1. Seagate's Strategy and Operational Execution [20 min]

1. *What is Seagate's competitive strategy?*

- Variety: offer the broadest rang of disc products available
  - In all 4 segments:
    - » Personal computers (desktop & mobile): price sensitive
    - » Workstations: performance and price
    - » Server/Multi-user: mostly performance, reliability and capacity
- Quality: innovation ("being among the first to market") and performance
- Low price/Cost: through high-volume production
- Timeliness: wants to be "among" the first to market

2. *What about the competition?*

- 2 types of competitors:
  - independent manufacturers: Seagate ($8.9B), Quantum ($5.3B), Western Digital ($4.1B)
  - 'captive' disk drive manufacturers (sell also the end-product computer systems): IBM, Toshiba, NEC, Fujitsu.
- *Difference?*
  - Captive producers have deeper pockets + are the customers of the independent manufacturers + can be direct competitors (IBM also sells to 3td parties)
- Trend?
  - Towards consolidation in the industry because of *highly dynamic environment:* key is the rapid, ongoing technological change ("new generations"). The density doubles each year (faster than Moore's 18 months in CPUs!).
    - » This allows fewer parts/disks and hence lower costs.
    - » Larger capacities feed a rapidly changing customer needs
      - "hunger for capacity"
      - smaller and more mobile and removable disks
  - leading to
    - » history of declining product life cycles and prices
  - taking a toll, especially on companies with small market share
    - » 59 companies manufactured rigid disk drives at the beginning of the 1990s, but only 18 active manufacturers remained in 1999, down to from 1998! (source: DiskTrend industry report)
    - » In 1999, overall leader was IBM (27% global share, including captive and noncaptive), followed by Seagate (20%) and Quantum (12.4%)

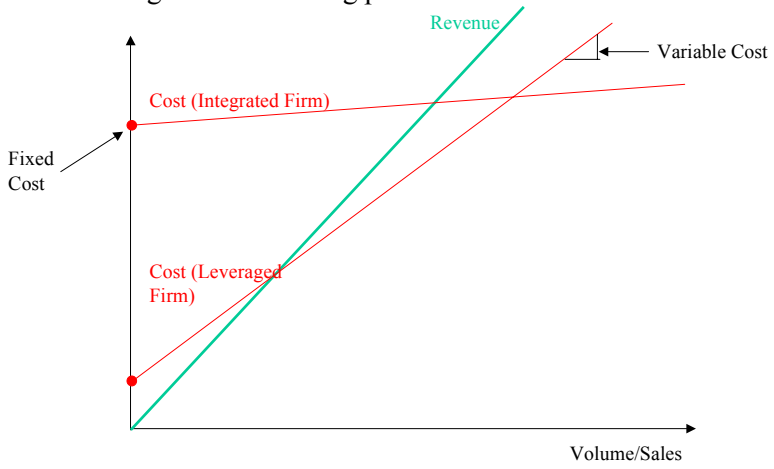
- This is an industry where one makes "big bets" on new products and technology that can make or break the company.

3. *Competitor Quantum (6000 employees, $5.3B) uses Matsushita as manufacturing partner. Why does Seagate follow a strategy of vertical integration?*

- Fact: The cost, quality and availability of certain components including heads, media, ASICs (application specific integrated circuits), spindle motors, actuator motors, printed circuit boards and custom semiconductors are critical to the successful production of disc drives.
- Pro's: vertical integration has allowed Seagate to internally manufacture substantial percentages of its critical components other than ASICs and motors. The Company's objectives of vertical integration are
  - to maintain control over component technology, quality and availability,
  - and to reduce costs.
- Con's: This strategy entails a high level of fixed costs and requires a high volume of production to be successful. During periods of decreased production, these high fixed costs in the past have had and in the future could have a material adverse effect on the Company's results of operations.

4. *What is the difference in cost-structure and risk between Quantum's and Seagate's business model?*

- Quantum = leveraged
  - Low fixed cost, at the expense of higher variable cost
- Seagate = integrated
  - High fixed cost with low variable cost
- Here I bring in the following picture to discuss the difference in risk:



  - Leverage = low risk (low break even), but lower profts in good times
  - Integrated = high risk, but higher profits
- *What does this mean for Seagate's risk exposure to demand uncertainty?*
  - Uncertainty/changes in volume have big impact on Seagate's bottom line. I stress that, therefore, hedging risk can provide substantial improvements.

- Update: on April 2, 2001, Maxtor bought Quantum, creating what Maxtor calls the world's largest disk-drive company.

5. *What are Seagate's key capabilities?*
   - Development of new technologies
   - Development of new products
   - High volume, low cost production

6. *How does its manufacturing strategy and processes support this corporate strategy of vertical integration?*
   - Key is to have low variable cost and to be able to sustain high volume to arrive at a reasonable *average product cost*
   - Tailored implementation:
     - FA&T is in-house and therefore must be high-volume, low-cost→Far-East production for low marginal cost
     - Vertical integration *only* of selected key components:
       - » Heads (three steps: wafer production, slider fabrication and head gimbal assembly)
       - » Substrate finishing = machined, plated and polished of blank substrate
       - » Media mfg = deposit magnetic storage alloy layer + coating on finished substrate→assure surface smoothness and quality assurance
       - » Design of ASIC controllers
     - Establish key vendor relationships to purchase less essential components:
       - » Blank substrates: the discs ("media") aluminum substrate blanks
       - » Spindle and actuator motors
       - » Production of ASICs

7. Strategic Operational Audit
   - *What do you think about the fit between strategy and Ops here?*
     - It is very difficult to be superior in these four markets, which demand different capabilities…

2. Seagate's risks exposure: *What are its major risks?* [10]

1. Demand uncertainty: impacts quantity, mix and thus revenues and costs.
   - This is *the* source of uncertainty that we will be studying

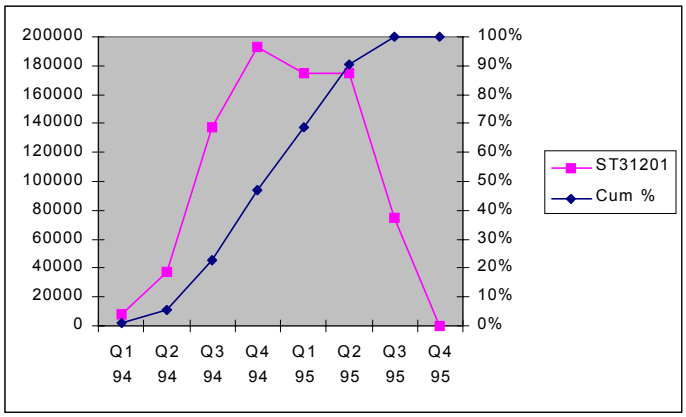
- The demand for disc drive and tape drive products depends principally on demand for computer systems and storage upgrades to computer systems, which has historically been volatile. Changes in demand for computer systems often have an *exaggerated* effect on the demand for disc drive and tape drive products in any given period, and unexpected slowdowns in demand for computer systems generally cause sharp declines in demand for such products.
  - Refer to the BullWhip effect (Ch 10 in MBPF)
- In addition, Seagate's future success will require, in part, that the market for computer systems, storage upgrades to computer systems and multimedia applications, such as digital video and video-on-demand, and hence the market for disc drives, remain strong.

2. Competition: Price competition due to over supply & new products

- The data storage industry has been characterized by periodic situations in which the supply of drives exceeds demand, resulting in higher than anticipated inventory levels and intense price competition. Even during periods of consistent demand, this industry is characterized by intense competition and ongoing price erosion over the life of a given drive product
  - Exhibit 3 shows a 40% annual decrease in price!
- One should expect that competitors would offer new and existing products at prices necessary to gain or retain market share and customers. Seagate expects that price erosion in the data storage industry will continue for the foreseeable future. This competition and continuing price erosion could adversely affect the results of operations in any given quarter and such adverse effect often cannot be anticipated until late in any given quarter.

3. Shorter Product Life Cycles + Changing Demands

- The demand of drive customers for new generations of products has led to short product life cycles
  - *How long?* Here I show the following historical graph of production quantities of a given drive model. Clearly, most sales are made in 1 year.



  -
- Short PLC require the Company **to constantly develop and introduce new drive products on a cost-effective and timely basis**.
  - *How important then are capacity investment decisions to Seagate?*
    - » Very! Because they make these almost continually.
  - *What happens to old products? How dependent is Seagate on new products?*
    - » Extremely dependent on new high-end

- The demand of drive customers for products with ever increasing storage capacity and more advanced technology has resulted in increased dependence by the Company on sales of high capacity disc drives. The increased difficulty and complexity associated with production of higher capacity disc drives increases the likelihood of reliability, quality or operability problems that could result in reduced bookings, increased manufacturing rework and scrap costs, increased service and warranty costs and a decline in the Company's competitive position.

4. Production uncertainty

- yields (rework and scrap)
- component availability due to single or limited sources of supply
  - Seagate has in the past experienced production delays when unable to obtain sufficient quantities of certain components. Any prolonged interruption or reduction in the supply of any key components has a material adverse effect on its business, operating results and financial condition
- delays in the development, introduction and production of new products
- delays or interruptions in the production of existing products
- Timing of orders from and shipment of products to major customers

5. High fixed costs resulting from the vertical integration strategy.

- As said earlier, a strategy of vertical integration entails a high level of fixed costs and requires a high volume of production and sales to be successful. During periods of decreased production, these high fixed costs have had, and could in the future have, a material adverse effect on the Company's operating results and financial condition.

6. Foreign currency exchange risk

- This is a good point to discuss hedging with financial instruments. The idea here is to use swaps, options or forward contracts to lock-in an exchange rate. Our discussion, on the other hand, will use operational instruments (capacity specifically) to mitigate demand uncertainty
  - Clearly, the model could be applied to exchange risks
  - It is important to add that actually rather few companies use financial hedging *because it is difficult and expensive*
    - » Fact: According to Goldman Sachs, hedging $500 million worth of earnings (against the euro say) costs about $26 million.
    - » That is 5% for taking a gamble! Golman figures only 30% of US companies buy options to hedge earnings.
  - One way to avoid this messy accounting and expense is to use operational hedging. It can entail matching revenues and costs in the same currency by manufacturing and sourcing locally.
- The Company transacts business in various foreign currencies, primarily in emerging market countries in Asia and in certain European countries. The Company has established a foreign currency hedging program utilizing foreign currency forward exchange contracts and purchased currency options to hedge local currency cash flows for payroll, inventory, other operating expenditures and fixed asset purchases in Singapore, Thailand and Malaysia.
- Under this program, increases or decreases in the Company's local currency operating expenses and other cash outflows are partially offset by realized gains and losses on the hedging instruments.
- The goal of this hedging program is to economically guarantee or lock in the exchange rates on the Company's foreign currency cash outflows rather than to eliminate the possibility of short-term earnings volatility.

7. Interest rate risk:

- Changes in interest rates impact Seagate's investment portfolio and long-term debt obligations.
- Seagate does not use derivative financial instruments in its investment portfolio.
  - It places its investments with high credit quality issuers and, by policy, limits the amount of credit exposure to any one issuer.
  - As stated in its policy, the Company is averse to principal loss and ensures the safety and preservation of its invested funds by limiting default risk, market risk, and reinvestment risk.

3. Seagate Process Development Strategy [5]

1. *Who and where are processes developed?*

- Process engineering groups are located with the product development groups and the reliability engineering groups in the US sites

2. *But production happens in the Far East?*

- Yup, after proto-type production lines are developed in the US, the *whole line (tooling etc.) and the process engineers* are flown to the Far East where development of the volume processes is completed at the volume manufacturing sites

3. Discussion of pro's and con's of this R&D strategy

- Instructors can elaborate here at infinitum about the qualitative pro's and con's, discussing knowledge transfer, learning, communication and organizational structures.
- Pros:
  - Use of 'focused plants' allows streamline ops: production runs are less likely to be interrupted for experiments, prototype runs, etc.
  - Allows low cost manufacturing, while keeping US plants focused on innovation and R&D.
  - Allows location of R&D closer to OEMs; anticipates and understand customer needs
  - Can perfect product and process before exporting it, reducing delopment and manufacturing costs.
  - Multi-country production hedges country-specific risks
- Cons: increased transaction and coordination costs:
  - Longer leadtime to market
  - Less knowledge sharing between product & process designers in US and volume manufacturing in Asia.
    - » Geographical and language issues exacerbate this learning problem
    - » Hard to benefit from value and reverse engineering to incorporate lower cost raw materials and volume manufacturing processes.
      - True, but the product life cycle here is so short that this becomes less of an opportunity.

- Transitioning new products from pilot to volume production plants entails risks on yields etc. The company needs to build expertise on such transfers and needs strict process controls
  - » Note that automobile companies and many other industries follow a similar strategy. The difference, however, is in frequency: Seagate does this almost continuously, while cars do it perhaps annually.

4. Chasing the low cost country

- A discussion can be held here about the strategic sustainability of going for a low wage country
- After going to Singapore in mid 1980s, competitors followed; wages rose, labor became more constrained, the advantage eroded
- Hence, jump to another country and the cycle continued.

4. Capacity Planning and Capital Investments [5]

1. *Are these decisions infrequent?*

- Not at all! Given the short life cycle + Seagate's commitment to technology, Seagate *continuously* makes capital acquisition decisions

2. *How does Seagate decide on capacity investments?*

- Demand forecast (stochastic) → single demand plan (deterministic)
  - Use D for demand (a random variable)
- Master Production Schedule
  - Use x for production vector
- Derive capacity requirements
- Check with plants + negotiate + iterate
  - Plant managers are thus "empowered" to challenge their production allocations when they feel they are "infeasible."
  - *What incentives does give for improvement in process efficiency or to make stretch goals?*
- In three days, MPS is finalized [which is updated frequently]
  - Both serve as an efficient coordination tool for corporate wide capacity planning
  - This is what we call "coordinated planning"
- Last step is that senior management "perturb" the capacity plan to make it more profitable (see below)

3. *How do MPS folks allocate demand to plants?*

- By rule of thumb.

- No cost or profitability information is used!
  - ONLY 14 people in Seagate know all product margins! (I was told in 1994)

4. *Where is cost and margin information used?*

- Only for new product introduction

  product line costing and profitability is assessed by the product developers and product line management

- And the decisions (including the 'hedging' or 'perturbation' decisions in the case) by senior management

5. *What happens if MPS is infeasible?*

- Manufacturing facilities do their best to meet the MPS whatever the cost of flying equipment from place to place, or acquiring new capacity.
- Eventually, all major decisions are finalized by senior management, but this is generally after some iterations of the MPS

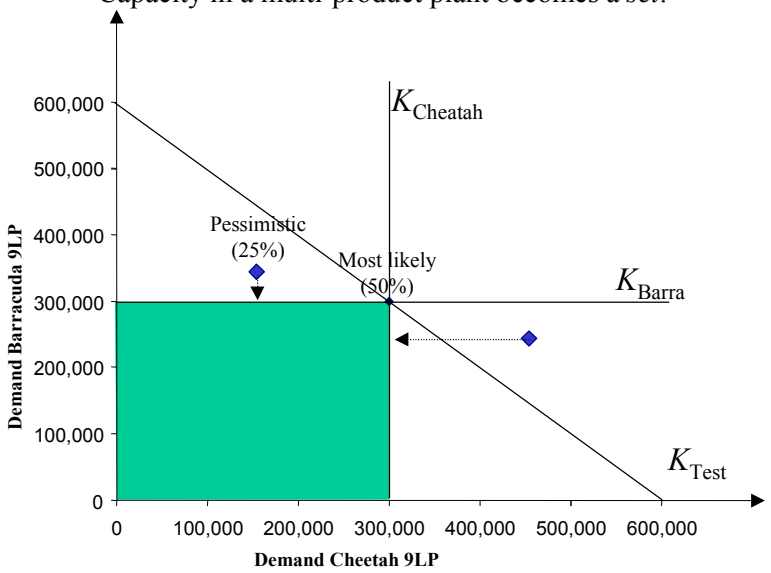
5. Capacity Investment and Hedging [30]

1. Class plan and expectations

- Most students will get the evaluation of the current CAR correct
- Most then will identify the plan $K =$ (450,350,700) as the "optimal" hedging plan
  - Smart folks will say: "Margins of \$300-\$400 clearly outweigh the capacity costs of \$30, \$20 and \$80 per unit." Hence, newsvendor logic tells us to go "all the way" and cover all demand scenarios.
  - This actually gets to most of the insights, yet it is worthwhile to pursue the multi-dimensionality issue here. That is what leads to hedging and the "true" optimal capacity plan.
- Experienced students may put the problem in Excel and use Solver.
  - Depending on how it is modeled, Solver finds the optimal solution or comes up with something weird.
  - In any case, I do the marginal analysis on a gird on a transparency in class.
  - The key is the intuition behind the solution, not the technique itself.
- This is definitely a good place to talk about whether a firm should satisfy all demand or not
  - Typically demand shortage costs are used in math programming models, somehow incorporating "next-period" effects on revenue. Yet, one can debate what to do with products that really live only 1 period.
  - Also, it is true that one does want to keep the big customers (OEMs), but that may have been reflected in the "sure part" of the demand and the volatility may represent a lot of smaller, opportunistic customers

2. Evaluation of current CAR capacity proposal

- Capacity diagram
  - Production quantities are constrained by three resources:
    - » Cheetah FA: $x_C \leq K_C = 300$
    - » Barra FA: $x_B \leq K_B = 300$
    - » Joint Test: $x_B + x_C \leq K_T = 600$
  - Good question to ask here is: *What is the capacity of this process?*
    - » It no longer is "600 drives", but the mix matters
    - » Correct answer is any product combination inside the green rectangular box. Capacity in a multi-product plant becomes a *set*.



- Contingent production decisions (dotted arrows) and operating profit
  - I make a big deal here about differentiating between *demand* and *sales/output*. The difference comes from capacity, which acts as a "filter" on demand by projecting it onto the capacity boundary
    - » *How project? How find contingent production?*
      - Maximize operating profit
      - In this case: simply prioritize the higher margin product (Cheetah)
  - This system behaves approximately like *make to order*
    - » Well, from an investing perspective it does, because we must invest 6 months before we start production.
    - » Typical newsboy logic, although this is an approximation for aggregate planning
      - One could allow inventory buildups and/or capacity adjustments.
  - Pessimistic scenario:
    - » $x_1 = (150, 300)$

  - » $\pi_1 = m' x_1 = (400, 300)' (150, 300) = \$60M + \$90M = \$150M$
- Most likely:
  - » $x_2 = (300, 300)$
  - » $\pi_2 = m' x_2 = (400, 300)' (300, 300) = \$120M + \$90M = \$210M$
- Optimistic:
  - » $x_3 = (300, 250)$
  - » $\pi_3 = m' x_3 = (400, 300)' (300, 250) = \$120M + \$75M = \$195M$
- Expected operating profit
  - » $E\pi = 25\%*\$150M + 50\%*\$210M + 25\%*\$195M = \$191.25M$

◆ Investment Return
- Investment Cost = $\$40M + c'K == \$40M + \$9M + \$6M + \$48M = \$103M$
- Expected Value $EV = \$191.25M - \$103M = \$88.25M$
- ROI = 88.25/103 = 86%
  - » While this is high, one should not forget that a substantial part of the profits must be used to recoup substantial R&D and corporate expenses!

◆ *What is the problem with this capacity plan?*
- Capping production → loosing customers

3. Most likely approach taken by students: "total insurance" or "cover all contingencies"

◆ Most smart practitioners will recognize that capping production is not smart in this intense environment. ("Once you loose customers, you may never get them back.")
- You cannot afford that and thus they suggest the "cover all contingencies" capacity plan: $K = (450, 350, 700)$
- Mathematically curious (and adept) students will investigate the "full combinatorial array" of capacity choices: $K_C = \{300, 450\}$, $K_B = \{300, 350\}$, and setting either $K_T = K_C + K_B$ or allowing $K_T = \{600, 700\}$

◆ Valuation of "covering all contingencies" plan:
- We can now always produce to demand.
  - » Expected sales = expected demand = (300, 300)
  - » Thus, like the most likely scenario above
- $E\pi = \$210M$
- Investment cost = fixed cost + assuming straight-line expansion costs
  - » Reasonable for testing capacity because tester are just zillions of computers, debatable for FA lines (yet OK given the 1/6 and ½ increments)
  - » In any case, it's the simplest assumption + it's reasonable

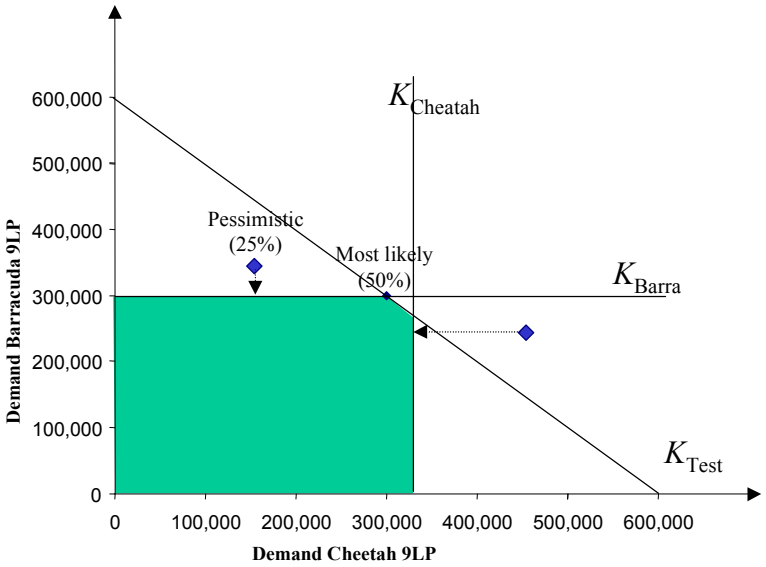
  - » $c'K$ = \$9M*(450/300) + \$6M*(350/300) + \$48M*(700/600) = \$13.5M + \$7M + \$56M = \$76.5M
- Expected Value EV = \$210M - \$76.5M - \$40M = \$93.5M
- ROI = 93.5/116.5 = 80%

4. *What is the appropriate objective: profits or ROI?*

- Students will notice that although EV increased, ROI decreased. Some may say: stick with old
- *What would you choose: ROI or Profits?*
  - Typical finance story: you have two investment options
    - » Lemon juice bar on the street: investment about \$1 and returns may be \$10→ very high ROI = 1000%
    - » Big company investment: investment almost \$1M and returns may be \$100K → ROI = 10%
      - Investment in the juice bar would have yield a \$10 return on my investment (of which \$1M-\$1 is sitting idle)
      - ROI = 1/1M = 1ppm
  - Thus, depending on the available investment capital and the available investment option, you should take into account the absolute value of the returns
  - → use NPV
    - » in this single period model, NPV equals expected value
    - » it also makes sense to maximize profits to finance R&D
- Correct reasoning requires analysis of the ROI of the *marginal* investment:
  - Marginal EV = ΔEV = \$93.5M-\$88.25M = \$5.25M
  - Marginal investment cost = ΔC = \$76.5M - \$63M = \$13.5M
  - ROI on marginal investment = 5.25/13.5 = 39%
    - » Clearly less than the overall 88% earlier
    - » Typical due to decreasing returns to investment
  - This is still pretty good and probably above the hurdle rate of most companies
- Bottomline:
  - The correct approach is to investigate the profitability of *marginal* investments!
- *What is the real trade-off in this investment problem?*
  - Balancing the cost of not meeting demand (underages) with the cost of having excess capacity (overages)
  - *Is the total insurance optimal?*
    - » Students should start noticing that perhaps we went too far!

5. Optimal Capacity Plan through Hedging

- To check whether we can improve, do a marginal analysis
- Increase K_C by one unit (measured in thousands) to 301:
  - Impact on contingent production decisions: only in optimistic case:
    - » $x_3 = (301, 250)$; $\Delta x_3 = (1, 0)$;
    - » $\Delta\pi_3 = m' \Delta x_3 = (400, 300)' (1, 0) = \$400K$
    - » $\Delta E\pi = 25\% \Delta\pi_3 = 25\% \$400K = \$100K$
  - Increased investment cost = assume incremental cost is \$9M/300 = \$30K per unit K_C (1 thousand)
  - Thus: $\Delta EV = \$100K - \$30K = \$70K > 0 \rightarrow$ it is profitable to increase K_C by one unit.
  - ROI on $\Delta K = 70/30 = 233\%$ > our starting ROI
    - » $\rightarrow$ this action increases *both goals* of EV and ROI!
- $\rightarrow$ Keep increasing K_C until when?
  - With $K_C = 301$, the capacity region increases and becomes a rectangular with a cutout corner.



  - Notice that the argument above founds its value on increased Cheetah production under the optimistic scenario. Clearly, the argument works as long as the optimistic production point falls on the Cheetah vertical capacity constraint: until $K_C = 350$.
- Should we go past $K_C = 350$? Marginal value of increasing to 351:
  - Because Cheetah is more profitable than Barra, we will always maximize Cheetah production (at the expense of Barra). Thus, the optimal optimistic production point is at the intersection of Test and Cheetah capacity:
    - » $x_3 = (351, 249)$; $\Delta x_1 = (1, -1)$;

» $\Delta\pi_3 = m' \Delta x_3 = (400, 300)' (1, -1) = \$100K$

– Increased investment cost = \$30K per unit K_C (1 thousand)

– Thus: ΔEV = \$25K - \$30K = -\$5K < 0 → it is not profitable to increase K_C beyond 350.

– ROI on ΔK = -5/30 = -1/6 < our starting ROI → also not profitable from ROI perspective

◆ Total value increase going from K_C = 300 to K_C = 350:

– ΔEV = 50*\$70K = \$3.5M

– ΔC = 50*\$30K = \$1.5M

– ROI on ΔK = 7/3 = 233%

6. Similarly:

◆ Increase K_B to 350 because

– Only pessimistic scenario is affected with an additional Barra unit

» $\Delta E\pi$ = 25% $\Delta\pi_1$ = 25% \$300K = \$75K

» ΔC = 6M/300 = \$20K

» ΔEV = \$75K - \$20K = \$55K > 0 → Yes increase K_B .until 350.

– Total value increase going from K_B = 300 to K_B = 350:

» ΔEV = 50*\$55K = \$2.75M

» ΔC = 50*\$20K = \$1M

» ROI on ΔK = 275%

◆ Change K_T Test?

– Increasing does not change any production decisions and thus does not yield any marginal value → don't increase

– Decreasing is more difficult to analyze:

» It would decrease Barra production by one unit in the likely and optimistic scenario (recall: we maximize Cheetah, thus any reduction in testing would keep Cheetah production at the expense of Barra)

» $\Delta E\pi$ = 75% (-\$300K) = -\$225K < -\$80K (= \$48M/600K)

» don't decrease

7. Value of Hedging

◆ Conclusion: K = (350, 350, 600) is optimal

◆ Total increase in expected value is

– ΔEV = \$3.5M + \$2.75M = \$6.25M

– EV = \$88.25M + \$6.25M = \$94.5M

- As a ratio: 6.25/94.5 = 6.6% increase in profitability!

◆ New ROI =

- Investment Cost = $c'K$ = \$103M + 50*\$30K + 50*\$20K = \$105.5M
- ΔC = \$2.5M
- ROI = 94.5/105.5 = 90% > 88% of base case
  - » ROI on ΔK = 6.25/2.5 = 250%

6. Coordinated Planning versus Hedging: The Conceptual Insights and Implementation [5]

1. Coordinated planning

◆ *What is it?* The mechanism of capacity planning through the MPS is a convenient method of *synchronizing/aligning* capacity decisions through the multi-product plant

◆ *What does it do in essence?*

- It lets go of uncertainty by "picking one number", the demand plan
- This is done in most organizations. *Why?*
  - » Because dealing with uncertainty is difficult and for most people too hard/uncomfortable
- This plan yields a rectangular capacity region. If demand happens to equal the demand plan, all resources will be perfectly utilized (100%)

◆ Yet senior managers know this (as do seasoned ops managers) and they "perturb" the plan that is obtained through coordinated planning just as we did above

◆ *What are the advantages of coordinated capacity planning (CCP)?*

- Most importantly: it works in practice! A clear unique plan is a good marching order throughout the organization
- It leads to full capacity utilization of all resources if the demand plan materializes
- The above matches managerial to incentives in a cost-center
  - » If the plants are cost centers, they have every incentive to find the minimal cost capacity set to make the demand plan feasible
  - » This plan looks good to accountants and finance folks

2. Hedging

◆ *What is it?* It refers to "not putting all your eggs in one basket."

- In this case, we do not plan for just one demand scenario, but we consider the likelihood of other scenarios happening.
- It makes sense to build in some *extra capacity* at places where it may provide sufficient value

» The key criterion is whether the *expected* value of the extra capacity exceeds the *deterministic* cost of investment.

» At optimality one balances the expected marginal value of extra capacity with its costs.

• Equivalently, balance opportunity costs of not meeting demand (underage) with the cost of keeping excess capacity (overage). A generalization of the one-dimensional newsvendor model

– Covering all contingencies (full insurance) is hedging, but it may not be optimal

» In this case it was shown that a marginal increase of test capacity is too expensive relative to its increased profitability

» Yet, even full insurance shows the essence in hedging (see later):

• It yields a capacity region with a "cut-off corner"

• NEVER will all resources be fully utilized. i.e., there is NO demand outcome that will force *all* resources to be fully utilized

◆ RULE OF THUMB for hedging via capacity:

– If margins are high relative to investment costs→go to full insurance

» This is what we did with Barra capacity

– Otherwise, you should back off some

» This is what happened with Cheetah capacity

– However, because the difficult interdependence of the 3 variables with the demand distribution, true optimality requires you to solve my generalized newsvendor model

» But one can get close by simple marginal reasoning on 1 variable at a time (obviously, iterating that procedure gets you to optimality)

◆ *What are the advantages of hedging?*

– It leads to an increase in both financial measures (expected profits and ROI)

– *But the word hedging always is used together with "risk": what is the risk here?*

» Risk here is manifested through variability in operating profits.

» And it works: one can verify that the optimal hedge point *dominates* all the CPP and full insurance plan: by definition it yields the highest expected profit, but at the same time, the standard deviation of operating profits is lower than both CPP and full insurance!

» Link back to the "filtering role" of capacity: the cut-off corner region is the "optimal filter" in this process to filter/reduce the demand variability and turn it into "optimal" profit variability that maximizes expected profits.

	Expected Value	ROI	Std dev
Coordinated:	$ 88,250	86%	$ 24,590
Optimal	$ 94,500	90%	$ 20,310
Full Insurance:	$ 93,500	80%	$ 31,820

»

- *What is the financial value of these sophisticated investment models* (multi-dimensional and stochastic)*?*
  - » Compared to low benchmark (case base mark): Value of Hedging
    - $\Delta E[V] = \$3.5M + \$2.75M = \$6.25M = 5\%$ increase in profitability
    - $\Delta C = \$2.5M$
    - ROI on $\Delta K = 6.25/2.5 = 250\%$
  - » Compared to better benchmark (full insurance): Value of Hedging
    - $\Delta E[V] = \$134.5M - \$133.5M = \$1M$ (not bad for an hour's work!!) = 1% increase in profitability

◆ *How would this work in practice? How would you implement a planning procedure that leads to the optimal hedge?*

- This question suggests that there are problems with the optimal hedge:
- 1. Utilization problem:
  - » *What is the utilization of the resources under each scenario?*
  - » Most important insight: Leads to 'imbalance' in the sense that, regardless of the scenario of demand that is actually observed, even if it is overwhelmingly huge, the capacity provided will never be fully utilized
    - $\rightarrow$ excess capacity is optimal
    - a similar conclusion was reached by Goldratt in The Goal, but this was based on operational factors such as variance in throughput times
    - It is significant that the same conclusion can be reached purely by considering optimal investment strategies.
  - » This is a problem: *how would you explain to a board member that you are asking for an investment that you never ever will fully utilize?*
    - Reinforce the value of hedging your bets here
- 2. Incentive problem:
  - » As long as the cost of excess capacity is attributed to the plant or the manager (versus to the product), managers have no incentive to invest in excess capacity
  - » Even under Activity Based Costing (ABC) there is a problem
    - In any cost accounting scheme, a perennial problem is how, and whether, to allocate costs of unused capacity to specific products. Cooper and Kaplan, authors of ABC, argue that product costs, and hence product line profitability, should be allocated on a basis that excludes unused capacity and they go on to say:
    - "Management, to obtain higher profits, must take conscious actions either to use that available capacity to support a higher volume of business (i.e., by increasing revenues) or to reduce spending on resources by eliminating the unused capacity. Costs and profits are fixed only if management takes no action and leaves the unused capacity undisturbed. Management behavior, not cost behavior, determines whether reductions in resource demands become translated into higher profits."
  - » If the facility is a profit center, it may work; but typically production plants are cost centers…

- 3. The hedged plan is *inconsistent* with CCP: no single demand scenario can ever lead to the hedged capacity proposal
  - » Notice that the "full combinatorial array" of 9 'obvious' capacity choices for K_C (150, 300 or 450) and K_B (250, 300 or 350) did not include the optimal point (which includes $K_C = 350$!)
  - » Note also that even with a continuous demand distribution, one never uses all capacity (that fact is independent of the demand distribution; full utilization requires that there is one demand scenario where *all* three capacity constraints intersect!)
- 4. The solution procedure is technically hard
  - » the hedged plan cannot be found by "decomposing" the problem.
  - » How do you do it when the demand distribution is no longer three scenarios, but say a multi-variate normal distribution?
    - See below!

◆ Conclusion: the challenge is to come up with an incentive structure and a planning procedure that is in line with the hedged plan!

3. Other Actions

◆ DFM and commonality: Standardize components so that we can have 1 FA line

◆ Invest in additional tooling and make one FA line flexible

- *Do we need two flexible FA lines?*
  - » No! Here we could go into flexibility
  - » Do 'base demand' = (250,150) in dedicated facilities
  - » Do 'swing demand' in flexible FA line
    - Actual optimal is more complicated
- Making one FA line flexible will probably get most of the benefits
  - » We could calculate…

◆ Make an initial conservative investment and, after say 20% of demand is observed, adjust capacity if necessary

- This leads into a discussion about forecasting and similar issues as in "accurate response" by Marshall Fisher
- However, with the leadtimes involved, after two months of demand, a substantial investment would take another 6 months, leaving only 4 months to cover near end-of-life cycle
- Clearly, if small capacity adjustments can be made quickly, this is the way to go
  - » Here one can stress that the hedging model is a *planning* model. In execution, one can play with shifts, overtime and inventory to adjust capacity.

7. Newsvendor Networks: Correlation and Extensions

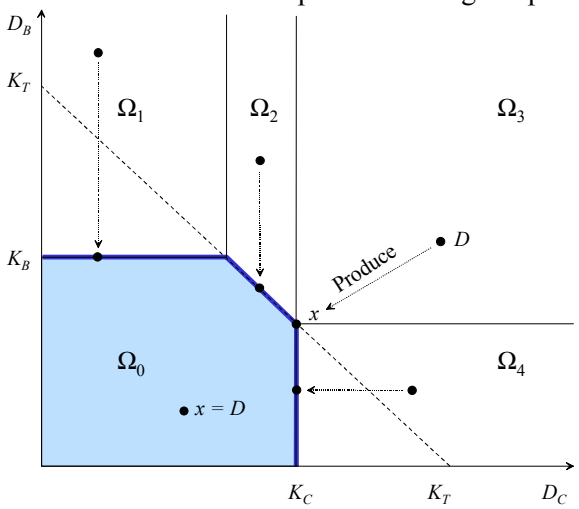
1. (Optional) *What if we have a "better" demand forecast?*

- Clearly, in real life if we have these 3 demand scenarios, most likely any scenario "in between" is also possible
- Also, we are not certain about the forecast
  - Hence, do some sensitivity analysis: even if optimistic scenario becomes less likely, our hedged plan remains optimal. Only if optimistic becomes more likely may it become optimal to increase *both* Cheetah and Test
- What should a "good forecast" look like?
  - Most likely it is continuous
  - And must have some measure of uncertainty
  - Central limit theorem suggests a multi-variate normal distribution for the demand forecast
    - » How many parameters do I need?
      - Two means, two std deviations AND 1 covariance!
      - 5, not 4!
- As in finance, hedging is driven by covariance!
  - What forecast do you prefer for the Seagate process: negative or positive correlation?
  - Negative = mix uncertainty
    - » As that fits directly with the product-flexibility imbedded in Test
  - Notice that positive correlation refers to scale uncertainty, and our process is not effective in dealing with that
    - » Indeed, it can be shown that in any newsvendor network value decreases in correlation (see my paper with Nils)
- How do we find the solution with normal demand?
  - 1. optimize via simulation
    - » this is very effective and can be done in Excel
    - » instead of only considering 3 scenarios as in the case, now draw say 1000 random vectors:
      - Fix a capacity vector K
      - solve for the contingent production vector and compute contingent profit. Now, take average (sum and divide by 1000) to find expected profit for that given K
      - iterate on K (or use Solver) to improve profits
    - » I have an excel spreadsheet that I use to discuss the *trends* or *what-if* analysis:
      - What if correlation/margins etc. changes?

- 2. do analytically
  - » see below

2. (Optional): The Generalized Newsvendor Solution Method

- Cf. My EJOR 98 paper. Partition the demand space according to optimal ex-post production decisions.



- Then, superimpose the demand distribution and calculate the associated probabilities P_i of the domains Ω_i. General optimality equations for a continuous demand distribution:
  - $\Delta m\ P_3 + m_C\ P_4 = c_C$
  - $m_B\ P_1 = c_B$
  - $m_B\ P_{2+3} = c_T$
- With this discrete distribution: Same as newsboy. The value function is concave increasing and the LHS of the general OE above is the marginal value (which is decreasing in K). Thus, start with $K = (0, 0, 0)$ and keep increasing until the LHS above falls below the RHS. Then stop.
  - $100\ P_3 + 400\ P_4 = 30$
  - $300\ P_1 = 20$
  - $300\ P_{2+3} = 80$
- At the nominal plan (take K_T to be 600 – epsilon = 599.999 for simplicity) we have $P_1 = 25\%$, $P_2 = 50\%$, $P_3 = 0\%$, $P_4 = 25\%$ such that P_4
  - $400*25\% = 100 > 30 \rightarrow$ keep increasing K_C
  - $300*25\% = 75 > 20 \rightarrow$ keep increasing K_B
  - $300*50\% = 150 > 20 \rightarrow$ keep increasing K_T (beyond 599.99)
  - This holds until the Hedging solution above (350,350,600) – epsilon = (349.99, 349.99, 599.99). Increasing any parameter beyond (350,350,600) makes the LHS less than the RHS. Thus, (350,350,600) is optimal

- If the demand distribution is continuous (e.g., normal), one must solve the optimality equations numerically.