Data Center Management Test Case

Story

The CEO and founders of a major internet information services company (the Company) believed that they could increase their shareholder value substantially with an improved strategy for upgrading their data center capabilities as new technology became available. The CEO charged the Director of Data Center Operations (the Director) with creating a new strategy, beginning with a single data center. His top manager/analyst (the Analyst) spent several months creating an Excel spreadsheet model valuing four different strategic options.

The Analyst recognized that there were many future uncertainties that would impact the strategy, but had known that it would take him several months just to put together a spreadsheet that assumed no uncertainty and upgrade decisions at fixed three-year intervals. The decision criterion, while reflecting the specific interests of the Information Technology group, was ad-hoc and acknowledged to lack the foundation and alignment with corporate goals desired by a major technology leader.

The Director asked Provisdom to work with the Analyst, and the Analyst asked Provisdom to begin by building a model to replicate the spreadsheet results as validation of Provisdom's decision platform. After being given a brief description of the problem and model, Provisdom implemented the logical structure of the spreadsheet; however the numbers did not match. The transparency of Provisdom's system made it easy to compare various values at different points in the models, and quickly narrow down the possible sources of disagreement. After a day of wading through an opaque spreadsheet, Provisdom had identified numerous inconsistencies and errors in the spreadsheet. The spreadsheet was reviewed with the Analyst over a 45 minute meeting. Then Provisdom spent the next two days creating an accurate model, seeking to directly maximize shareholder value and include all the major factors like revenue effects and greater decision flexibility.

Business Problem

The Analyst knew of the following choices and had the following relevant information regarding the data center operations.

Choices

- Whether to store servers from an existing datacenter and install in the new data center when construction was complete, OR simply sell the existing servers and upgrade to a more powerful server platform.
- When/if to upgrade to new servers as improved technology became available.

Information

- Parameters describing future server platforms (next-gen, 32, 64, and 128-core), including estimated cost as a function of time, performance metrics, power consumption, etc.
- Upgrade costs
- Depreciation effects and 80% platform salvage value

- Data Center Total Power Capacity = 36.96MW
- Platform Build Duration = 6 months
- Current Platform Forklift Cost Per Rack = $34651
- Monthly Storage Cost Per Rack = $113
- Platform Build Cost Growth Rate = 25%
- Platform Build Cost Percentage Fixed = 25%
- New Platform Training Cost = $1M

The Analyst's Spreadsheet

Four strategies were modeled (labeled 1-4) over a seven-year period. Strategy 1 included the choice of salvaging the platform from the existing data center and populating the new data center with next-gen servers. Strategy 1 additionally called for installation of the most advanced platform that was estimated to be available in three years (128-core). Strategies 2-4 all chose to store the existing platform until the new datacenter was ready to go online, and then use those servers to populate the new datacenter. Strategies 2-4 differed in their upgrade plans, installing platforms of various performance metrics at different future times.

- Strategy 1: salvage current and upgrade to next-gen; when available, upgrade to 128-core
- Strategy 2: store current; when available, upgrade to 32-core and then later to 128-core
- Strategy 3: store current; when available, upgrade to 64-core
- Strategy 4: store current; when available, upgrade to 128-core

Comparing Strategies

The strategies were compared using a ratio (The Performance Ratio) of the NPV of operations to an "Average Performance Metric per quarter". The NPV of operations was calculated by discounting the costs and salvage values at 10%. The Average Performance Metric per quarter was calculated as the max number of queries per second (QPS) that could be handled, discounted at 25% annually.

Assumptions

Due to the limitations of spreadsheet software, the following six numbered assumptions were used in the modeling effort even though they were known to not be representative of the Company's information:

1. Changes to the platform could not be made for at least 3 years.
2. Capital expenditure of a platform upgrade was amortized, such that the capital expenditure (CAPEX) charged in the model was only the total amortized amount from when the platform was installed to the end of the model. Thus if a platform was installed later in time, less cost was charged.
3. Future demand for the data is exactly known. Data center capacity would always exceed demand for the next seven years with any platform.
4. Even though capacity was assumed to always exceed demand, the operating expenses of each platform were assumed to not be a function of demand.
5. Taxes and depreciation were ignored.

6. Information about the future cost of power and the future platforms availability date and capacity is exactly known.

Errors

The following errors were brought to light through Provisdom's attempt to match the Analyst's spreadsheet model:

- Improper use of the Excel NPV function.
- Operating expenses were not calculated consistently – some places done quarterly, others done monthly.
- Operating expenses charged before platform installation.
- Platforms were salvaged inconsistently at the end of the model.
- Calculation of the quarterly discount rate from the nominal yearly corporate rate was done incorrectly.
- Capital expenditures were not incurred over the proper time period.
- Salvage values were calculated inconsistently, in some cases using a fixed quantity and others using a percentage.
- Some costs were calculated using the wrong platform data (copy/paste error).

Results

Fixing these errors resulted in changes to the NPV of between $119M and $172M for the four fixed strategies.

	NPV of Operations (@10%) with errors	NPV of Operations (@10%) corrected
Strategy 1	-$1.119B	-$1.000B
Strategy 2	-$1.108B	-$.936B
Strategy 3	-$1.060B	-$.907B
Strategy 4	-$1.065B	-$.916B

Even though Strategy 3 had the highest NPV, Strategy 2 had the highest Performance Ratio in both the original and corrected spreadsheets.

First-Cut Model

Using the Provisdom Decision Platform, Provisdom proceeded to create a model to match the error-corrected spreadsheet results. The spreadsheet was full of assumptions, and the first major improvement goals of the Analyst were to explore the entire range of upgrade choices and to compare them by their shareholder value instead of by the Performance Ratio.

A Flexible Strategy

Adding flexibility in making platform upgrade choices allows the Company to break free of the limitations of a few fixed strategies, instead choosing a truly optimal upgrade strategy from all possible choices. Assumption #1 (3-year upgrades) was removed by allowing the upgrade decision to be made yearly, with the platform choices based on the time of the decision and the platform availability data.

Maximizing Shareholder Value

The maximization of shareholder value is the explicit goal in the Provisdom Decision Platform and is how strategies are compared. This is always done by the platform (unless explicitly directed otherwise), and requires no extra effort. Assumption #2 was removed by using the platform salvage value in terms of shareholder value at the end of the model.

Results

The best strategy for the Company was to move the existing platform into the new data center, but then never do any future upgrades. Since the Analyst had assumed that the Data Center capacity would always exceed demand for the next seven years (Assumption #3), there was no need to model revenue effects. The best strategy was therefore the minimum-cost strategy. This did not match the Company's instincts on this issue. The Analyst could now fully appreciate the effects of the poor assumptions he was forced to use with a spreadsheet. It was clear to the Analyst, the Director, and the CEO that it was possible that demand could exceed capacity.

- Minimum-Cost Strategy: store current; don't upgrade

Provisdom was also able to calculate the shareholder value of each of the four original strategies and compare them with the minimum-cost strategy.

	Shareholder Value
Minimum-Cost	$11.02M
Strategy 1	-$356.75M
Strategy 2	-$307.36M
Strategy 3	-$256.63M
Strategy 4	-$165.78M

Note that the minimum-cost strategy actually had a positive shareholder value because of the salvage value at the end of the model.

More Accurate Model

To remedy this inconsistency and remove Assumption #3 (capacity always exceeding demand), the best available information about revenue and queries per second (QPS) demand was used, acknowledging that the future demand is unknown with a positive growth rate and correlation with the Market. The particular datacenter being modeled held approximately 18% of the Company's servers, so the initial QPS demand shown below and used in the model is 18% of the estimated total demand.

- Initial QPS Demand = 42.29M.
- QPS Demand Growth Rate = 55%.
- QPS Demand Growth Rate Yearly Decrease = 10%.

- QPS Demand Volatility = 40%.
- QPS Demand Market Correlation = 30%.
- Average Revenue per Billion Queries = $1887.
- QPS Demand Lifetime = 20 years.

To remove Assumption #4 (platform operating expenses not a function of demand), a price of $.05 per kWh of electricity was used and a monthly fixed operating cost per machine of $138 was added.

To remove Assumption #5 (ignorning tax and depreciation), a 39% corporate tax rate was used and captial was linearly depreciated properly over a 16-year span.

To more accurately reflect the shareholder value at the end of the model, we added the shareholder value of the future current revenue stream after tax to the salvage value of the current platform. (With the decreasing growth rate, the future revenue stream peters out quickly. The difference between 20 years and 200 years is rounding error. One interpretation of this is that if the Company wants to have a market similar to this 20 years from now, they'll need to innovate.)

Results

The optimal strategy is to store the current platform and then to upgrade to other platforms depending on the QPS demand.

- If demand rises to 99M over the first year, upgrade to the 8-core platform and then upgrade to the 32-core platform for all of the modeled discretized demands of 79M, 140M, and 246M at the end of the second year.
- If demand only rises to 44M over the first year, don't upgrade, but then upgrade to the 8-core platform for both of the modeled demands of 42M and 94M at the end of the second year.
- If the demand doesn't increase above 44M over the next 7 years, don't upgrade again.
- If the demand is always increasing rapidly, upgrade to the 8-core after a year, then the 32-core the next year, then 64-core the next year, then wait two years before upgrading to the 128-core platform.

The shareholder value of the optimal, minimum-cost, and original four strategies are shown in the table below.

	Shareholder Value
Optimal	$43.49B
Minimum-Cost	$40.07B
Strategy 1	$42.54B
Strategy 2	$43.03B
Strategy 3	$42.84B
Strategy 4	$42.42B

Compared to the strategy considered optimal in the spreadsheet analysis (Strategy 2), the optimal strategy increased shareholder value by $460M over the seven-year strategy.

Analysis

To get an even clearer picture of why the Optimal Strategy provides a significant increase in shareholder value over Strategy 2, we calculated the average electricity usage and average met QPS demand for both seven-year strategies. In addition, the amount of carbon dioxide emissions was estimated from electricity usage[1].

	Electricity Usage (kWh)	Demand Met	Carbon Dioxide Emissions (tons)
Optimal	233.6M	100%	222K
Strategy 2	302.8M	100%	288K

The optimal strategy would reduce the average electricity usage by 23% and prevent an average of 66K metric tons of carbon dioxide emissions while still meeting 100% of the QPS demand even in extreme cases. Although the analyst did not mention carbon dioxide emissions as relevant to shareholder value, a strong case could be made that carbon dioxide emissions could be taxed or capped in the near future and that reductions in carbon dioxide emissions could improve shareholder value through the Company's reputation.

Conclusion

The total effort required by Provisdom was several days, along with a few hours of the Analyst's time.

Assumption #6 (power cost and future platform dates and capacities known exactly) was not addressed in these models. The final model contained the revenue but not all the costs. The platform and power costs were included which represent about 10% of the total costs of the Company. The model also only represented a single datacenter holding approximately 18% of the servers. If this model incorporated all of the Company's most relevant information, and the Company applied the strategy to every datacenter, we'd expect to see an instantaneous gain in shareholder value of over $2.5B.

From the optimal strategy, however, it became apparent that the option to build new data centers to meet demand should be considered. Including this option into the model could have a major impact on the upgrading strategy. An improved model would model not just a single data center, but all the current data centers and the option to build new ones.

[1] See The Carbon Calculus - New York Times