Identifying Supply Chain Strategies of Firms with Best Supply Chain Performance

by

Nitin Gulati & Amar Sharma

Submitted to the System Design and Management Program
in Partial Fulfillment of the Requirements for the Degree of

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Abstract

The Global Business Climate has been rapidly changing and has become more competitive. Enterprise now not only needs to operate at a lower cost to compete, it must also develop its own core competencies to distinguish itself from competitors and stand out in the market. The focus has now moved towards improving operational efficiency to stay competitive. Supply Chain is one of the important areas which almost every company is currently working to improve their operation efficiency. Improving operational efficiency in supply chain has three aspects including improving supply chain strategies, following better supply chain management practices, and aligning supply chain strategy with overall business strategy.

Our thesis research objective is to understand what policies, capabilities, and strategies of an enterprises leads to best supply chain management. The research is cross industry, across all supply chain management domain and will shed light on what makes companies "best performer" by identifying and exploring the distinctive capabilities required in five key supply chain domains that contribute to high performance in the relevant operational metrics. The domains studied in our research are supply chain planning, fulfillment, service management, product lifecycle management, and, manufacturing. Another objective of our thesis is to relate domain performance of the firm with the firm's value proposition. The three value propositions considered in the thesis are product leadership/innovation, cost competitiveness, and customer service.

Acknowledgements

We are grateful for the knowledge, wisdom, insight, and support from our thesis advisor Prof. David Simchi-Levi. This thesis will not have been possible without his guidance which provided the direction for our research and encouraged us to think beyond traditional boundaries of this topic. Prof. David always inspired us with his out-of-the box ideas when we were stuck in our research.

We are also grateful to our research patron Mr. Derek Jones for his continual support throughout the project. Derek provided all the material for the research and guided us with the research direction. Without Derek's comments and feedback, this thesis wouldn't have been possible.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Introduction and Thesis Overview

The Global Business Climate has been rapidly changing and has become more competitive. Enterprise now not only needs to operate at a lower cost to compete, it must also develop its own core competencies to distinguish itself from competitors and stand out in the market. The focus has now moved towards improving operational efficiency to stay competitive. Supply Chain is one of the important areas which almost every company is currently working to improve their operation efficiency. Improving operational efficiency in supply chain has three aspects including improving supply chain strategies, following better supply chain management practices, and aligning supply chain strategy with overall business strategy.

On first sight business strategy, supply chain strategy, and supply chain management (SCM) look very similar because all of these deals with strategy but a closer look reveals that they all are very different. Business strategy[1] is more concerned about the overall direction that an organization wishes to go. It involves leveraging the core competencies of the organization to achieve a defined high-level goal or objective such as entering new market, gaining advantage over competitors, meeting needs of customers, product differentiation, selectively investing in differentiating capabilities etc. Supply chain strategy constitutes the actual operations of the organization and transforming their operations from suppliers to the ultimate customer to gain more agility, improving existing network, and gaining competitive advantage. While, Supply Chain management (SCM)[2] is more about how existing supply chain operations can be controlled to reduce costs. SCM is about controlling and managing a network of interconnected businesses involving a portfolio of assets (human, equipment, components, etc.) and relationships (customers, suppliers, staff, etc.) to transform a customer's product from raw material to finished product as efficiently as possible. It spans all movement and storage of raw

[1] http://www.ups-scs.com/solutions/white_papers/wp_supply_chain.pdf
[2] http://en.wikipedia.org/wiki/Supply_chain_management

materials, work-in-process inventory, and finished goods from point-of-origin to point-of-consumption

Our thesis research objective is to understand what policies, capabilities, and strategies of an enterprises leads to best supply chain management. The research is cross industry, across all supply chain management domain and will shed light on what makes companies "best performer" by identifying and exploring the distinctive capabilities required in five key supply chain domains that contribute to high performance in the relevant operational metrics. The domains studied in our research are:

- **Supply chain planning:** Supply chain planning refers to company's ability to predict future demand, make necessary changes to improve processes & product design, improve customer satisfaction, and decrease bull-whip effect[3]. Poor planning may result loss profit/revenue opportunities, and may strain relationship with vendors or distributors. Planning can be improved by partnering directly with customers, suppliers and by utilizing technology to use real-time information and utilizing efficient forecast technology.

- **Manufacturing:** Manufacturing in supply chain management includes all intermediate processes required for transforming raw materials into finished goods which support overall business and product strategies. Manufacturing handles trade-offs across key factors including labor supply, labor & capital cost, asset utilization, and continuous process improvement.
- **Fulfillment[4]:** Fulfillment refers to the ways in which firm can respond to customer needs, influence customer behavior and improve customer intimacy. The goal is to be cost efficient and delivering high quality products while continuously reducing fulfillment times. Fulfillment strategies depends on P:D ratio where P is defined as the amount of time required to manufacture a product and D is defined as the amount of time customers are willing to wait. The P:D ratio will differ depending on

[3] http://en.wikipedia.org/wiki/Bullwhip_effect
[4] http://en.wikipedia.org/wiki/Order_fulfillment

type of industry and customer segmentation. Depending on the P:D ratio a firm can have several strategic fulfillment options: Ex Engineer to Order (ETO), Make to Order(MTO), Make to Stock (MTS), Assemble to Order (ATO).

- **Product lifecycle management**[5]**:** Product lifecycle management (PLM) is the process of managing a product from idea generation, through design and manufacturing, to fulfillment and service management. PLM focuses on minimizing time to market, reducing wastage, decreasing product cost while improving product quality. A good PLM process should be capable of satisfying changing customer needs by re-inventing itself by proper product design & innovation, and by integrating people, processes & new ideas.
- **Service management:** Service management deals with providing end to end solution to products and services by coordinating actual sales and customer demands. A better service management will increase customer loyalty, increase revenue without increasing inventory cost. Research has shown there is a strong correlation between overall customer satisfaction and sales volume. Service management has been the key for many firms growth and it requires strategies including service portfolio management, go to market strategy, and service offerings based on customer's buying habits. Regular customer feedbacks and satisfaction surveys are important for assessing how one's service management compares to competitors and what steps should to be taken to reach the next level.

Before we started our research, our Patron (not disclosed for confidentiality reasons) had already surveyed over 350 global companies on the above supply chain domains. Some of the companies participated in multiple supply chain domains while some participated in only one domain. Every domain survey was designed after consulting industry experts including Prof. David Simchi-Levi[6]. Each survey comprised of the following format.

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[5] http://en.wikipedia.org/wiki/Product_lifecycle_management
[6] http://web.mit.edu/dslevi/www/

- **General Information:** This part of the survey included questions on demographics including but not limited to industry type, the designation of person answering the survey, and financials such as revenue and revenue growth over the past year.
- **Domain operation:** This part of the survey included questions to measure firm's capability in the domain. For each domain, a set of hypothesis were identified and for each hypothesis a set of questions were designed on a quantitative framework of scale 1-5 to measure firm's performance. The hypotheses are best practices in theory and practice that should be followed to achieve high performance in a particular domain. For instance, one of the hypotheses in planning domain is companies who excel at planning collaborate extensively with customers and trading partners. The hypotheses are discussed in detail in the individual domain chapters.
- **Domain Metrics:** Domain metrics measured operational performance in the domain, not overall firm performance (as would be measured by profit, ROIC, etc)

The overall outline of our research is as follows:

- Cleaning and elimination of data which was not filled properly.
- Build statistical models & perform analysis on the survey results.
- Identify best performers in each domain: Domain metrics entered in the survey questions was used to identify best performers.
- Do an in-depth analysis to find out differences between best performers and non best performers. This included finding which hypotheses in a domain are statistically correlated to high performance in the domain. For example, this module answered questions like does collaborating with trading partners in supply chain planning correlates to high

performance (defined by low inventory cost and better forecast & customer service).

- Cross domain analysis: For firms that participated in multiple domain surveys, a cross domain study was done to relate domain performance of the firm with the firm's value proposition. The three value propositions considered in the study were product leadership/innovation, cost competitiveness, and customer service.

Prior Research in this area[7]

A recent study by MIT, PRTM, and SAP suggests that there is a link between IT strategy, sound business processes, and supply chain performance. The study used the data from about 75 different supply chains to claim that companies that invest mostly in business processes do better than those who invest in IT only and lack the appropriate business processes. The study also suggests that investments only in technology without the appropriate business processes lead to negative returns. The main objective of the study was to find whether there is a direct correlation between the maturity of the business process, the amount of investment in IT infrastructure, and supply chain performance. One of the main challenges in the study was to develop measures to characterize the level of maturity of the business processes and the information technology employed by the company. This is because of the fact that different portions of the company's business can be at different levels of maturity, or even the same portion of the business may be out of balance in the sense that the maturity of the business process and the information technology do not complement Each other very well.

To overcome abovementioned challenges, the authors of the study developed two sets of questions: one to characterize the level of business maturity and the second to characterize the level of maturity of the information technology. The overall maturity of

[7] Designing and Managing the Supply Chain 3e David Simchi-Levi, Philip Kaminsky, Edith Simchi-Levi Pg 408-412

the firm's business processes is based on the SCOR model which has four categories of business processes:

- **Level 1: Disconnected processes.** This level is characterized by low level of integration and companies are organized functionally. There are many independent processes and supply chain planning is typically done for each site independently of other sites.
- **Level II: Internal integration.** At this level, companies are organized functionally with a high degree of integration. Business decisions are made through the integration of key functional areas, that is, sales, manufacturing, and logistics.
- **Level III: Intra-company integration and limited external integration.** At this level, companies are cross-functionally organized and involve key suppliers and customers in decision-making processes.
- **Level IV: Multi-enterprise integration.** At this level, organizations apply multi-enterprise processes, use common business objectives, and have an extensive knowledge of the suppliers and customers business environments.

Similar levels (outlined below) were created for information technology infrastructure.

- **Level I:** This level is characterized by batch processes, independent systems, and redundant data across the organization. Focus is on spreadsheet and manual manipulation of data for decision making.
- **Level II:** Data is shared across the supply chain. Decisions are made using planning tools that apply data across the supply chain; for example, demand planning module that applies expert knowledge, advanced algorithms, and statistical methods for forecasting.
- **Level III:** At this level there is complete visibility of internal data. Key suppliers and customers have access to some of these data; for example, forecast is shared with key suppliers. Both processes and data are shared across the supply chain.
- **Level IV:** At this level, data and processes are shared internally and externally.

Supply Chain Planning – Identifying Best performers

Supply chain planning is one of the most important aspects of managing the entire supply chain. The purpose of our analysis is to identify companies that are best performers in the supply chain planning. There is no fixed rule or formula in literature to find out whether a firm is best performer in supply chain planning. Identifying best performers is more of a subjective process although statistical methods such as factor analysis can be used.

We studied the data of over two hundred companies across various industries. The industries represented in the data were communications, electronic & high tech, retail, food & consumer goods, automotive & IE, travel & transportation, health & life sciences (biotech & med devices), health & life sciences (plans and providers), natural resources, and utilities. Figure-1 below shows the planning survey demographics.

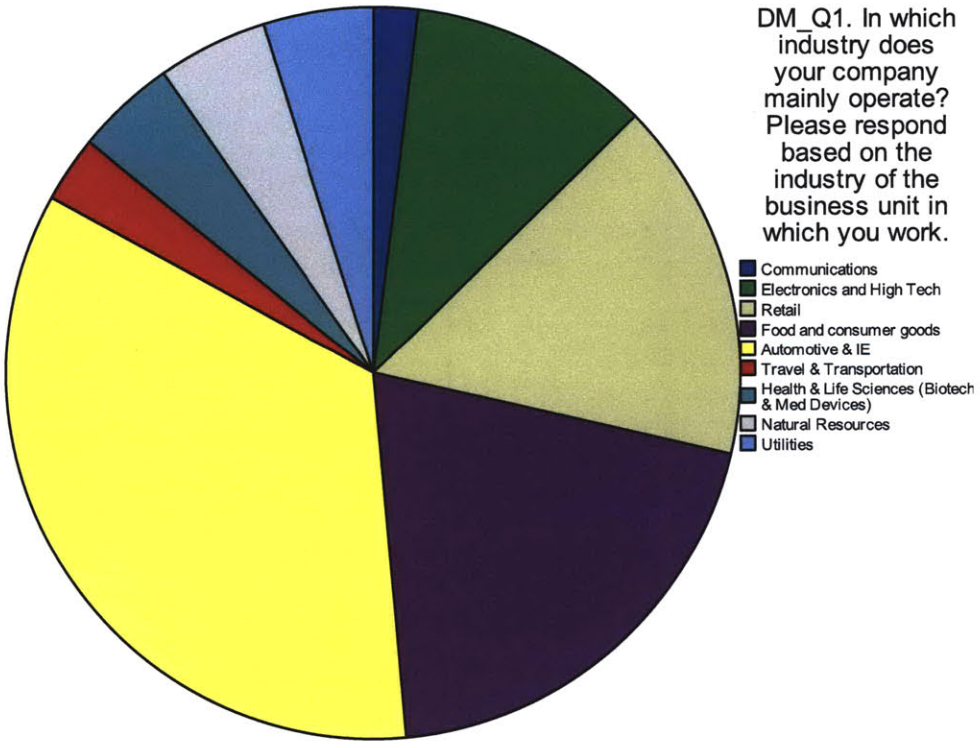


Figure 1 Planning Survey Demographics

The metrics part of planning survey had eight questions about forecast accuracy, inventory costs, and customer service. The responses to this question were considered as a basis to identify best performers in supply chain planning. The objective of our analysis here is to identify best performers in supply chain planning and give each firm a rank between zero and one based on its relative performance among the total firms that participated in the survey.

Methodology

We considered the following approaches for identifying best performers. For all the approaches we included the external constraint that around ten percent of the firms in the survey are best performers. The external constraint is necessary because there is no formula in theory which says that if your forecast accuracy is above 90% or your inventory cost is below a certain level then you are a best performer. These metrics change across various industries and definition of best performer is very subjective. Therefore, if we are analyzing (and ranking) firms in a peer group we need a constraint that certain percentages of the firms are best performers in a group. The ten percent was chosen after discussing with industry experts.

Approach #1 – Equal weight age to each question

In this approach, all eight questions in the survey were given equal weight age. First, for all eight questions the relative rank of each firm was calculated based on its performance in that particular question among its peer group. Second, we added the relative ranks for each of the eight equations. Lastly, all the ranks were averaged and the final number was called the final rank (which is between 0 and 1). A high final rank implies that a firm is better than a low scoring firm. One of the major disadvantages with this approach was that some of the questions in the survey were asking the same

thing in a different manner, therefore some questions had higher weight age in the final score.

Approach #2 – Optimization approach

In this approach, the first task was to identify manually the firms that are sure shot best performers or non best performers. A sure shot best performer is firm that is good on each metric for example it is good in forecast accuracy, has high inventory turnover, low inventory costs, and excellent customer service. A sure shot non best performer is just the opposite of sure shot best performer. At the end of this exercise, we have a list of firms who are either sure shot best performer or non performer. For all these firms a discrete score of 1 or 0 is given if they are best performer or non performer. The next step is to run the optimization on these firms to determine the set of weights for each question in the metrics part of the survey. Figure-2 below shows the details of optimization.

Objective Function

- Min $\sum_I (F_I - \sum_J w_J X_{IJ})^2$
  - w_J - where J varies from 1 to number of metrics question. w_1 for first metric question and so on
  - X_{IJ} - is the response of company I in metric question J
  - F_I - It is 0 if the company is sure shot non best performer and 1 if its a sure shot best performer

Decision variables

- w_J

Constraints:

- $w_J >= 0$ for all J
- $\sum_J w_J = 1$

Figure 2 Optimization Mechanics

After determining the optimal weights by running the optimization, the next step is to calculate each company's final rank by the product sum of weight vector and responses to metrics questions vector. This approach can be used reliably if we can identify significant number of sure shot best performers and non performers. High performing companies can be identified by sorting (descending order) companies based on final rank and choosing a certain percentage of companies (external constraint defined above).

Approach #3 – Factor Analysis[8]

Factor analysis is a statistical technique to find unobserved variables called factors which describe the variability among observed variables. Factor analysis is generally used to reduce the number of variables by combining two or more variables into one factor. Factor analysis is useful when there is high correlation among observed variables. One of the main disadvantages of factor analysis is that interpretation of factor analysis is normally based on a "heuristic", which is a solution that may be convenient but not absolutely true. Analysis becomes even harder as more than one interpretation can be made of the same data factored in same way. Also like correlation and regression, factor analysis cannot identify causality. Using factor analysis, best performers can be identified by following the below mentioned steps.

- **Data cleaning:** In this stage all the questions included in the factor analysis are brought to similar scale. By similar scale we mean that for all questions a higher value means better. For instance, in cost related questions normally a lower value is desirable. For these questions the responses are appropriately adjusted so that a higher value is good. However, the scale of each question can vary.
- **Factor analysis:** At this stage factor analysis is performed to reduce the set of metrics questions into few factors. The factors are selected using standard

[8] http://en.wikipedia.org/wiki/Factor_analysis

technique of selecting factors that have higher than one eigen-value[9]. For each factor the standardized factor scores are calculated. A factor score is a weighted score based on responses to the questions included in the factor. The factor score method used in our analysis was regression in which the mean factor score is 0 and variance is the squared multiple correlation between estimated factor scores and the true factor values[10].

- **Best performer Selection:** The next step is to average the factor scores for all factors. Thereafter, companies are given final rank (between 0 and 1) based on their average factor score. Finally, companies are sorted on final rank in descending order and top ten percent of companies (external constraint) are selected as best performers.

Approach #4 – Identify best performers subjectively

The motivation of using a subjective approach rather than a statistical technique comes from the fact that many metric questions in the survey were measuring the same thing and many questions were not universally understood by respondents across multiple industries and geographies. After studying the metric questions we identified some questions were secondary metrics and not primary indicators of overall performance in the domain (for example, throughput time) and should not be included in the analysis. By visual inspection, the metric questions can be broadly divided into three categories cost, service, and accuracy. The details of these categories are defined below.

- **Cost:** This category included questions regarding inventory turns, cost as a percentage of sales, and cost as a percentage of revenue.
- **Forecast:** This category included questions regarding forecast accuracy.
- **Service:** This category included questions regarding customer lead time, and customer order fill rate.

[9] http://www.psych.cornell.edu/Darlington/factor.htm
[10] SPSS Help – Factor Analysis Score

Ideally, factor analysis should have identified these three categories as factors but we got mixed results using factor analysis mainly because of missing data.

Best performers were selecting using the following process.

- Each firm was ranked between 0 and 1 in each of the three categories based on its response to the questions included in the respective categories. Also for each firm a discrete score of 1 or 0 was given. A discrete score of 1 signified that they are best performer in that particular category. A score of 1 was given to firms that were one standard deviation away from the mean score.
- A final rank of each company was calculated as an average of all category ranks.
- Best performers in planning domain were identified who were best performers in at-least two categories out of three categories identified above.

The following table (Table-1) discusses the advantages and disadvantages of all the four approaches described above.

Approach	Discussion
Equal weight age to each question	All questions in the survey were not equally important and therefore should not be given equal weight age.
Optimization approach	There were not many sure shot best performers and non performers in the data and therefore the data set for optimization was not enough to carry out meaningful analysis.
Factor analysis	The planning data has lot of missing values which made factor analysis results unreliable. Also some of the factors identified by factor analysis were non intuitive.
Subjective approach	This approach was most appealing because we could subjectively study the questions and decide which should be included and how questions should be categorized based on experience. Also because of missing data this approach allowed us to tailor the selection of questions based on total number of response to each question.

Table 1 Comparison of various approaches

As discussed in the above table (Table-1) we selected the subjective approach for identifying best performers and for calculating the final rank in planning domain for each firm. The results are discussed in the next section.

Results & Discussion

The following tree diagram (Figure-3) shows the companies included in planning survey based on their discrete score of 0 or 1 in three categories.

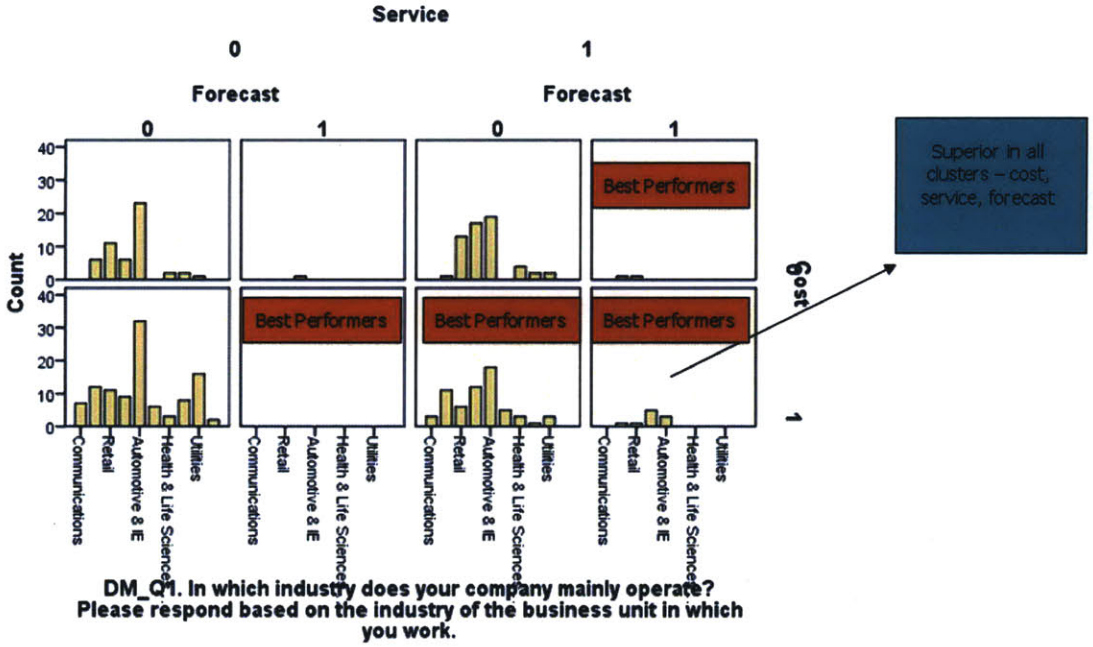


Figure 3 Supply Chain Planning - Tree Diagram

Figure-3 above shows that the majority of best performers in planning are good in service and cost. One of the most important key take away from the analysis is that forecast most of the best performers in planning domain focus on improving their cost and service competitiveness rather than on forecast. Also the above figure it shows that almost none of the companies are best performers in cost and forecast and non best performer in service.

Supply Chain Planning – What does it take to be a best performer?

In previous chapter, we identified high performing companies in the planning domain. Also, each firm in the survey was given a final rank between 0 and 1 based on its performance among the firms participating in the survey. In this chapter, our focus is to identify what makes best performers different than non high performing companies.

The planning survey contains seven hypotheses about planning domain which can be used to find out differences between the practices of best performers and non best performers. For each of the seven hypotheses, the survey has a set of questions to gauge the performance of the firm in that hypothesis. The set of questions in the planning survey are mostly based on quantitative framework on a 1-5 scale.

The seven hypotheses are defined below:

1. **Hypothesis A, Collaboration with trading partners**: Best performers plan extensively between partners (key customers and key suppliers) and across distribution tiers to improve performance throughout the entire extended supply chain—from raw materials to the end customer.
2. **Hypothesis B, Ability to respond to disruptive events and new market opportunities:** Best performers plan for and rapidly respond well to both disruptive events and new market opportunities—in other words, they use their planning savvy to not only avoid or minimize negative consequences but also to be first to capitalize on growth potential.
3. **Hypothesis C, Planning tools, processes, and operating model:** Best performers extensively leverage their tools, processes and operating model (e.g., automation, centers of excellence, outsourcing), which enables their deep,

skilled planning professionals to shift their attention away from low-level, routine planning activities toward higher-value activities.

4. **Hypothesis D, Talent management strategy for planning professionals:** Best performers have a global talent management strategy and organization structure that enables them to deploy planning roles in the most appropriate location (local or central), optimize planning talent, and give planning professionals opportunities for career development.
5. **Hypothesis E, Ability to predict and shape demand:** Best performers are at least as good at demand shaping—i.e., steering customers toward their preferred products and services—as they are at demand sensing—i.e., predicting what demand will arise.
6. **Hypothesis F, Extent of product lifecycle planning:** Best performers incorporate total product lifecycle planning to dramatically reduce stock outs and excess and obsolete inventory at product inception, maturity and retirement.
7. **Hypothesis G, Ability to plan across multiple dimensions simultaneously:** Best performers plan by product, market and geographic segments—not just one or two of the three—which enables them to more effectively respond to demand and capture new revenue opportunities.

The following section discusses the methodology and approach followed to find the key characteristics of best performers.

Methodology and Approach

The in-depth analysis of planning domain is divided into three modules described below:

- **Hypothesis Testing:** In this module the objective is to identify which of the seven hypotheses are most important for best performers.
- **Key Insights:** This module focuses on finding all statistically significant differences between best performers and non best performers in all questions under each hypothesis.

- **Planning capability:** This module finds the correlation of planning capability as a whole and performance in planning domain. The planning capability as a whole is defined as the aggregate performance in the entire seven hypotheses.

Hypothesis Testing

For hypothesis testing, the following steps were followed for each of the seven hypotheses to conduct the statistical analysis.

- The first step was the data cleaning. Survey questions ranking were not consistent and in some cases being 5 was best on a 1-5 scale while in others being 1 was best. The objective of this method was to make all the rankings consistent.
- The second step was to identify the set of questions that will be included in the hypothesis testing. Only questions in which the rankings were strictly categorical ordinal (i.e. one rank is better than the other) were included. Also questions which don't seem to be the representative of the hypothesis being tested were excluded.
- The next step is to use the statistical technique called categorical principal component analysis (CATPCA) to reduce the relevant set of questions under a hypothesis into a few dimensions that capture most of the variance in the data. For details on the CATPCA statistical technique, refer Appendix I.
- After reducing the set of questions into few dimensions, the next step is to generate factor score for each dimension. A factor score is a weighted score based on responses to the questions included in the dimension. The factor score method used in our analysis was regression in which the mean score is 0 and variance is the squared multiple correlation between estimated factor scores and the true factor values. Finally, the average of factor scores in all the dimensions. The final average score is called hypothesis CATPCA score.

- The next step is to categorize CATPCA score into valid or not valid based on its value. If the CATPCA score is above zero then we categorize the score as valid. Valid means that a particular firm is following that hypothesis because it has scored well in the responses to the set of questions included in the hypothesis testing.
- After we have categorized the CATPCA score as valid or not valid, we can create a 2x2 table of best performers and non best performers with valid and not valid in a particular hypothesis.
- The final step is to conduct a chi-square or Fischer test to test the hypothesis: "Is high performance in planning and being good in a hypothesis is independent"? Fischer test is preferred over chi-square test if any of the cell count in the 2x2 table is less than or equal to five.

Results & Discussion

Table-2 below shows the 2x2 table for hypothesis A – Collaboration with trading partners.

	Hypothesis A		
	Not Valid	Valid	**Total**
Non Performers	47	51	98
Best performers	6	17	23
Total	53	68	121

Table 2 Supply Chain Planning - Cross Tabulation for Hypothesis A

The p value or significance for the above chi-square test is 0.057, which implies that there is 5.7% probability that these results have occurred by chance. The numbers in each cell is the count, for instance 17 out of 23 best performers are valid in hypothesis A. Based on the above table 74% of best performers are valid in hypothesis A, while only 52% of non best performers are valid in hypothesis A. Because the significance of the

test is low we can reject the hypothesis that high performance in planning and being valid in hypothesis A are independent. In other words, by collaborating with partners, key customer, and key suppliers a firm can strongly increase its chances of being a best performer in supply chain planning.

Table-3 below shows the 2x2 matrix for hypothesis B – ability to respond to disruptive events and new market opportunities.

	Hypothesis B		
	Not Valid	Valid	**Total**
Non best performers	41	57	98
Best performers	9	14	23
Total	50	71	121

Table 3 Supply Chain Planning - Cross Tabulation for Hypothesis B

The p value or significance of the above chi-square test is more than 0.5, in other words these results are statistically insignificant. Although there are a greater percentage of best performers (61%) who have valid hypothesis B than non best performers (58%), nothing conclusive can be said statistically. In theory, best performers should have a good ability to respond to disruptive events and new market opportunities but the data does not support the conclusion that being good in hypothesis B correlates with high supply chain performance.

Table-4 below shows the 2x2 matrix for hypothesis C – planning tools, processes, and operating model.

	Hypothesis C		
	Not Valid	Valid	**Total**
Non Best performers	44	54	98
Best performers	7	16	23

Total	51	70	121

Table 4 Supply Chain Planning - Cross Tabulation for Hypothesis C

The p value or significance of the above chi-square test is 0.24. The data in the table suggest that the around 70% of best performers have valid hypothesis C or they follow planning tools, processes, and operating model, while this number is only 55% for non best performers. Because of high p value we can say there is a weak correlation between hypothesis C and best performers in planning.

Table-5 below shows the 2x2 matrix for hypothesis D – talent management strategy for planning professionals.

	Hypothesis D		
	Not Valid	Valid	**Total**
Non best performers	61	37	98
Best performers	10	13	23
Total	71	50	121

Table 5 Supply Chain Planning - Cross Tabulation for Hypothesis D

The p value or significance of the above chi-square test is 0.1. As per the data in the table, around 57% of best performers follow hypothesis D, while only 38% of non best performers do the same. Because of the fairly low value of significance, we can say there is some correlation between hypothesis D and best performers in planning.

Table-6 below shows the 2x2 table for hypothesis E – Ability to predict and shape demand.

	Hypothesis E		
	Not Valid	Valid	**Total**

Non best performers	50	48	98
Best performers	9	14	23
Total	59	62	121

Table 6 Supply Chain Planning - Cross Tabulation for Hypothesis E

The p value or significance of the above chi-square test is 0.3. As per the data in the table around 61% of the best performers follow hypothesis E while only 49% of the non best performers do the same. Theoretically, best performers should have good ability to predict and shape demand. The data also suggest so, but a high p value of 0.3 indicates that the results are statistically inconclusive.

Table-7 below shows the 2x2 matrix for hypothesis F – extent of product lifecycle planning.

	Hypothesis F		
	Not Valid	Valid	Total
Non best performers	46	52	98
Best performers	8	15	23
Total	54	67	121

Table 7 Supply Chain Planning - Cross Tabulation for Hypothesis F

The p value or significance of the above chi-square test is 0.3. As per the data in the table around 65% of the best performers follow hypothesis E while only 52% of the non best performers do the same. Theoretically, best performers should have valid hypothesis F. The data also suggest so, but a high p value of 0.3 indicates that the results are statistically inconclusive.

Table-8 below shows the 2x2 matrix for hypothesis G – Ability to plan across multiple dimensions simultaneously.

	Hypothesis G	

	Not Valid	Valid	**Total**
Non best performers	35	63	98
Best performers	7	16	23
Total	42	79	121

Table 8 Supply Chain Planning - Cross Tabulation for Hypothesis G

The p value or significance of the above chi-square test is more than 0.5, in other words these results are statistically insignificant. Although there are a greater percentage of best performers (70%) who have valid hypothesis B than non best performers (64%), nothing conclusive can be said statistically. In theory, best performers should be able to plan across multiple dimensions simultaneously but the data does not support the conclusion that being good in hypothesis G correlates with high supply chain performance.

The following graph (Figure-4) summarizes the results of hypothesis A to G. The x axis in the graph is the hypothesis A to G, while the y axis is the percentage of best performers and non best performers good in a particular hypothesis.

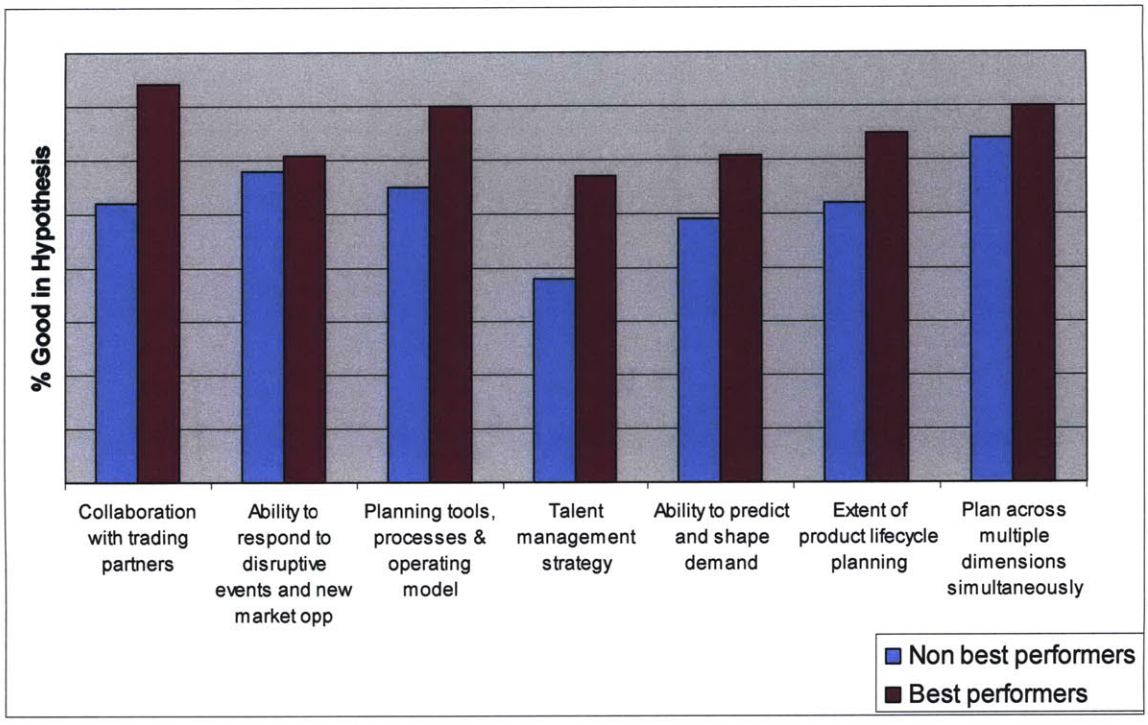


Figure 4 Supply Chain Planning - Hypothesis Testing Summary

From the above graph (Figure-4) it is clear that nearly in all hypothesis best performers do better than non best performers, but statistically conclusive results can only be drawn for some hypothesis. Figure-5 below summarizes the results for hypothesis testing by taking significance of the tests into account.

Hypotheses	Importance	Significance	Comments
Collaboration with trading partners		Good (0.057)	Being good in this hypothesis **strongly** increases the chances of becoming a best performer in planning
Ability to respond to disruptive events		Bad (>0.5)	Although more percentage of best performers are good in this hypothesis than non best performers, but statistically nothing conclusive can be said.
Planning tools, processes, & operating model		Medium (0.25)	Being good in this hypothesis increases the chances of becoming a best performer in planning.
Talent management strategy		Good (0.1)	Being good in this hypothesis **strongly** increases the chances of becoming a best performer in planning
Ability to predict and shape demand		Medium (0.3)	Being good in this hypothesis increases the chances of becoming a best performer in planning
Extent of lifecycle planning		Medium (0.3)	Being good in this hypothesis increases the chances of becoming a best performer in planning
Plan across multiple dimensions simultaneously		Bad (>0.5)	Although more percentage of best performer are good in the hypothesis non best performers, but statistically nothing conclusive can be said.

Figure 5 Supply Chain Planning - Hypothesis Testing Summary (with statistical significance)

Key Insights

Here, our focus is to identify all statistically significant differences between best performers and non best performers for each question in all the hypotheses. The questions in the hypothesis were based on the quantitative framework on a scale of 1 to 5. The statistical technique used to perform this test was cross tabulation where Fischer test or chi-square test was performed. Fischer test was preferred if any cell in the cross tabulation entry was less than or equal to five.

The following figure (Figure-6) summarizes the results of the statistical analysis. Only results where significance was less than or equal to 0.2 are shown here.

Question Description	% Best Performers	% of Non Best Performers	Significance
Involve key suppliers in planning process	73	52	0.16
Planning capaility and processes for different products by customer	74	56	0.16
Regularly and systematically involve key suppliers, customers, and distribution tiers in supply chain planning	50	23	0.2
Use planning to respond to disruptive events	61	33	0.084
Use centralized planning organization for all products and channels	57	37	0.13
Have scope of centralized planning organization as global	84	57	0.12
Planning is strategic differentiator and is tightly integrated with long term corporate goal	30	20	0.029
Can predict demand by more than 80% accuracy	61	23	0.006
Incorporate total lifecycle product planning	35	16	0.19
Through effective connectivity between planning and marketing we determine a best estimate of product launch quantities	30	12	0.09
Incorporate local market intelligance in forecasting demand and planning	39	14	0.06

Figure 6 Supply Chain Planning - Key Insights Summary

The first column in the above figure describes the survey question, the second column specify the percentage of best performers who performed good in this question (i.e. they selected top two choices in the scale of 1-5), the third column specifies the same for non best performers, and finally the last column list the statistical significance or p value of the test.

Based on the significance values, the above table suggests that best performers in planning do following things well:

- Planning is tightly integrated with their long term goal and is their strategic differentiator.
- Best performers can predict demand by more than 80% accuracy.
- Best performers incorporate local market intelligence in forecasting demand and planning.

Planning Capability Analysis

This module finds the correlation of planning capability as a whole and performance in planning domain. The planning capability is defined as the aggregate performance in the entire seven hypotheses.

For planning capability analysis, the following steps were followed:

- The first step was the data cleaning. Survey questions ranking were not consistent and in some cases being 5 was best on a 1-5 scale while in others being 1 was best. The objective of this method was to make all the rankings consistent.
- The second step was to identify the set of questions in all hypotheses that will be included in the planning capability analysis. Only questions in which the rankings were strictly categorical ordinal (i.e. one rank is better than the other) were included.
- The next step is to use the statistical technique called categorical principal component analysis (CATPCA) to reduce the relevant set of questions under a hypothesis into a few dimensions that capture most of the variance in the data. For details on the CATPCA statistical technique, refer Appendix I.
- After reducing the set of questions into few dimensions, the next step is to generate factor score for each dimension. A factor score is a weighted score based on responses to the questions included in the dimension. The factor score method used in our analysis was regression in which the mean score is 0 and variance is the squared multiple correlation between estimated factor scores and the true factor values. Finally, the average of factor scores in all the dimensions. The final average score is called planning capability CATPCA score.
- The final step is to plot the planning capability CATPCA score and the planning performance. Planning performance is the final rank of the firms that we calculated in chapter-X.

Figure-7 below shows the scatter plot of planning performance versus planning capability.

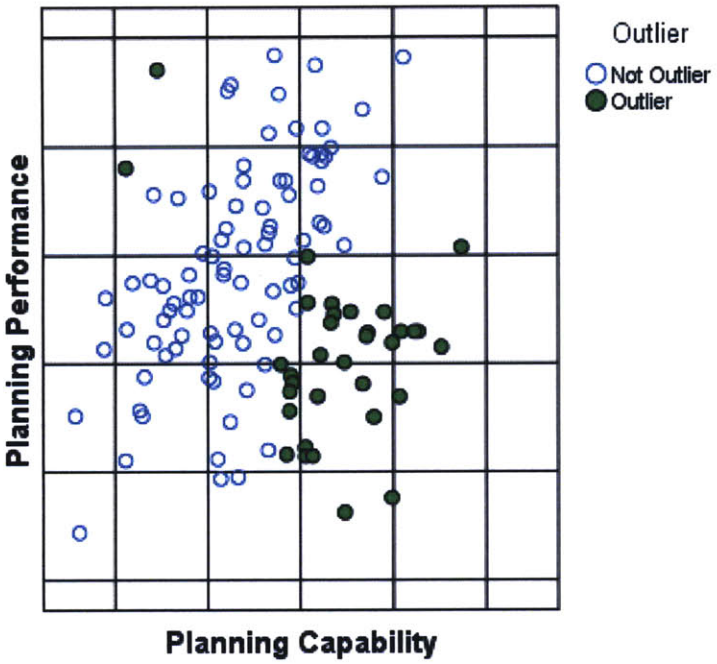


Figure 7 Scatter plot of Planning Capability vs. Performance

In the above graph, we identified some outliers which are shown in dark green. The outliers are the firms that reported very high on planning capability but at the same time performed very low in the planning metrics and vice versa. The method used to identify outliers was visual inspection. After removing the outliers, we get the following graph (Figure -8).

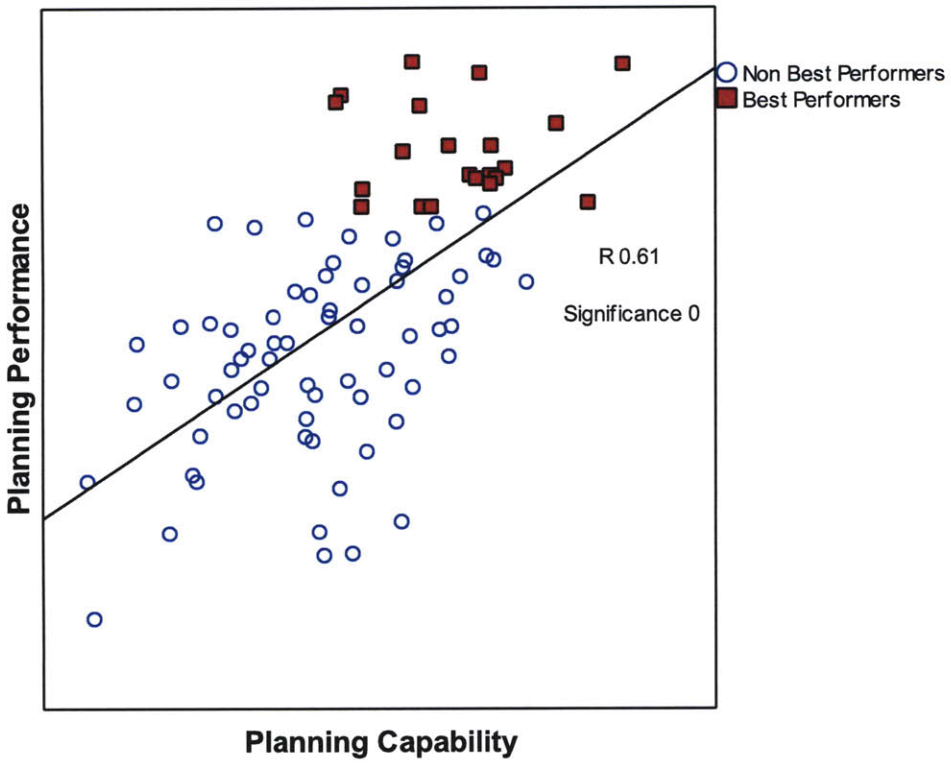


Figure 8 Scatter plot of Planning Capability vs. Performance after removing outliers

The above graphs clearly shows that planning capability highly correlates (R = 0.61) with planning performance. In other words, if a firm does the seven hypotheses well it is expected to do well in supply chain planning. These results signify only correlation and not causation.

We also considered removing firms based on one standard deviation away from the mean. The following figures (Figure-9 & Figure-10) show the distribution of the planning capability score and planning performance score.

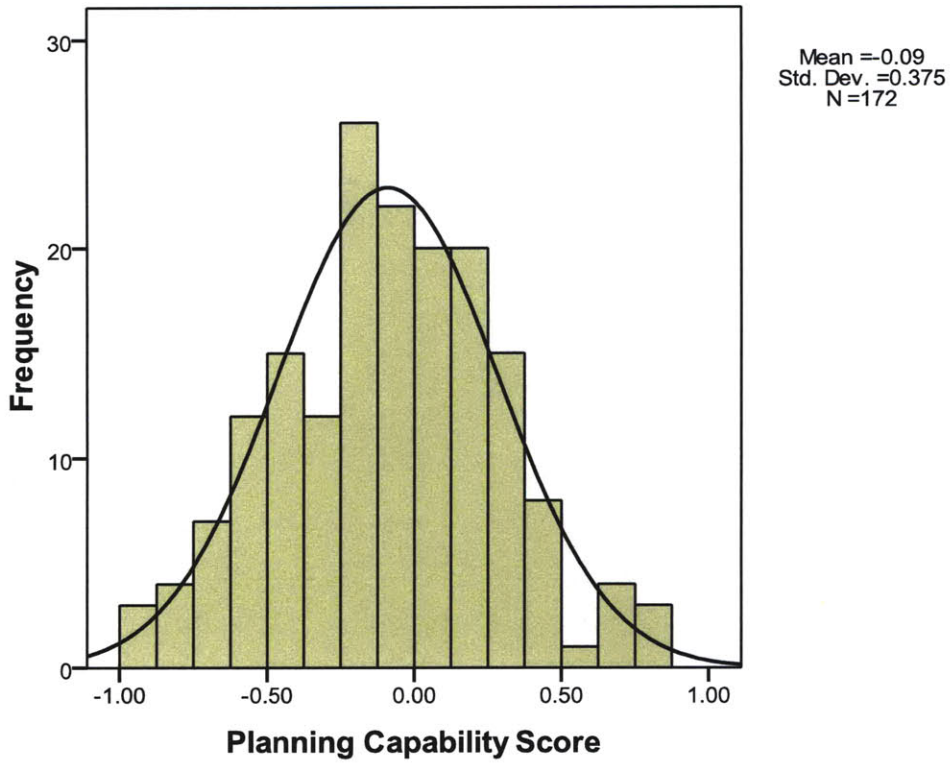


Figure 9 Planning Capability Score Distribution

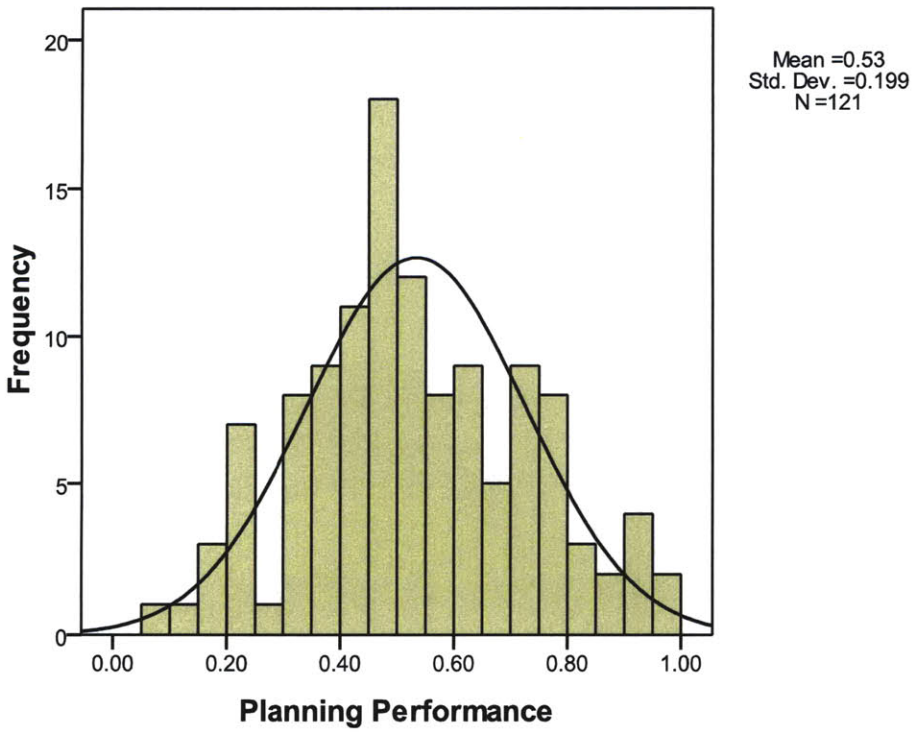


Figure 10 Planning Performance Distribution

We identified outlier to be the ones which are one standard deviation above (and below) the mean performance level and one standard deviation below (and above) mean in the planning capability. Based on the data in the figure 9 & 10 above, the outliers are the ones which have the following property:

- Planning performance above 0.73 and planning capability below -0.45
- Planning performance below 0.33 and planning capability above 0.285

If we remove outliers based on the criteria above then the correlation between planning performance and planning capability is 0.4 (Significance 0). Figure-11 below shows the scatter plot of planning performance and planning capability.

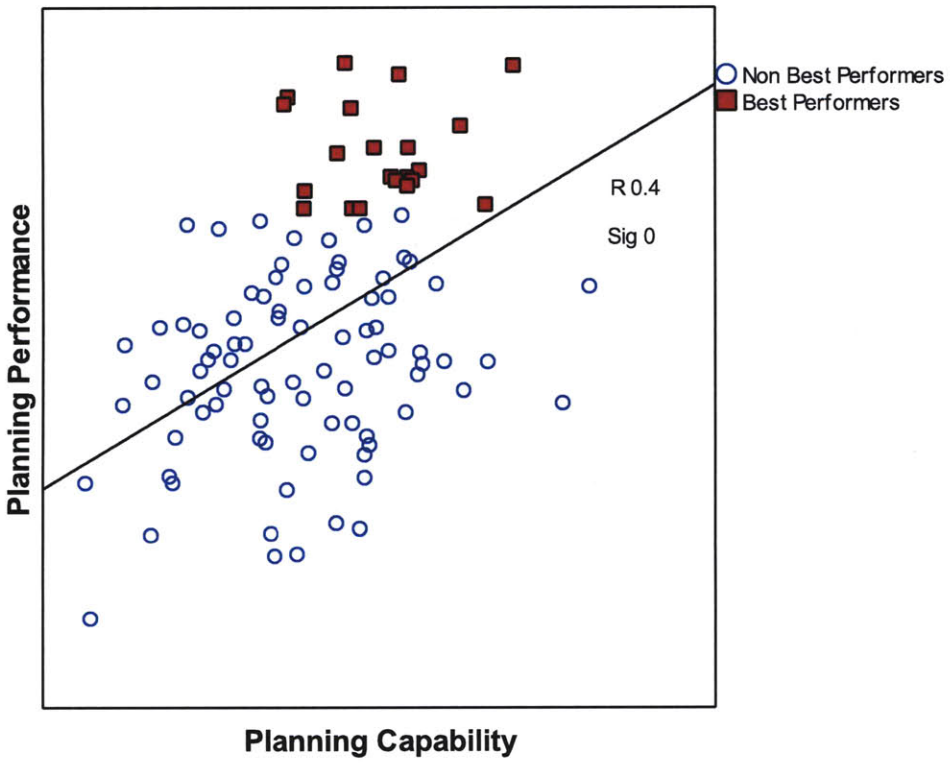


Figure 11 Planning Capability vs. Performance

Fulfillment

Fulfillment is the process or business of handling and executing customer orders, as packing, shipping, or processing checks[11]. We studied the data of over two hundred companies to identify best performers in fulfillment domain. The survey included data from various industries. Figure-12 below shows the fulfillment survey demographics.

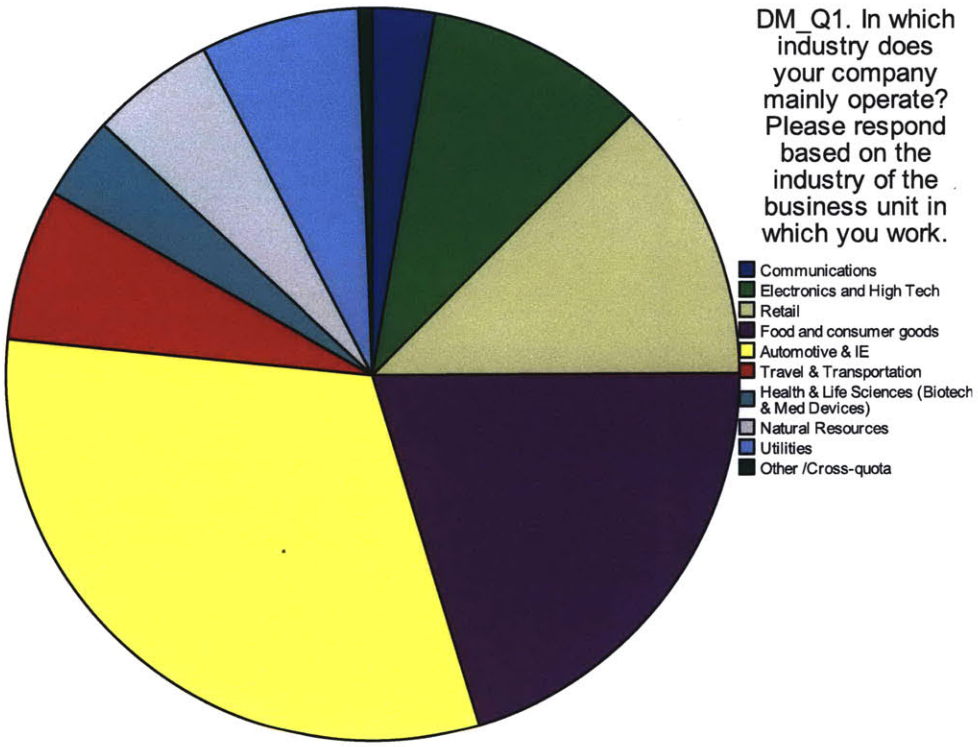


Figure 12 Fulfillment Survey Demographics by Industry

The fulfillment survey was divided into three parts described below:

- Demographics: This section contained questions to identify industry type, geography, details of person answering survey, and other demographic data.
- Hypothesis: This section included questions about eight hypothesis (described later in the chapter) which are related (in theory) to best performers.

[11] http://dictionary.reference.com/browse/fulfillment

- Metrics: This section contained questions to identify performance in fulfillment domain. The responses to the metric section were used to determine best performers in fulfillment domain.

The eight hypotheses included in the fulfillment survey are:

1. **Fulfillment Strategy – network design, route to market, and new product development:** Best performers use real time fulfillment information to ensure that customers' needs can be profitably satisfied at point of order, to influence customer behavior and improve customer intimacy.
2. **Fulfillment Strategy – 3PL Strategy:** Best performers optimize inventory and assets across the supply chain by substituting fixed and variable capital for information that enables them to effectively match supply and demand.
3. **Fulfillment operations – order capture:** Best performers reduce order fulfillment lead time by triggering all processes needed to complete an order at the point of order entry,
4. **Fulfillment operations – inventory management and postponement:** Best performers operate and optimize multiple Supply Chain channels based on the nature of customer service requirements and product characteristics.
5. **Fulfillment operations – warehousing & warehousing systems:** Best performers build flexibility across fulfillment channels to quickly and profitably meet surges in demand.
6. **Fulfillment operations – transportation and transportation systems:** Best performers continuously improve cost and service by analyzing and adapting fulfillment infrastructure (including partners and 3PL's) to meet changes in market and geography demand.
7. **Fulfillment operations – reverse logistics:** Best performers have standardized and often centralized process and IT infrastructure that allows them to quickly

and effectively respond to global market changes, mergers and other significant business change.

8. **Fulfillment systems – data integration and IT investment:** Best performers efficiently handle products through the reverse supply chain to final disposition. They achieve lower return levels by collecting detailed returns data to drive continual improvement in product and process.

The objective of our analysis here is twofold. First, we want to identify best performers in fulfillment and give each firm a rank between zero and one based on its relative performance among the total firms that participated in the survey. Second, we want to analyze which of the eight hypotheses correlate to the performance in fulfillment.

Identifying Best performers - Methodology

We considered four approaches to identify best performers. The approaches considered are defined below:

- Giving equal weight age to every metric question
- Factor analysis
- Optimization based approach
- Subjective approach

For details about the first three approaches above refer Methodology & Approach section of chapter "Supply Chain Planning – Identifying Best performers". The subjective approach was used to identify best performers because of the reasons outlined in Table-1 in chapter "Supply Chain Planning – Identifying Best performers".

In the subjective approach, best performers were identified as firms who were among top ten percent in the performance across two metric categories – cost effectiveness and customer service. Cost effectiveness is measured by total logistics cost (inbound and outbound) or outbound logistics cost. While customer service is determined by

average OTIF (On time in full) fill rate across all company's products. For each of the category the firms were given a rank between zero and one based on their performance in the peer group. Thereafter, the average of the two category ranks was taken to determine the final rank. The top ten percent of the companies in the final rank were identified as best performers.

Results & Discussion

Figure-13 below shows the scatter plot with two category ranks on the X (Cost) and Y (Service) axis. The best performers are shown in green fill color.

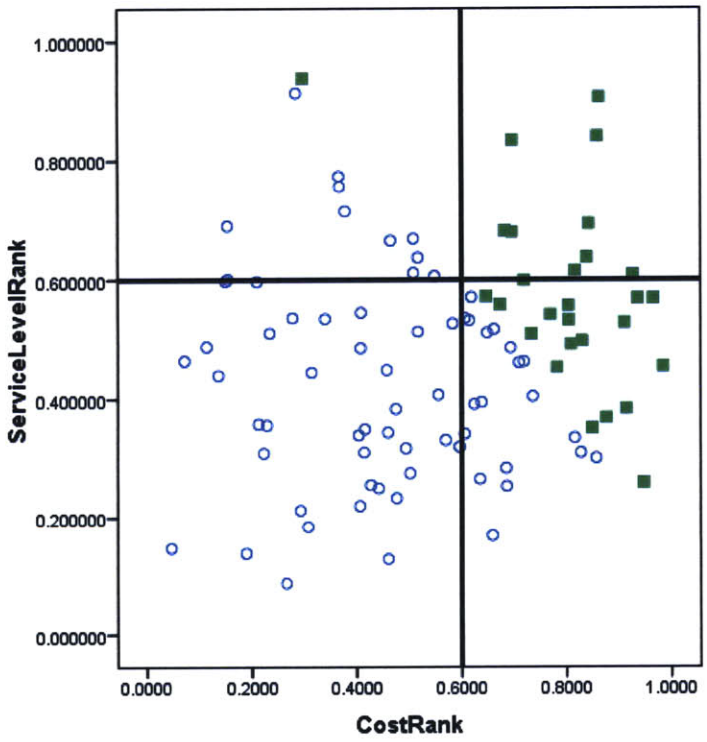


Figure 13 Fulfillment - Scatter plot of category ranks

The data in the above figure shows that best performers were mostly better in cost effectiveness than customer service.

Fulfillment – What does it take to be a best performer?

The in-depth analysis of fulfillment domain is divided into two modules described below:

- **Hypothesis Testing:** In this module the objective is to identify which of the eight hypotheses are most important for best performers.
- **Key Insights:** This module focuses on finding all statistically significant differences between best performers and non best performers in all questions under each hypothesis.

Hypothesis Testing

For hypothesis testing, the following steps were followed for each of the seven hypotheses to conduct the statistical analysis.

- The first step was the data cleaning. Survey questions ranking were not consistent and in some cases being 5 was best on a 1-5 scale while in others being 1 was best. The objective of this method was to make all the rankings consistent.
- The second step was to identify the set of questions that will be included in the hypothesis testing. Only questions in which the rankings were strictly categorical ordinal (i.e. one rank is better than the other) were included. Also questions which don't seem to be the representative of the hypothesis being tested were excluded.
- The next step is to use the statistical technique called categorical principal component analysis (CATPCA) to reduce the relevant set of questions under a hypothesis into a few dimensions that capture most of the variance in the data. For details on the CATPCA statistical technique, refer Appendix I.

- After reducing the set of questions into few dimensions, the next step is to generate factor score for each dimension. A factor score is a weighted score based on responses to the questions included in the dimension. The factor score method used in our analysis was regression in which the mean score is 0 and variance is the squared multiple correlation between estimated factor scores and the true factor values. Finally, the average of factor scores in all the dimensions. The final average score is called hypothesis CATPCA score.
- The next step is to categorize CATPCA score into valid or not valid based on its value. If the CATPCA score is above zero then we categorize the score as valid. Valid means that a particular firm is following that hypothesis because it has scored well in the responses to the set of questions included in the hypothesis testing.
- After we have categorized the CATPCA score as valid or not valid, we can create a 2x2 table of best performers and non best performers with valid and not valid in a particular hypothesis.
- The final step is to conduct a chi-square or Fischer test to test the hypothesis: "Is high performance in planning and being good in a hypothesis is independent"? Fischer test is preferred over chi-square test if any of the cell count in the 2x2 table is less than or equal to five.

Results & Discussion

The following graph (Figure-14) summarizes the results of hypothesis A to H. The x axis in the graph is the hypothesis A to G, while the y axis is the percentage of best performers and non best performers good in a particular hypothesis.

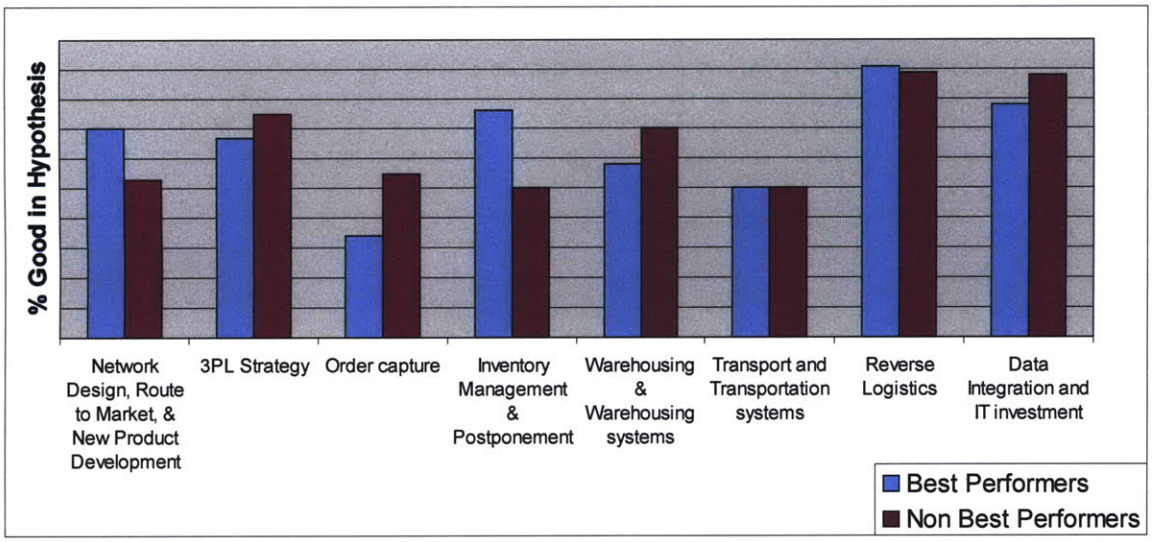


Figure 14 Fulfillment- Hypothesis Testing Summary

From the above graph best performers perform better in inventory management & postponement, fulfillment strategy (network design, route to market, & new product development), and reverse logistics. Out of these only performance in inventory management and postponement is statistically significant (p value 0.035).

Key Insights

Here, our focus is to identify all statistically significant differences between best performers and non best performers for each question in all the hypotheses. The questions in the hypothesis were based on the quantitative framework on a scale of 1 to 5. The statistical technique used to perform this test was cross tabulation where Fischer test or chi-square test was performed. Fischer test was preferred if any cell in the cross tabulation entry was less than or equal to five.

The following figure summarizes the results of the statistical analysis. Only results where significance was less than or equal to 0.2 are shown here.

Description	% Best performers	% of Non Best performers	Significance
Evaluate inbound and outbound network flow together	67	39	0.14
Transport provider is key element considered while evaluating inbound and outbound flow network	86	52	0.03
Capabilities in defined sales & operation planning (S&OP) and new product & market effort is important for new market entry	83	52	0.01
Continual evaluation of demand requests against inventory and production scheduled and make adjustments based on demand requirements	67	41	0.02
Product return data is regularly and systematically fed to R&D and incorporated into new product development	67	34	0.08

Figure 15 Fulfillment- Key Insights Summary

The first column in the above figure describes the survey question, the second column specifies the percentage of best performers who performed good in this question (i.e. they selected top two choices in the scale of 1-5), the third column specifies the same for non best performers, and finally the last column list the statistical significance or p value of the test.

Service Management

Service Management helps firms to improve customer loyalty by focusing on relationship with customers and by providing end to end solution to products and services. We studied the data of over seventy companies to identify best performers in service management domain. The survey included data from various industries. Figure-16 below shows the service management survey demographics.

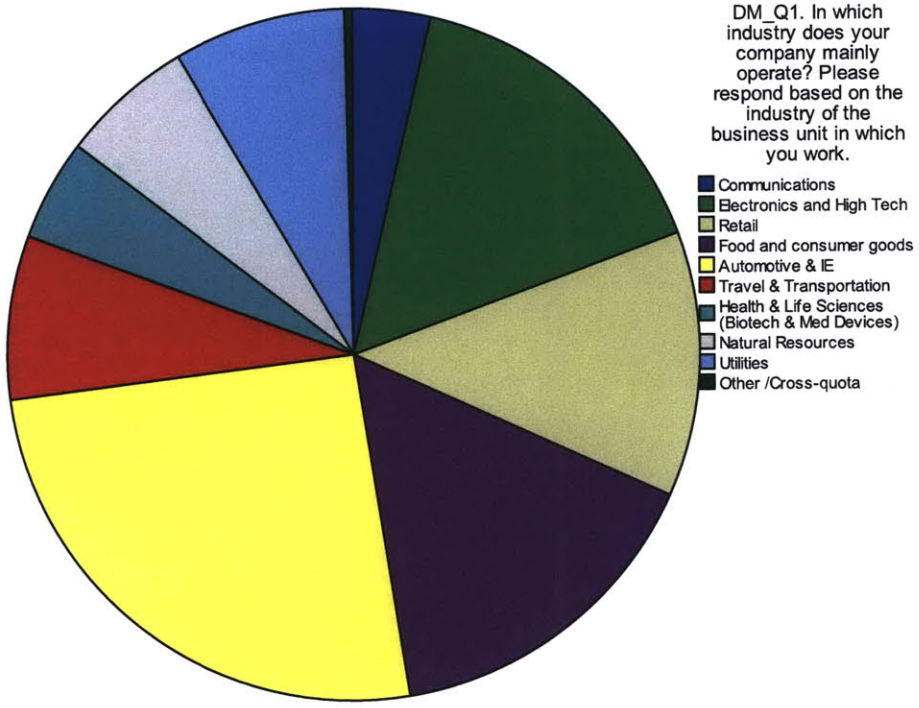


Figure 16 Service Management Survey Demographics by Industry

The SM survey was divided into three parts described below:

- Demographics: This section contained questions to identify industry type, geography, details of person answering survey, and other demographic data.
- Hypothesis: This section included questions about six hypotheses which are related to best performers.

- Metrics: This section contained questions to identify performance in service management domain. The responses to the metric section were used to determine best performers in service management domain.

The six hypotheses included in the service management survey are:

1. **After Sales Service Offerings:** Best performers create greater customer value by not simply selling quality products, but rather, by providing true end-to-end solutions of products and appropriate services.
2. **Service Delivery Model:** Best performers have a highly flexible service delivery model to serve customers where they are, on time, with high quality, at optimal cost.
3. **Asset Management and MRO (Maintenance, Repairs & Operations):** Best performers take a portfolio management approach to products, services and solutions to optimize revenue and margin while managing risk.
4. **Service Management Structure:** Best performers have clearly articulated partner strategy, consistent with their overall business strategy, which spells out how and when partners will be used to serve customers.
5. **Approach to and Use of Service Management Resources:** Best performers use historic and real-time data to proactively plan the optimal use of people, parts, facilities and partners.
6. **Overall Return on Service:** Best performers maximize return on service in terms of both financial return as well as customer satisfaction.

The objective of our analysis here is twofold. First to identify best performers in service management and give each firm a rank between zero and one based on its relative performance. Secondly to analyze which of the six hypotheses correlate to performance in service management.

Identifying Best performers - Methodology

We considered four approaches to identify best performers. The approaches considered are defined below:

- Giving equal weight age to every metric question
- Factor analysis
- Optimization based approach
- Subjective approach

For details about the first three approaches above refer Methodology & Approach section of chapter "Supply Chain Planning – Identifying Best performers". The subjective approach was used to identify best performers because of the reasons outlined in Table-1 in chapter "Supply Chain Planning – Identifying Best performers".

In the subjective approach, best performers were identified as firms who were among top ten percent in the performance across four metric categories – efficiency, service level, inventory management and cost. Below are the areas that were available in 'Metric' section of survey to measure each category.

- Efficiency: Equipments, maintenance efficiency and utilization.
- Service level: SKU fill rate and completion of work orders.
- Inventory management: Inventory turns, forecast and inventory level.
- Cost: Warranty and service inventory cost

For each of the category the firms were given a rank between zero and one based on their performance in the peer group. Thereafter, we followed below steps to calculate the ranks:

- Final Rank = Efficiency Rank * 0.3 + Service Level Rank * 0.3 + Inventory Management Rank * 0.2 + Cost Rank * 0.2
- Final Rank is calculated if a firm has at least 2 category ranks.
- Final Rank is multiplied by a suitable multiplier if final rank is calculated by using less than 4 categories

The top ten percent of the companies in the final rank were identified as best performers.

Results & Discussion

Figure-17 below shows the scatter plot with four category ranks against the final rank. The best performers are shown in green fill color.

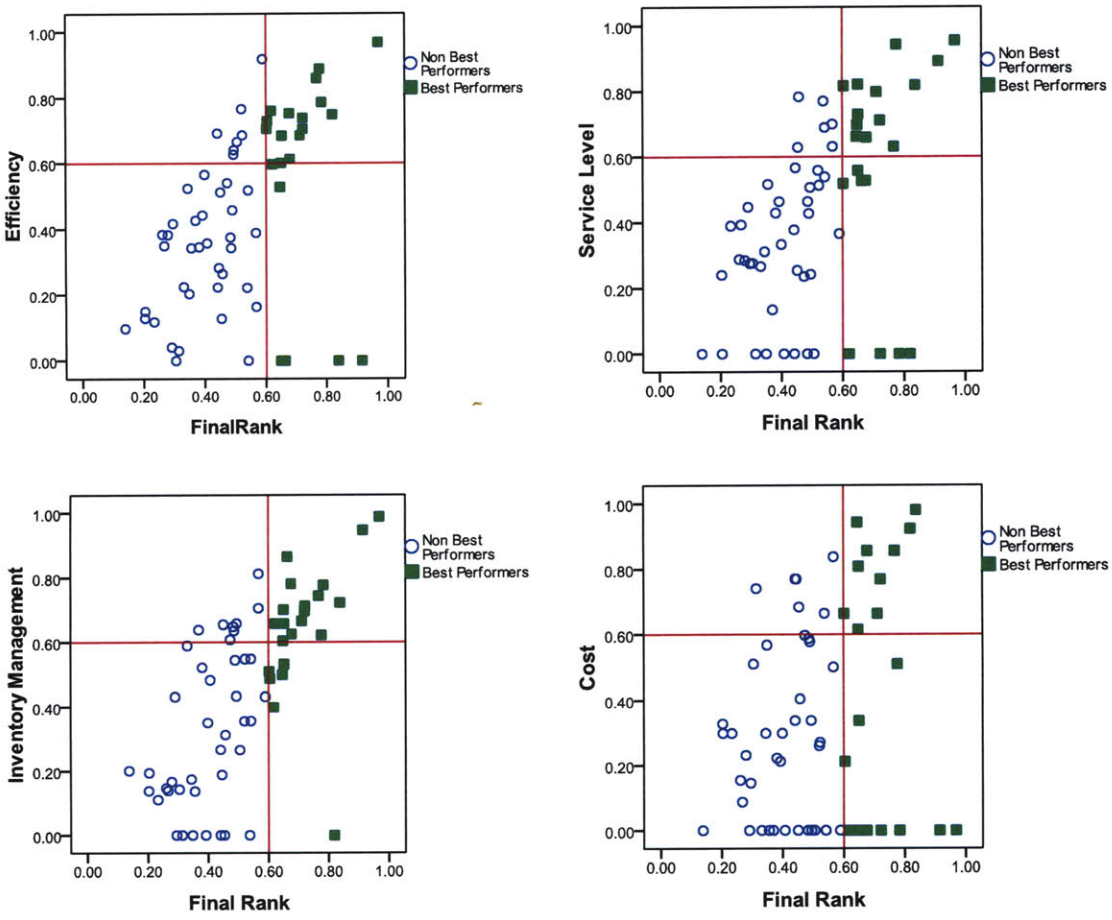


Figure 17 Service Management - Scatter plot of category ranks

The data in above figure clearly shows that almost all best performers were better in efficiency.

Manufacturing

Manufacturing includes all intermediate processes required for the production and integration of a product's components[12]. We studied the data of over two hundred companies to identify best performers in manufacturing domain. The survey included data from various industries. Figure-18 below shows the manufacturing survey demographics.

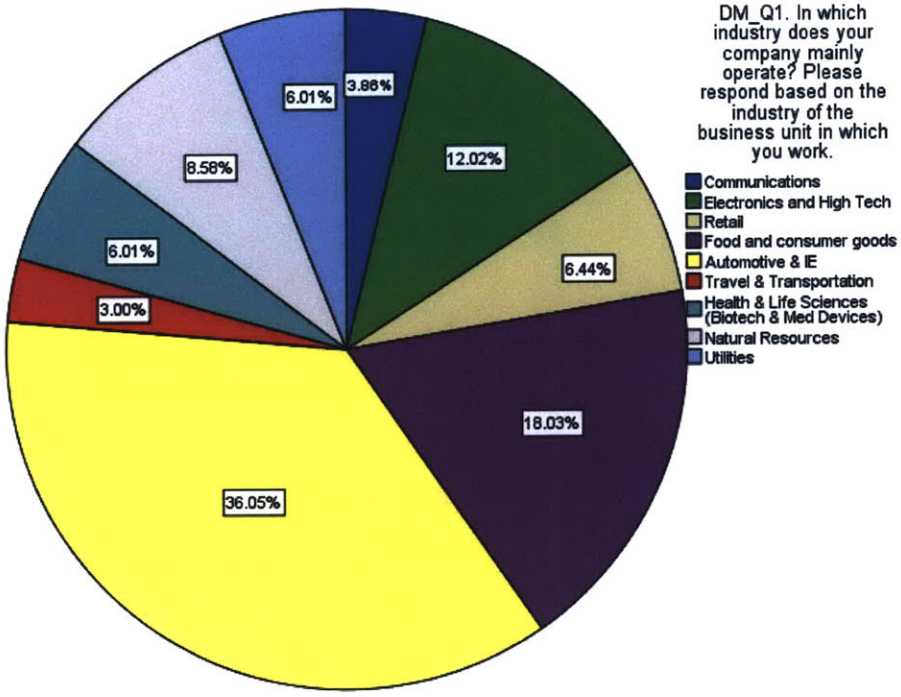


Figure 18 Manufacturing Survey Demographics by Industry

The manufacturing survey was divided into three parts described below:

- Demographics: This section contained questions to identify industry type, geography, details of person answering survey, and other demographic data.
- Hypothesis: This section included questions about seven hypotheses which are related to best performers.

[12] http://en.wikipedia.org/wiki/Manufacturing

- Metrics: This section contained questions to identify performance in manufacturing domain. The responses to the metric section were used to determine best performers in manufacturing domain.

The seven hypotheses included in the manufacturing survey are:

1. **Manufacturing Strategy Development:** Best performers develop global manufacturing strategies by modeling and achieving the right trade-offs across various key factors, including manufacturing operations' proximity to customers and proximity to/compatibility with suppliers; labor supply; labor and capital costs; and "copy exact" versus new manufacturing models.
2. **Use of Lean and Six Sigma Principles:** Best performers have adopted and internalized lean principles, including working jointly with third-party and contract manufacturers to embed lean principles into their operations.
3. **Integration of Manufacturing with Other Processes:** Best performers have an end-to-end manufacturing model that integrates process and design, planning & scheduling, S&OP, and service.
4. **Operation Flexibility and Visibility:** Best performers use leading indicators to gauge and achieve appropriate levels of operational flexibility, redundancy, and visibility.
5. **Continuous Process Improvement Approach:** Best performers continually search for manufacturing process improvement opportunities and prioritize them according to their overall business and product strategies.
6. **Employee Engagement:** Best performers enjoy a high degree of employee engagement among their manufacturing personnel, which translates into higher workforce productivity and greater contributions to the company's overall financial performance.
7. **Health, Safety and Environment:** Best performers maintain a safe, healthy work environment.

The objective of our analysis here is twofold. First, we want to identify best performers in manufacturing and give each firm a rank between zero and one based on its relative performance among the total firms that participated in the survey. Second, we want to analyze which of the seven hypotheses correlate to the performance in manufacturing.

Identifying Best performers - Methodology

We considered four approaches to identify best performers. The approaches considered are defined below:

- Giving equal weight age to every metric question
- Factor analysis
- Optimization based approach
- Subjective approach

For details about the first three approaches above refer Methodology & Approach section of chapter "Supply Chain Planning – Identifying Best performers". The subjective approach was used to identify best performers because of the reasons outlined in Table-1 in chapter "Supply Chain Planning – Identifying Best performers".

In the subjective approach, best performers were identified as firms who were among top ten percent in the performance across four metric categories – productivity, utilization, quality and fulfillment. Below are the areas that were available in 'Metric' section of survey to measure each category.

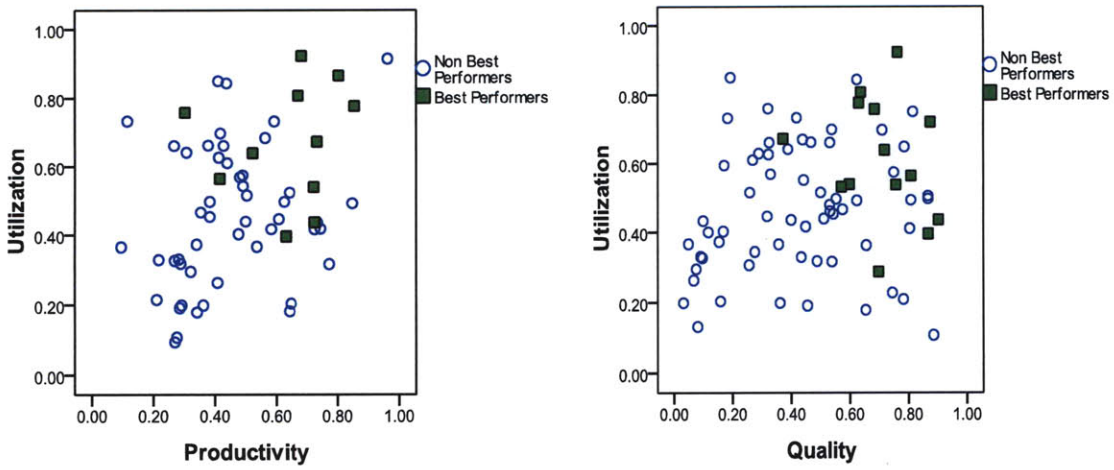
- Productivity: Manufacturing lead time and workforce effectiveness.
- Utilization: Equipment and Asset utilization.
- Quality: Scrap rate, material efficiency and first pass yield rate.
- Fulfillment: Plan, Schedule adherence and delivery conformance.

Following steps were followed to find the best performers.

a. Every company was ranked between 0-1 in each metric based on its performance across all industries
b. Every company was ranked between 0-1 across all industries on these four categories – equal weight age was given to each metric in a category. Only companies that answered data in more than 50% metric contained in a category were given a category rank.
c. For each category, a discrete score of 0 or 1 was also given if a company is in top 33%
d. A final score between 0-1 was calculated for each company by giving equal weight age to four categories. Only companies that had ranks in 3 or 4 categories were included
e. Finally the top ten percent of the companies in the final rank were identified as best performers

Results & Discussion

Figure-19 below shows the six scatter plot. The best performers are shown in green fill color.



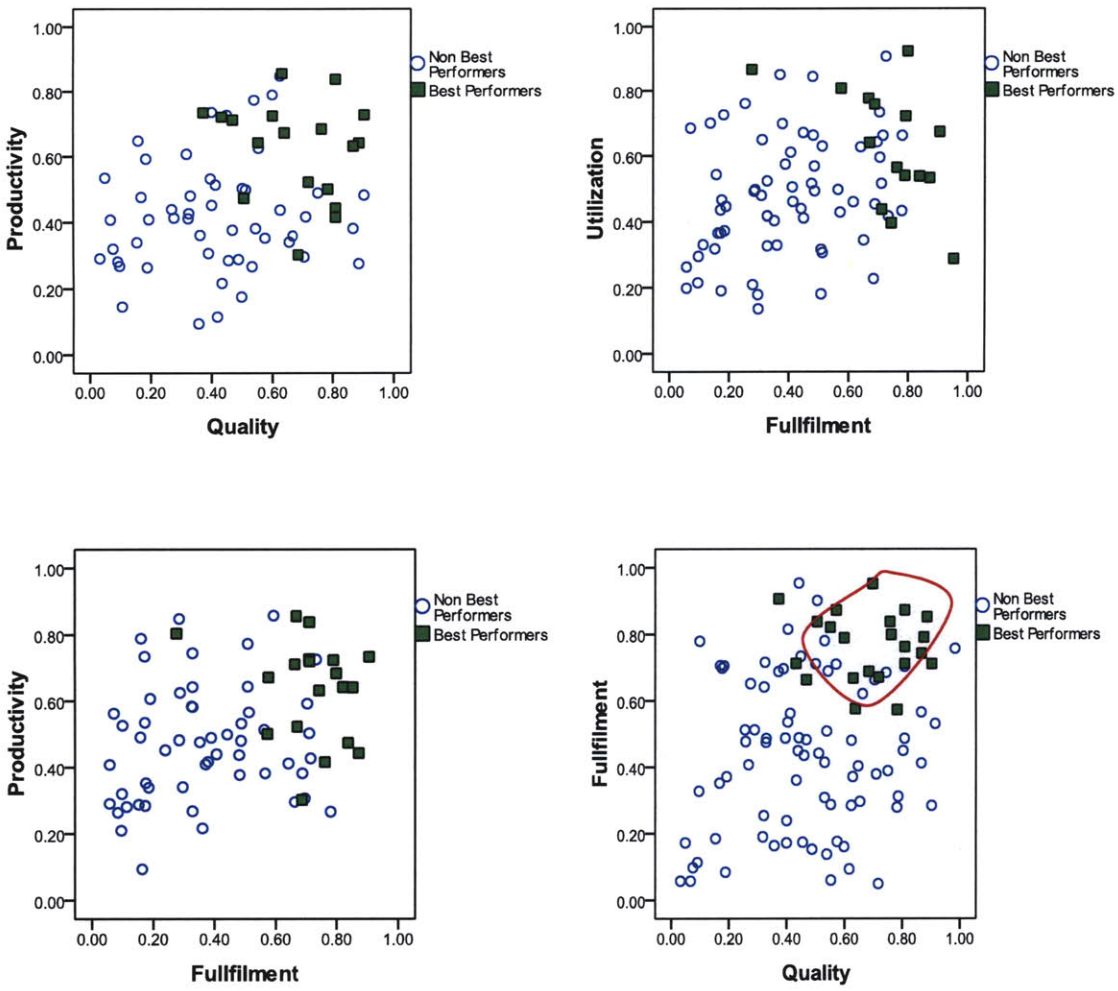


Figure 19 Manufacturing - Scatter plots

The data in the above figure shows that best performers were better in quality and fulfillment.

Manufacturing – What does it take to be a best performer?

The in-depth analysis of manufacturing domain is divided into two modules described below:

- **Hypothesis Testing:** In this module the objective is to identify which of the eight hypotheses are most important for best performers.
- **Key Insights:** This module focuses on finding all statistically significant differences between best performers and non best performers in all questions under each hypothesis.
- **Manufacturing capability:** This module finds the correlation of manufacturing capability as a whole and performance in manufacturing domain. The manufacturing capability as a whole is defined as the aggregate performance in the entire seven hypotheses.

Hypothesis Testing

For hypothesis testing, the following steps were followed for each of the seven hypotheses to conduct the statistical analysis.

- The first step was the data cleaning. Survey questions ranking were not consistent and in some cases being 5 was best on a 1-5 scale while in others being 1 was best. The objective of this method was to make all the rankings consistent.
- The second step was to identify the set of questions that will be included in the hypothesis testing. Only questions in which the rankings were strictly categorical ordinal (i.e. one rank is better than the other) were included. Also questions which don't seem to be the representative of the hypothesis being tested were excluded.
- The next step is to use the statistical technique called categorical principal component analysis (CATPCA) to reduce the relevant set of questions under a

hypothesis into a few dimensions that capture most of the variance in the data. For details on the CATPCA statistical technique, refer Appendix I.

- After reducing the set of questions into few dimensions, the next step is to generate factor score for each dimension. A factor score is a weighted score based on responses to the questions included in the dimension. The factor score method used in our analysis was regression in which the mean score is 0 and variance is the squared multiple correlation between estimated factor scores and the true factor values. Finally, the average of factor scores in all the dimensions. The final average score is called hypothesis CATPCA score.
- The next step is to categorize CATPCA score into valid or not valid based on its value. If the CATPCA score is above zero then we categorize the score as valid. Valid means that a particular firm is following that hypothesis because it has scored well in the responses to the set of questions included in the hypothesis testing.
- After we have categorized the CATPCA score as valid or not valid, we can create a 2x2 table of best performers and non best performers with valid and not valid in a particular hypothesis.
- The final step is to conduct a chi-square or Fischer test to test the hypothesis: "Is high performance in planning and being good in a hypothesis is independent"? Fischer test is preferred over chi-square test if any of the cell count in the 2x2 table is less than or equal to five.

Results & Discussion

The following graph (Figure-20) summarizes the results of hypothesis A to G. The x axis in the graph is the hypothesis A to G, while the y axis is the percentage of best performers and non best performers good in a particular hypothesis.

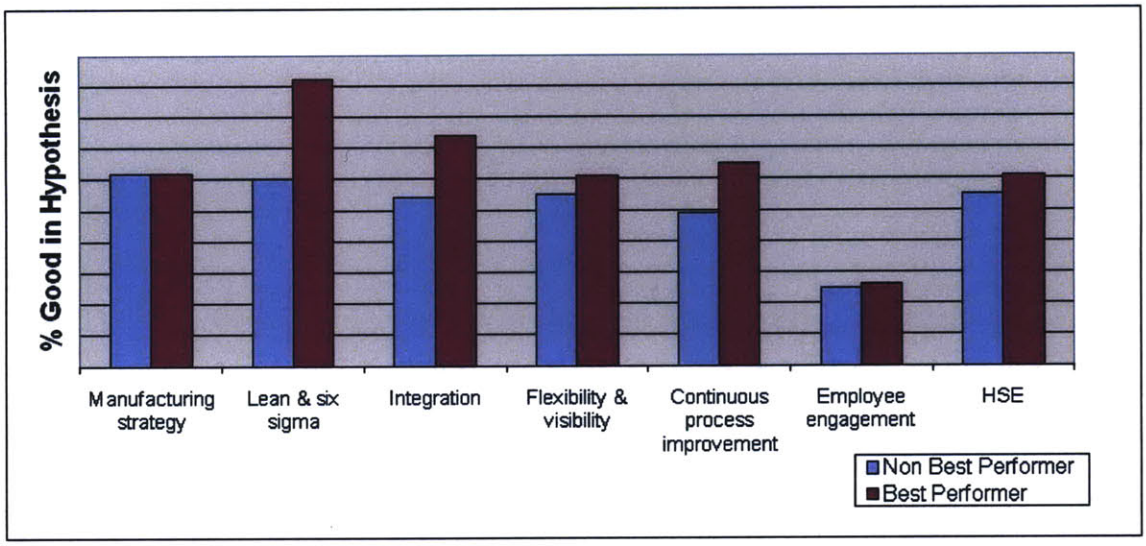


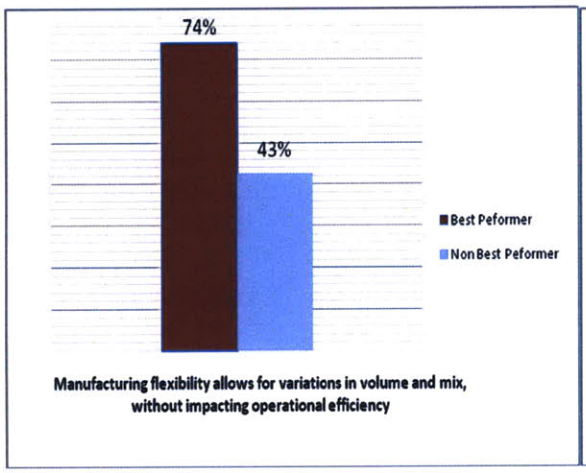
Figure 20 Manufacturing- Hypothesis Testing Summary

From the above graph best performers perform better in Lean & six sigma, Integration and Continuous process improvement. Out of these only performance in Lean & Six Sigma is statistically significant (p value 0.006).

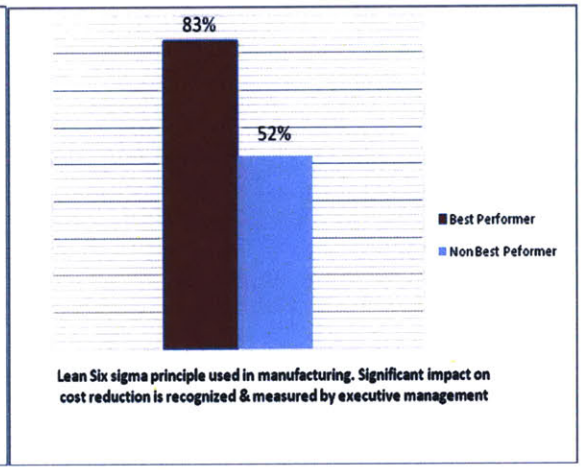
Key Insights

Here, our focus is to identify all statistically significant differences between best performers and non best performers for each question in all the hypotheses. The questions in the hypothesis were based on the quantitative framework on a scale of 1 to 5. The statistical technique used to perform this test was cross tabulation where Fischer test or chi-square test was performed. Fischer test was preferred if any cell in the cross tabulation entry was less than or equal to five.

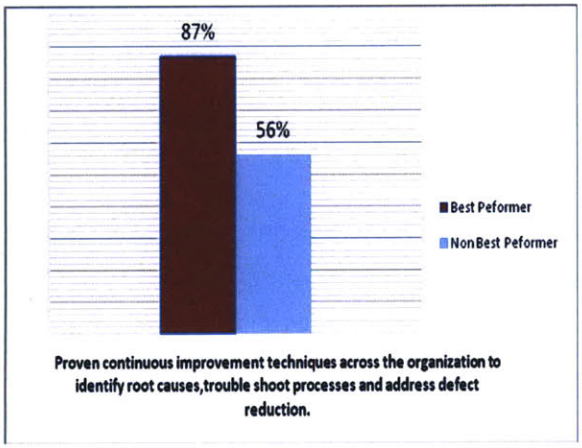
The following figures show the key areas where best performers are better than others. Only results where significance was less than or equal to 0.2 are shown here.



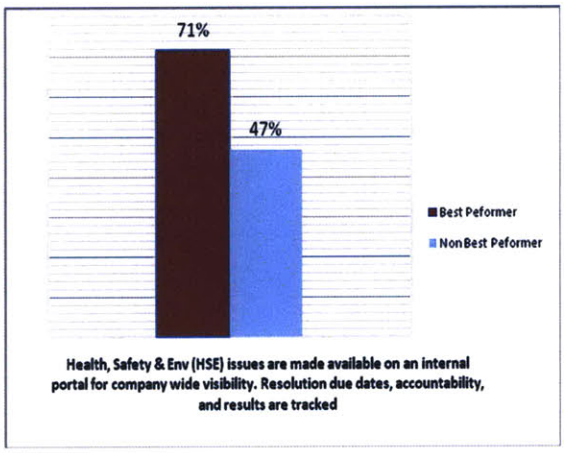
Statistical Significance – 0.089



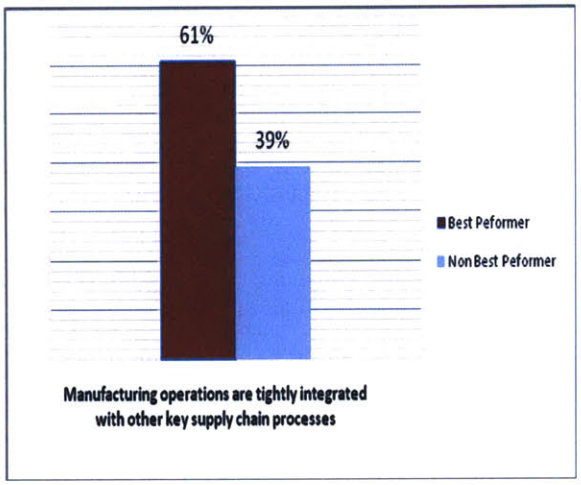
Statistical Significance – 0.107



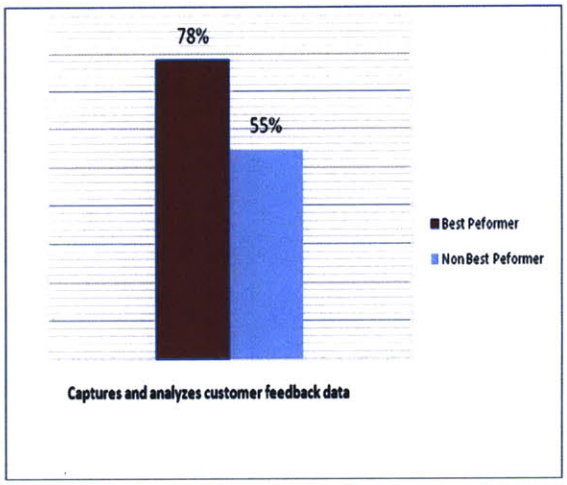
Statistical Significance – 0.0001



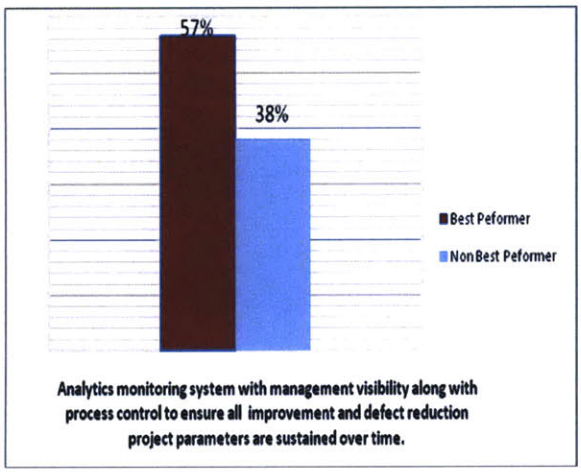
Statistical Significance – 0.001



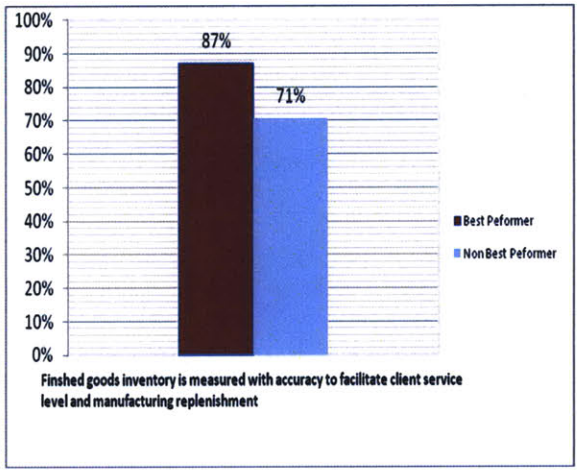
Statistical Significance – 0.039



Statistical Significance – 0.022



Statistical Significance – 0.101



Statistical Significance – 0.07

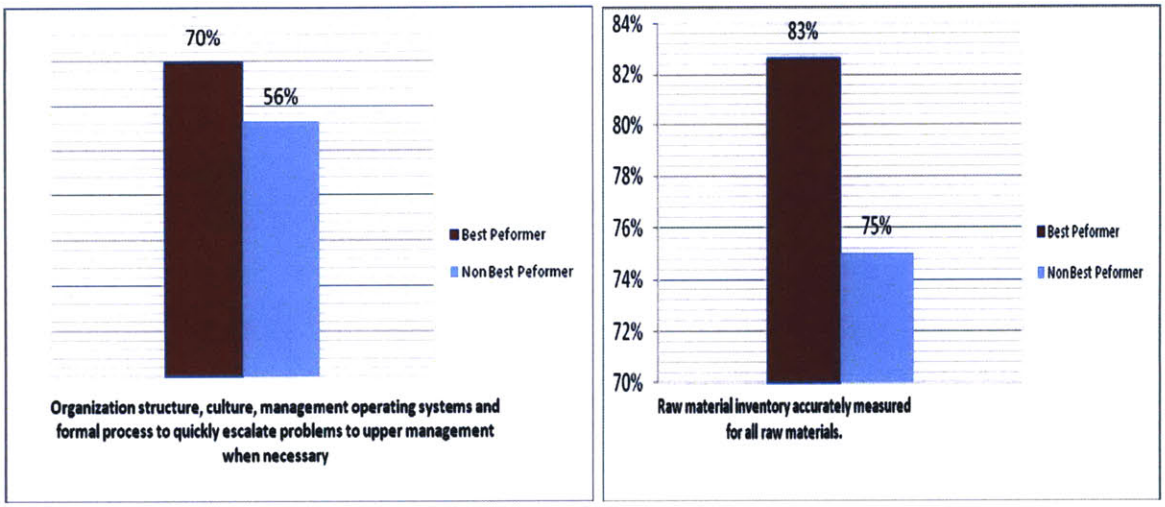


Figure 21 Manufacturing- Key Insights Summary

Manufacturing Capability Analysis

This module finds the correlation of manufacturing capability as a whole and performance in manufacturing domain. The manufacturing capability is defined as the aggregate performance in the entire seven hypotheses.

For manufacturing capability analysis, the following steps were followed:

- The first step was the data cleaning. Survey questions ranking were not consistent and in some cases being 5 was best on a 1-5 scale while in others being 1 was best. The objective of this method was to make all the rankings consistent.
- The second step was to identify the set of questions in all hypotheses that will be included in the manufacturing capability analysis. Only questions in which the rankings were strictly categorical ordinal (i.e. one rank is better than the other) were included.

- The next step is to use the statistical technique called categorical principal component analysis (CATPCA) to reduce the relevant set of questions under a hypothesis into a few dimensions that capture most of the variance in the data. For details on the CATPCA statistical technique, refer Appendix I.
- After reducing the set of questions into few dimensions, the next step is to generate factor score for each dimension. A factor score is a weighted score based on responses to the questions included in the dimension. The factor score method used in our analysis was regression in which the mean score is 0 and variance is the squared multiple correlation between estimated factor scores and the true factor values. Finally, the average of factor scores in all the dimensions. The final average score is called manufacturing capability CATPCA score.
- The final step is to plot the manufacturing capability CATPCA score and the manufacturing performance. Manufacturing performance is the final rank of the firms that we calculated in chapter-X.

Figure-22 below shows the scatter plot of manufacturing performance versus manufacturing capability.

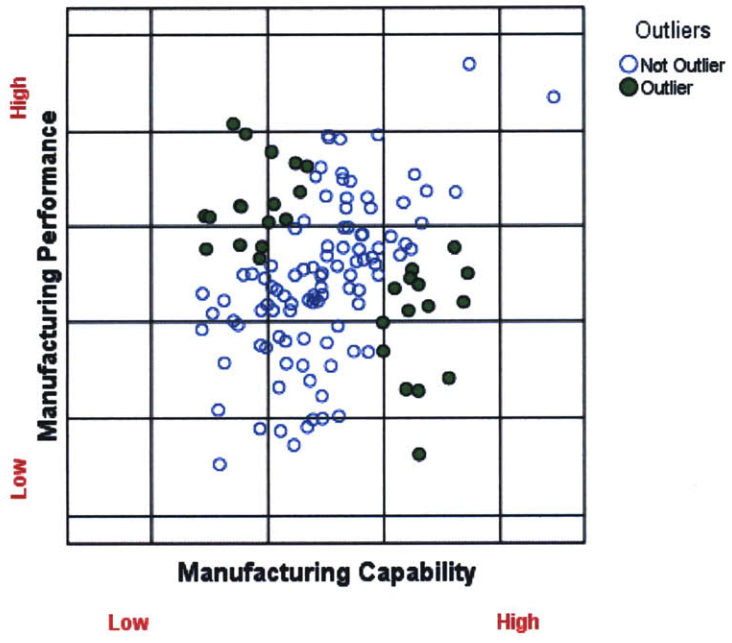


Figure 22 Scatter plot of Manufacturing Capability vs. Performance

In the above graph, we identified some outliers which are shown in dark green. The outliers are the firms that reported very high on manufacturing capability but at the same time performed very low in the manufacturing metrics and vice versa. The method used to identify outliers was visual inspection. After removing the outliers, we get the following graph (Figure -23).

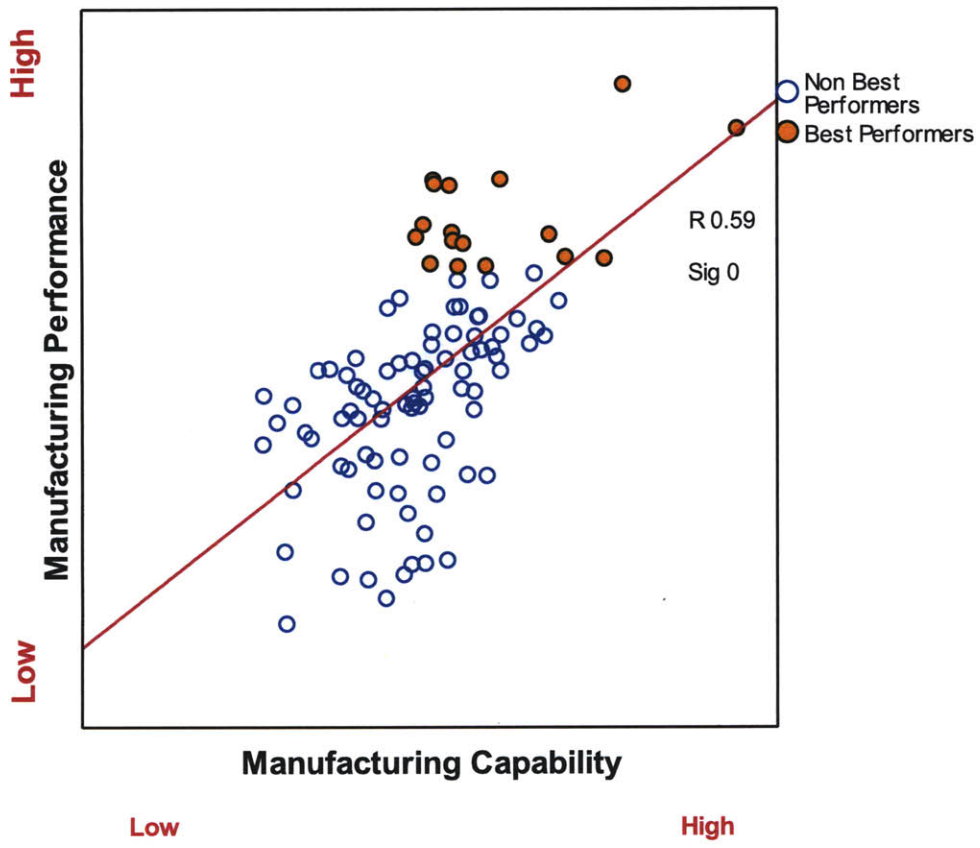


Figure 23 Scatter plot of Manufacturing Capability vs. Performance after removing outliers

The above graphs clearly shows that manufacturing capability highly correlates (R = 0.59) with manufacturing performance. In other words, if a firm does the seven hypotheses well it is expected to do well in supply chain planning. These results signify only correlation and not causation.

We also considered removing firms based on one standard deviation away from the mean. The following figures (Figure-24 & Figure-25) show the distribution of the manufacturing capability score and manufacturing performance score.

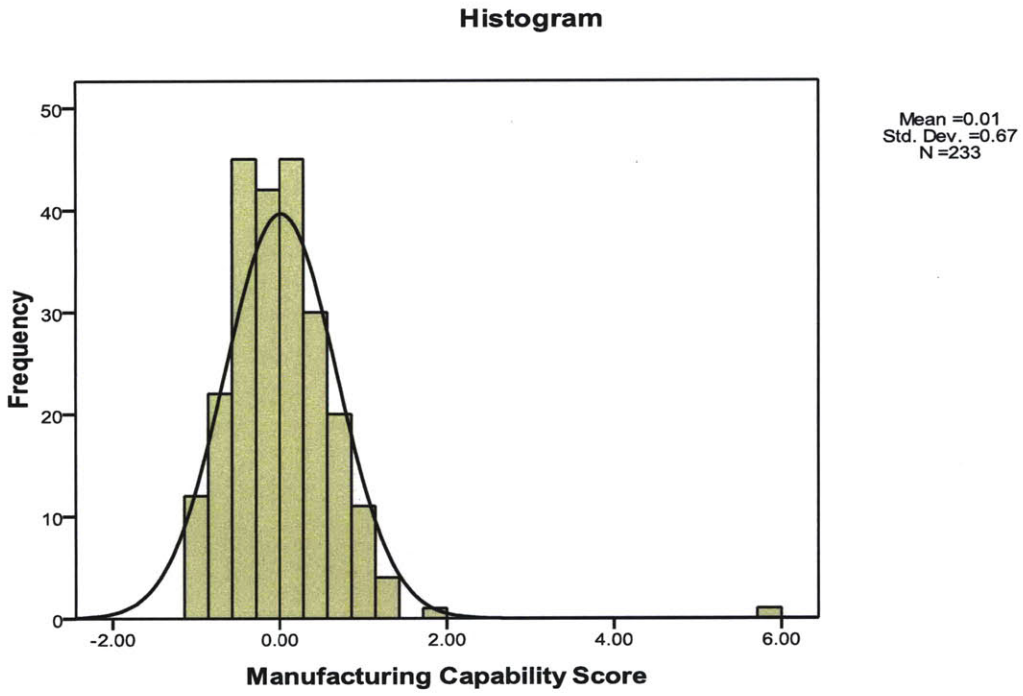


Figure 24 Manufacturing Capability Score Distribution

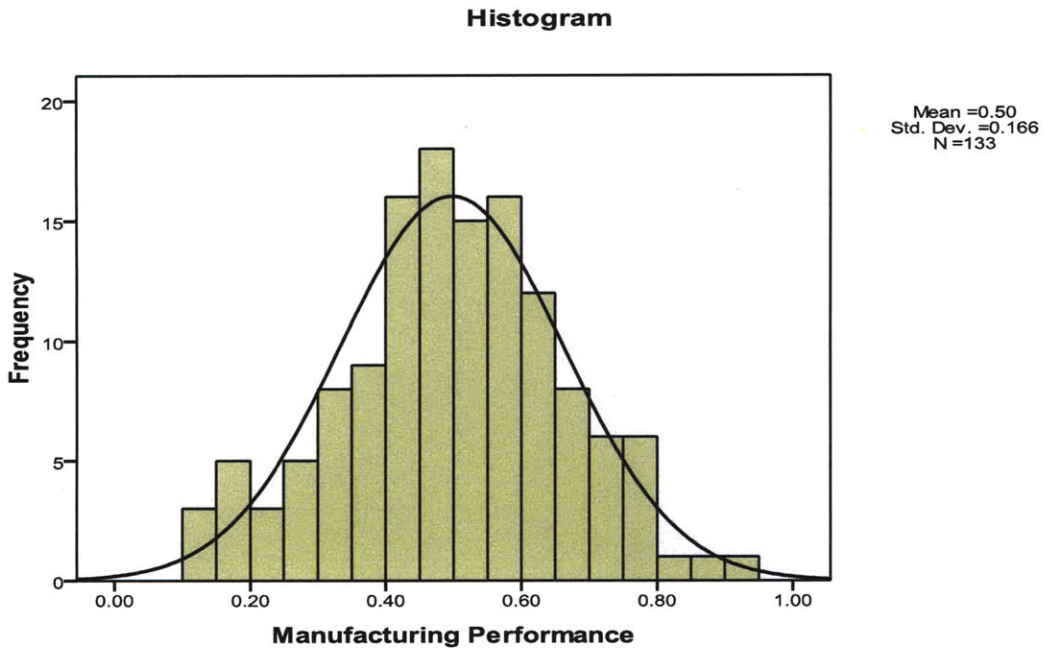


Figure 25 Manufacturing Performance Distribution

We identified outlier to be the ones which are one standard deviation above (and below) the mean performance level and one standard deviation below (and above) mean in the manufacturing capability. Based on the data in the figure 24 & 25 above, the outliers are the ones which have the following property:

- Manufacturing performance above 0.67 and Manufacturing capability below -0.66
- Manufacturing performance below 0.33 and Manufacturing capability above 0.68

If we remove outliers based on the criteria above then the correlation between manufacturing performance and manufacturing capability is 0.34 (Significance 0.01). Figure-26 below shows the scatter plot of manufacturing performance and manufacturing capability.

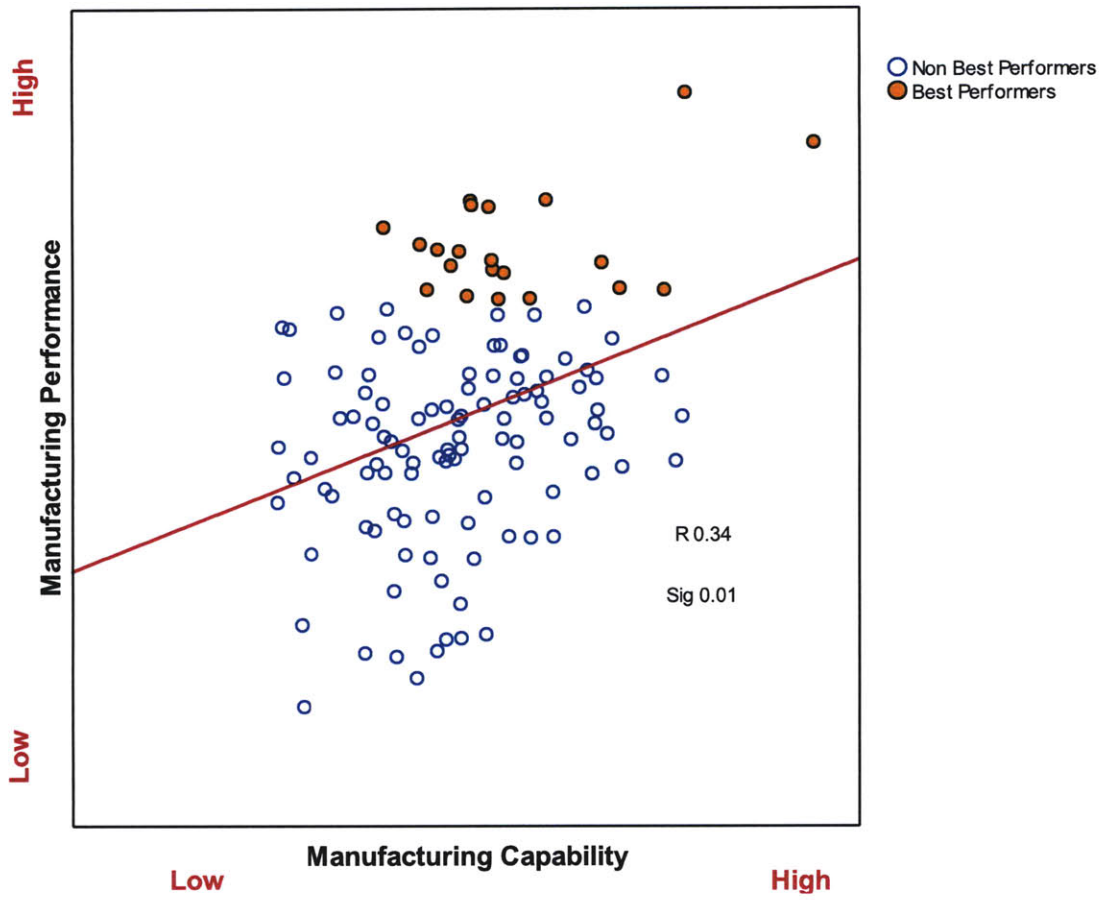


Figure 26 Manufacturing Capability vs. Performance

Product Lifecycle Management (PLM)

PLM manages properties and characteristics of a product in its life cycle mainly from engineering and business point of view. Product life cycle has four different stages: Market Introduction Stage, Growth Stage, Mature Stage and Saturation & Decline Stage[13]. We studied the data of over two hundred and fifty companies to identify best performers in PLM domain. The survey included data from various industries. Figure-27 below shows the PLM survey demographics.

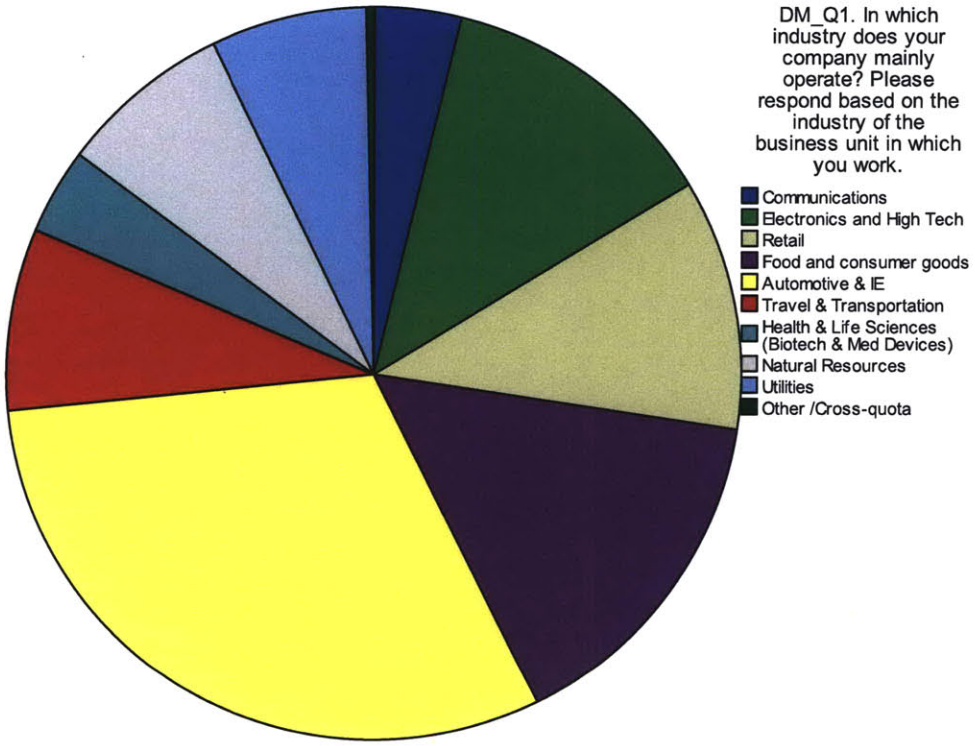


Figure 27 PLM Survey Demographics by Industry

The PLM survey was divided into three parts described below:

[13] Levitt, T. (1965) Exploit the product life cycle, *Harvard Business Review*, vol 43, November-December 1965, pp 81–94

- Demographics: This section contained questions to identify industry type, geography, details of person answering survey, and other demographic data.
- Hypothesis: This section included questions about seven hypotheses which are related to best performers.
- Metrics: This section contained questions to identify performance in PLM domain. The responses to the metric section were used to determine best performers in PLM domain.

The seven hypotheses included in the PLM survey are:

1. **Overall New Product Development (NPD) philosophy:** Best performers are better at anticipating customer needs when they introduce new products to the market—thus helping to ensure stronger acceptance of new products overall. Best performers enable this through seamless hand-offs between marketing and product development and extensive, non-traditional use of customer data.
2. **The Voice of Customer in NPD:** Best performers embed the voice of the customer within New Product Development.
3. **Introduction of New Technology in NPD:** Best performers are adept at introducing new technology in their products. They do this by striking the right balance in taking on the associated technology risk within their new product programs, having an actively managed risk mitigation plan, and by developing strong external partnerships.
4. **NPD People, Organization Structure and Operating Model:** Best performers source talent and innovation worldwide, while optimizing delivery cost and efficiency using a variety of operating models.

5. **Sources of New Product Ideas:** Best performers get a much larger percentage of their new product ideas from outside their organization than do non-performers.
6. **Use of Platform and Modular Approaches to Product Design:** Best performers have more flexible and adaptable product development capabilities because they take a platform approach to product design and have a modular product strategy to make it easier to change specific technology components.
7. **Developing Products for Sustainability and Efficiency:** Best performers apply sustainability principles at product design and through the entire product lifecycle—not only to the products themselves but also to the processes through which the products are produced and distributed. Best performers are adept at developing products that incorporate characteristics enhancing downstream operational efficiencies such as in manufacturing and fulfillment.

The objective of our analysis here is twofold. First, we want to identify best performers in PLM and give each firm a rank between zero and one based on its relative performance among the total firms that participated in the survey. Second, we want to analyze which of the seven hypotheses correlate to the performance in PLM.

Identifying Best performers - Methodology

We considered four approaches to identify best performers. The approaches considered are defined below:

- Giving equal weight age to every metric question
- Factor analysis
- Optimization based approach
- Subjective approach

For details about the first three approaches above refer Methodology & Approach section of chapter "Supply Chain Planning – Identifying Best performers". The subjective approach was used to identify best performers because of the reasons outlined in Table-1 in chapter "Supply Chain Planning – Identifying Best performers".

In the subjective approach, best performers were identified as firms who were among top ten percent in the performance across four metric categories – leadership, technology, ideas and cost. Below are the areas that were available in 'Metric' section of survey to measure each category.

- Leadership: Market leadership.
- Technology: Utilization of technology and carbon footprint.
- Ideas: Product idea originated from outside the firm and number of patients issued.
- Cost: ROI on product development and monitoring of money spent on supply chain.

For each of the category the firms were given a rank between zero and one based on their performance in the peer group. Thereafter, the average of the four category ranks was taken provide they have at least two category ranks to determine the final rank. The top ten percent of the companies in the final rank were identified as best performers.

Results & Discussion

Figure-28 below shows the scatter plot with four category ranks against final rank. The best performers are shown in green fill color.

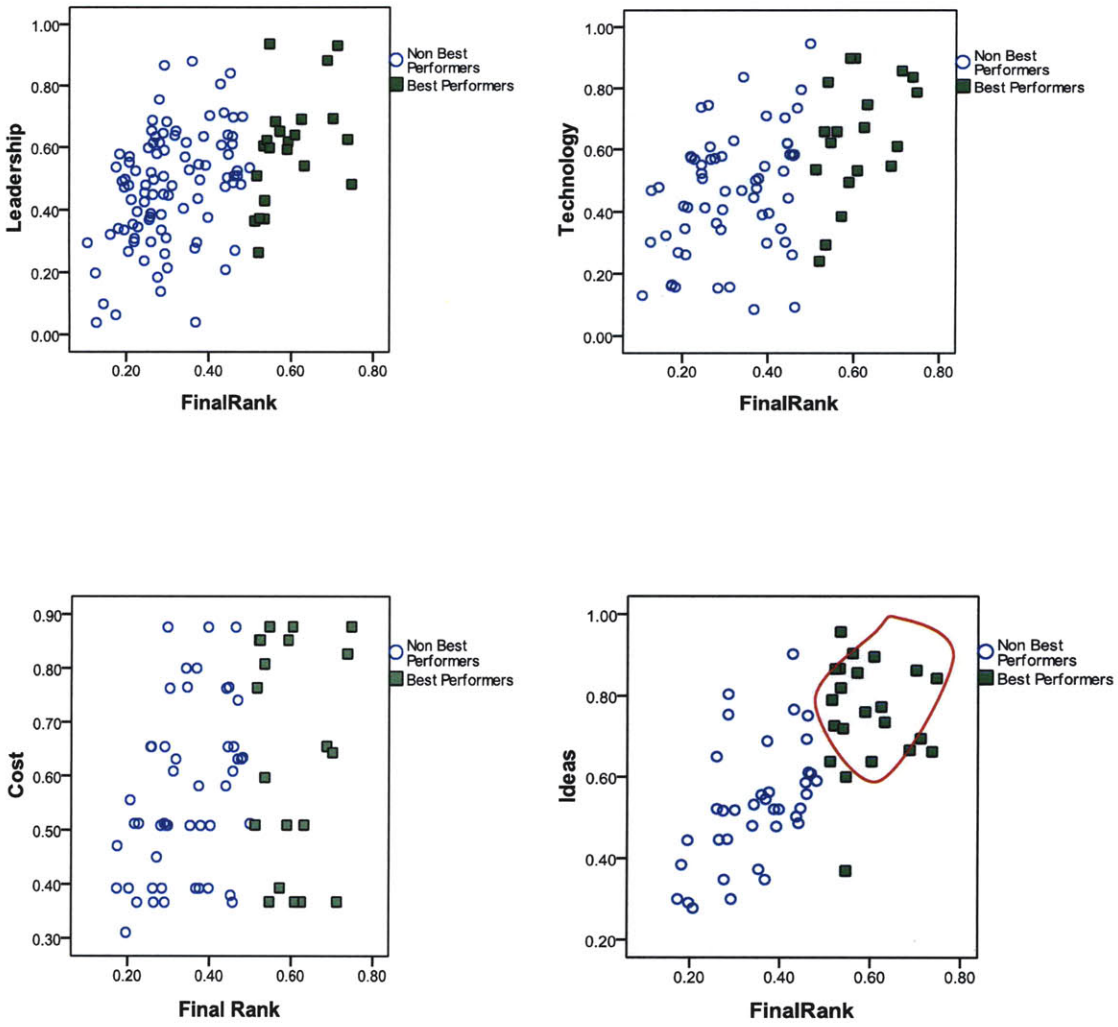


Figure 28 PLM - Scatter plot of category ranks

The data in the above figure shows that best performers were very good at taking product ideas from outside the firm.

Product Lifecycle Management – What does it take to be a best performer?

The in-depth analysis of PLM domain is divided into two modules described below:

- **Hypothesis Testing:** In this module the objective is to identify which of the eight hypotheses are most important for best performers.
- **Key Insights:** This module focuses on finding all statistically significant differences between best performers and non best performers in all questions under each hypothesis.

Hypothesis Testing

For hypothesis testing, the following steps were followed for each of the seven hypotheses to conduct the statistical analysis.

- The first step was the data cleaning. Survey questions ranking were not consistent and in some cases being 5 was best on a 1-5 scale while in others being 1 was best. The objective of this method was to make all the rankings consistent.
- The second step was to identify the set of questions that will be included in the hypothesis testing. Only questions in which the rankings were strictly categorical ordinal (i.e. one rank is better than the other) were included. Also questions which don't seem to be the representative of the hypothesis being tested were excluded.
- The next step is to use the statistical technique called categorical principal component analysis (CATPCA) to reduce the relevant set of questions under a hypothesis into a few dimensions that capture most of the variance in the data. For details on the CATPCA statistical technique, refer Appendix I.

- After reducing the set of questions into few dimensions, the next step is to generate factor score for each dimension. A factor score is a weighted score based on responses to the questions included in the dimension. The factor score method used in our analysis was regression in which the mean score is 0 and variance is the squared multiple correlation between estimated factor scores and the true factor values. Finally, the average of factor scores in all the dimensions. The final average score is called hypothesis CATPCA score.
- The next step is to categorize CATPCA score into valid or not valid based on its value. If the CATPCA score is above zero then we categorize the score as valid. Valid means that a particular firm is following that hypothesis because it has scored well in the responses to the set of questions included in the hypothesis testing.
- After we have categorized the CATPCA score as valid or not valid, we can create a 2x2 table of best performers and non best performers with valid and not valid in a particular hypothesis.
- The final step is to conduct a chi-square or Fischer test to test the hypothesis: "Is high performance in planning and being good in a hypothesis is independent"? Fischer test is preferred over chi-square test if any of the cell count in the 2x2 table is less than or equal to five.

Results & Discussion

The following graph (Figure-29) summarizes the results of hypothesis A to G. The x axis in the graph is the hypothesis A to G, while the y axis is the percentage of best performers and non best performers good in a particular hypothesis.

Hypothesis	Importance	Significance	Comments
Overall NPD philosophy		Not Significant	Statistically nothing conclusive can be said
Voice of the customer in the NPD		Not Significant	Statistically nothing conclusive can be said
Introduction of new technology in NPD		Not Significant	Statistically nothing conclusive can be said but masters seems to use this hypothesis more than non masters
NPD people, organization structure and operating model		Significant (0.08)	Being good in this hypothesis **strongly** increases the chances of becoming a master in fulfillment
Source of new product ideas		Not Significant	Statistically nothing conclusive can be said
Use of platform and modular approaches to product design		Not Significant	Statistically nothing conclusive can be said but masters seems to use this hypothesis more than non masters
Developing products for sustainability and efficiency		Significant (0.1)	Being good in this hypothesis **strongly** increases the chances of becoming a master in fulfillment

Figure 29 PLM- Hypothesis Testing Summary

From the above table we can confer best performers perform better in sourcing talent, innovation worldwide and in developing products by optimizing delivery cost and improving efficiency through a variety of operating models.

Key Insights

Here, our focus is to identify all statistically significant differences between best performers and non best performers for each question in all the hypotheses. The questions in the hypothesis were based on the quantitative framework on a scale of 1 to 5. The statistical technique used to perform this test was cross tabulation where Fischer test or chi-square test was performed. Fischer test was preferred if any cell in the cross tabulation entry was less than or equal to five.

The following figure summarizes the results of the statistical analysis. Only results where significance was less than or equal to 0.2 are shown here.

Description	% Best Performer	% Non Best Performer	Significance
Globally sourced NPD resources form integrated teams and coordinate efforts on product programs globally	58	30	0.14
Attraction of high quality product development talent to the compa	63	27	0.01
Ability to integrate the various information sources and systems related to new product development	58	39	0.07
Value-oriented IT support function allowing continuous improvement in process and IT	63	38	0.04
New products's manufacturing and distribution processes are designed with stainability in mind	74	50	0.00
Planning and concept development phase is more rigorous, relative to competition, in minimizing product design, prototyping, launch, and service-related issues.	58	36	0.03

Figure 30 PLM- Key Insights Summary

The first column in the above figure describes the survey question, the second column specifies the percentage of best performers who performed good in this question (i.e. they selected top two choices in the scale of 1-5), the third column specifies the same for non best performers, and finally the last column list the statistical significance or p value of the test.

Cross Domain Analysis

The objective of the cross domain analysis is to study the relationship between a firm's value proposition and its mastery in capability domains. The five capability domains included in the cross domain analysis are planning, manufacturing, fulfillment, service management, and product lifecycle management. The value propositions included in the cross domain analysis are:

1. Product leadership & Innovation
2. Customer Experience
3. Cost Competitiveness

The companies participating in the survey were directly asked about their value proposition. The survey had only the above mentioned choices and only one choice was allowed.

Data Preparation

For each domain best performers were identified and a final rank (between 0-1) was given. A higher rank implies the firm is good in that particular domain. For details for the assigning final rank, please refer to the following:

- Planning: Chapter "Supply Chain Planning – Identifying Best performers"
- Fulfillment: Chapter "Fulfillment"
- Service Management: Chapter "Service Management"
- Product Lifecycle Management (PLM): Chapter "Product Lifecycle Management"
- Manufacturing: Chapter "Manufacturing"

For the purpose of cross domain analysis we took the union of best performers from all domains i.e. all firms that are best performers in at least one domain were included. For all these firms, their final rank is taken from all the capability domains and also their value proposition. Few firms answered different value proposition in the different capability domains. This happened because different people from the same firms answered different capability domain surveys. For these firms a union of value proposition is taken. These cases are very few and their effect on the final result is negligible.

The following table shows the total number of firms that are included in the analysis and the number of the surveys they answered.

Total Firms included in analysis	108
Firms answered 1 survey	65
Firms answered 2 surveys	29
Firms answered 3 surveys	10
Firms answered 4 surveys	3
Firms answered 5 surveys	1

Table 9 Cross Domain Data Overview

Methodology

To find the relationship between value proposition and mastery in capability domains we adopted an optimization based approach. For each value proposition, the simple least square optimization is run to find the optimal weights in each capability domains. These weights don't have much significance in the absolute terms but relatively they can answer that which domains are most important for your organization if your value proposition is product leadership, for example.

The optimization mechanics of the cross domain analysis is shown in Figure-31 below.

- Objective Function
  - Min $\sum_I (F_I - \sum_J w_J X_{IJ})^2$
    - w_J – where J varies from 1 to 5. w_1 for planning, w_2 for manufacturing, w_3 for fulfillment, w_4 for PLM, and w_5 for service management
    - X_{IJ} is the final rank of company I in domain J
    - F_I – 1 if firm is focused in the value proposition, 0 otherwise
- Decision variables
  - w_J
- Constraints:
  - $w_J >= 0$ for all J
  - $\sum_J w_J = 1$

Figure 31 Optimization Mechanics for cross domain analysis

The optimization was run for each value proposition using excel solver. The optimization for each value proposition converged to a solution. Because the objective function is quadratic, the solution is indeed the global minimum and therefore the optimization results are reliable.

Results & Discussion

The following results (Figure-32) were obtained after running the optimization for each value proposition.

	PL	CE	Cost
Planning	0.15	0.06	0.21
Manufacturing	0.24	0.07	0.20
Fulfillment	0.19	0.23	0.25
Service Management	0.04	0.46	0.23
PLM	0.38	0.18	0.11

PL – Primarily Product Leadership/Innovation
CE – Primarily Customer Experience (referred to as Service Flexibility/customization in the survey)
Cost – Primarily low cost

Figure 32 Cross Domain Analysis - Quantitative Optimization Results

From the Figure-32 above we can see that if your firm's value proposition is customer experience (CE) then you should focus to achieve high performance in fulfillment, service management, and product lifecycle management (PLM). The quantitative numbers should not be used in the absolute sense but rather should be used relatively. For instance, in the case of CE service management domain is twice as important as fulfillment and PLM. The results of the optimization signify a relation (like in regression analysis) and therefore any inference related to causation cannot be reliably drawn. Therefore for CE value proposition is related to being good in fulfillment, service management, and PLM.

The results were also analyzed qualitatively where the exact numbers were removed and only domain that are important were give one, one and a half, or two stars. The qualitative results are shown below in Figure-33.

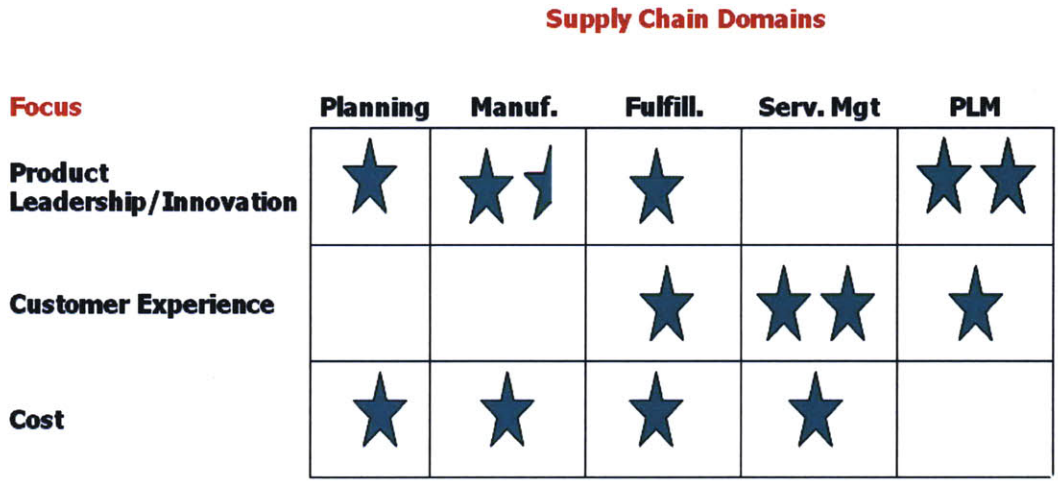


Figure 33 Cross Domain Analysis - Qualitative Optimization Results

From the qualitative results (Figure-33), it is clear that if your firm value proposition is customer experience then you should focus most of your resources to gain high performance in service management domain. The other two important domains for customer experience are fulfillment and PLM. These results also go with the conventional wisdom that for customer experience service management is the most important.

In the case of product leadership & innovation, our results show that product lifecycle management, and manufacturing are most important domains. The other two important domains after these are planning and fulfillment. Intuitively, one can argue that for product leadership planning lifecycle management is product lifecycle management and manufacturing are the most important domains.

In the case of cost, our results show that the planning, manufacturing, fulfillment, and service management domains are equally important.

These results do not mean for example that one should ignore planning and manufacturing domain for customer experience. Obviously, a certain level of

competence is required in each domain for a firm to compete. But if a firm has limited resources then it is better off by spending most on the domains identified by our study.

Conclusion

We started our research with the objective to understand what policies, capabilities, and strategies of an enterprises leads to best supply chain management in five key domains – planning, fulfillment, service management, product lifecycle management, and manufacturing. The main goal of the research was to identify best performers in each domain and study what strategies leads to high performance in those domains. The second most important objective of our research was to correlate high performance in each domain with firm's value proposition. All the findings of our research identify correlation among data of firms that participated in the survey and therefore causality conclusions cannot be drawn. The following table (Table-10) summarizes the most important research findings for supply chain planning, fulfillment, and cross domain analysis.

Supply Chain Planning – Identifying Best performers	Best performers were identified who were better than the rest of the population in managing cost, forecast, and providing better customer service. One of the key insights is that best performers are mostly good in cost and service while competency in forecast doesn't make any difference.
Supply Chain Planning – What does it take to be a best performer?	The main hypotheses that correlate well with high performance are collaboration with trading partners and talent management strategy. The next most important hypotheses are ability to predict & shape demand, extent of lifecycle planning, and planning tools, processes & operating model.
Fulfillment – Best performers	Best performers were identified who were better than the rest of the population in managing cost and providing better customer service. One of the key insights is that best performers are mostly good in cost competitiveness than

	customer service.
Fulfillment – What does it take to be a best performer?	Best performers perform better in inventory management & postponement, fulfillment strategy (network design, route to market, & new product development), and reverse logistics. Out of these hypotheses only performance in inventory management and postponement is statistically significant
Service Management – Best performers	Best performers were identified who were better than the rest of the population in equipments and maintenance efficiency & utilization.
Service Management – What does it take to be a best performer?	The analysis was not done as 70-75% of the survey data was not available.
Manufacturing – Best performers	Best performers were identified who were better than the rest of the population in Quality and Fulfillment. They had low scrap rate but high material efficiency and first pass yield rate. They were good at plan, schedule adherence and delivery conformance.
Manufacturing – What does it take to be a best performer?	Best performers are good in use of lean and six sigma principles and follows continuous process improvement philosophy. Only the hypothesis on lean and six sigma was statistically significant in our data analysis.
Product Lifecycle Management (PLM) – Best performers	Best performers were identified who were in evolving good product ideas. One of the key insights is most of the ideas originated from outside the firm.
Product Lifecycle Management (PLM) – What does it take to be a best performer?	Best performers perform better in sourcing talent, innovation worldwide and in developing products, while optimizing delivery cost and efficiency using a variety of operating models
Cross Domain Analysis	If firm value proposition is product leadership/Innovation

– Product Leadership/Innovation	then one should focus most of its resources to achieve high performance in product lifecycle management and manufacturing. The second most important domains are planning and fulfillment.
Cross Domain Analysis – Customer Experience	If firm value proposition is customer experience then one should focus most of its resources to achieve high performance in service management domain. The second most important domains for customer experience are fulfillment and PLM.
Cross Domain Analysis – Cost Competitiveness	If firm value proposition is customer experience then one should focus most of its resources to gain high performance in planning, manufacturing, fulfillment, and service management domain.

Table 10 Summary of Research Findings

Appendix I – Categorical Principal Component Analysis (CATPCA)14

CATPCA is a technique to find hidden dimensions in the data. It simultaneously quantifies categorical data using optimal scaling while reducing dimensionality of data using principal component analysis[15]. The goal of principal component analysis is to reduce an original set of variables into a smaller set of uncorrelated components that capture most the variance or information found in the original variables. This technique is most useful in cases where there is large number of variables and interpreting them is prohibitive. By reducing the number of dimensions, one can interpret few variables rather than the large initial variables.

Standard principal component analysis assumes that the data is scaled (i.e. continuous) and there are linear relationships between numeric variables. On the other hand, CATPCA optimal scaling approach allows variables to be scaled at different levels allowing optimal quantification of categorical variables in the specified dimensionality. As a result, nonlinear relationships between variables can be modeled. In CATPCA, optimal quantification of each variable is obtained through an iterative method called alternating least squares in which, after the current quantifications are used to find a solution, the quantifications are updated using that solution. This process is repeated until ending criteria is reached that signals the process to stop.

After reducing the initial set of variables into few dimensions, CATPCA can also generate factor score for each dimension. A factor score is a weighted score based on responses to the variables included in the dimension. The factor score method used in our analysis was regression in which the mean score is 0 and variance is the squared multiple correlation between estimated factor scores and the true factor values. The factor scores can be used as a performance measure in that particular dimension.

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[14] SPSS Categories 17.0 Documentation
[15] http://en.wikipedia.org/wiki/Principal_components_analysis