmaps are largely vendor driven. The choice of building home-grown solutions or sticking to vendor roadmaps always exists. Our current approach is to build simple tools for the purpose of piloting new methods while leading our business partners to develop new requirements for vendor-developed tools based on their experience with the pilots. Pulling vendors directly into research is another option, but the pros and cons are many. In some cases we will likely choose to engage vendors directly, but thus far it seems even layering simple tools above our more robust operational systems can yield good results.

SUMMARY

Planning and forecasting have become exercises of data sets and spreadsheets. The numbers themselves, judged and translated three or four times between customer and supply network, lose the business context of strategy and uncertainty. Along with hard data, the entire chain of customer fulfillment, from sales to marketing to planning to distribution, needs to grasp this context in order to manage the transition to the right global indicators and results.

Revenue, profit, and market position are optimized only when the right products can be sold at the right time at the right price. The uncertainties posed by markets, product changes, marketing actions, and the systems used to manage the business make this outcome largely unattainable.

Based on our case studies we developed PTI as a structured and repeatable method for evaluating the state and impact of market, product, and marketing factors. PTI helps aggregate, document, and communicate information from around the organization. Playbook then helps the organization identify and determine how to respond to risks in a rapid and coordinated manner, with the dashboard guiding navigation through the playbook.

Range forecasting complements statistical and Monte Carlo methods and produces more stable forecast signals with embedded uncertainty. Playbooks can be used to produce range forecasts, as can market mechanisms. A range forecast encourages more intelligent and strategic positioning of capacity, materials, and inventory and discourages chasing best guesses of demand.

Market mechanisms speed the transmission of demand signals and more often than not beat the accuracy of traditional forecasting systems. We plan to test market-based systems and compare the accuracy, volatility, and timeliness of their output to our standard forecasting systems.

Each of these solutions has been or will soon be piloted within Intel as our many business units seek to manage uncertainty more effectively. The results of our pilots with PTI and playbook have been encouraging, and the application of market and range forecasting methods outside Intel (and within Intel to the limited extent we have tried them) has shown considerable promise. In combination the methods form an arsenal of tools to drive a more profitable business and a better positioned and strategically and financially more valuable supply network.

CONCLUSION

The strong focus of this work on transitions begs the question of planning and forecasting in the steady state. In reality, steady state does not exist very long in high-tech industries. Shorter product lifecycles have resulted in rather dynamic markets; managing product lifecycles is now less relevant than managing transitions from peak to peak. A product's ramp up is followed by a ramp down, and the perspective of balancing the ramp down of each generation with the ramp up of the next focuses organizational energy toward the dynamic and uncertain reality of the transition.

During our research we encountered several methodologies that use mathematical models and historical data to forecast transitions and optimize supply. While these are sound approaches they fall short if they are blind to the factors in PTI. Managing supply without regard to the particulars of demand is optimizing the wrong problem, sweating the "ones" digit while hoping the "tens" digit comes in as expected.

Similarly, planners immersed in a world of spreadsheets and point estimates may not have insight into how a transition is unfolding or how the company will react. Without the formal mechanism of a playbook to convey the risks on the horizon and who will take what action to counter them, tribal knowledge, hallway conversations, and other informal networks are used to convey context

and guide policy. Managers may work together to develop strategy across the organization, but unless mechanisms are in place to coordinate the execution of those strategies and to drive strategy into local policies and decisions, the organization is not achieving its potential level of synchronization. Individual planners need not be able to articulate the complete management strategy for the new product, but they should certainly know what to expect next and which actions they themselves should take if the transition starts to go off track.

One capacity planner told us that at the end of the day models developed within the supply network are as accurate and only a fraction as volatile as the signals from the demand side of the organization. In other words, ignoring the demand signal until the time to build product draws near works just as well. If demand information is to be used to advantage, the supply network must perceive it to be a credible source of information. The PTI and playbook processes, in combination with range planning and market mechanisms, provide opportunities to make demand forecasting more structured, stable, honest, repeatable, and timely. The playbook also offers marketing, planning, and manufacturing teams a means to more effective coordination through advance planning.

Intel's Customer Fulfillment, Planning, and Logistics organization has articulated an objective of shortening the distance between the customer and the supply network. The methods described in this paper are among the options available to do exactly that.

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