# Report on Practices Related to Demand Forecasting for Semiconductor Products

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## Abstract

We have surveyed four SRC member companies on issues relating to short-term demand forecasting in the semiconductor industry. Specifically, the survey focused on forecasts that are generated in sufficient detail to drive production, typically, 1-9 months into the future. The goal of the survey was to understand current practices and facilitate benchmarking. This report summarizes the results of the survey.

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## I. Introduction

We prepared a survey of SRC member companies on issues relating to short-term demand forecasting in the semiconductor industry. Specifically, the survey focused on forecasts that are generated in sufficient detail to drive production. Typically these forecasts extend about 1-9 months into the future. This report summarizes the results of the survey.

The goal of the survey was to shed light on current practices in forecasting and in the training and evaluation of forecasters, and to facilitate benchmarking. The survey used appears in the appendix. It was mailed to 15 member companies of the Semiconductor Research Council (SRC). We received four detailed responses from different companies. This report summarizes our findings.

The importance of short-term demand forecasting to the semiconductor industry stems from a number of sources. As is typical of many industries, short-term demand forecasts are important in generating projections of revenue and cost. They are used for the short-term management of manufacturing resources, including materials, manpower and equipment. In terms of driving production decisions, when the industry is capacity-constrained, most semiconductor manufacturers produce product only in response to firm orders from clients. However when business is slow the pressure to utilize expensive resources comes to the fore. Under those circumstances many semiconductor companies produce partly to forecasts, hoping that orders for products will materialize before they are ready to be shipped. Under these circumstances the accuracy of short-term demand forecasts is crucial in ameliorating the risks inherent in producing without firm orders in hand.

In Section II we discuss the responses to the survey, question by question. Section III contains our main conclusions. The Appendix contains the survey instrument.

## II. Survey Results

To mask the identity of different companies who responded to the survey, in most tables where company labels are used, the identifiers are different. Thus the “Company A2” of Table 2 does not match the “Company A5” of Table 5.

Excerpts from the survey appear in italics below. Standard typeface is used for the responses and discussion of the responses. The complete survey is in the appendix.

### *Part 1: Practices for Generating Forecasts*

*By a “short-term demand forecast” we mean a demand forecast that is used to drive production planning and related short-term tactical decisions. These forecasts are typically made at the part-number level, and usually have planning horizons of approximately 9 months. All questions in this survey refer to short-term forecasts.*

***Question 1.*** ***At what levels of aggregation are demand forecasts generated in your company?***

**Table 1: Levels at which Forecasts are Generated**

| Response | # Companies (out of 4) | Degree of Aggregation |
|---|---|---|
| Part-number – Customer level | 2 | 1 |
| Part-number - Regional level | 2 | 2 |
| Worldwide demand for part-number | 1 | 3 |
| Mask set – Customer level | 0 | |
| Mask set – Regional level | 0 | |
| Worldwide demand for Mask set | 0 | |
| Product family – Customer level | 3 | 2 |
| Product family – Regional level | 2 | 3 |
| Worldwide demand for Product family | 1 | 4 |
| Total Customer demand | 2 | 3 |
| Total Regional demand | 2 | 4 |
| Total Worldwide demand | 2 | 5 |
| Other: device-package-region | 1 | 2 |

Regions are typically North America, Europe and the Far East. One company subdivides the Far East.

Note the simple scale for the Degree of Aggregation in the third column of Table 1. One company forecasts at all levels of aggregation. The other three companies use a smaller set of different levels of aggregation, and emphasize either disaggregated or more highly aggregated forecasts (see Table 2).

**Table 2: Levels at which Companies Forecast**

| Company | # of different levels of aggregation | Average Degree of Aggregation (range 1-5) |
|---|---|---|
| A2 | 9 | 3 |
| B2 | 4 | 2 |
| C2 | 4 | 3.5 |
| D2 | 1 | 2 |

*Forecasts are typically generated in time buckets (i.e. total demand for 1 week or 1 month) and with a given time horizon (i.e., we create forecasts for all demands occurring in the next 6 months). They are typically re-generated on a calendared basis. Some companies perform minor updates to forecasts in between major forecast generation cycles. The next four questions address these issues.*

***Question 2.*** ***What time horizon do you use when demand forecasts are generated?***

The responses are 6, 18, 24 and 36 months. The lengths of the forecast horizons that the companies use do not appear to be related to the number of levels at which the companies forecast, or to the "Average Degree of Aggregation" at which they forecast.

***Question 3.*** ***What time bucket(s) do you use for your forecasts?***

Responses: Uniformly, 1 month.

***Question 4.*** ***How often are forecasts generated?***

Responses: monthly for 3 companies; bi-monthly for the other.

***Question 5.*** ***How often are minor updates to forecasts formed?***

Responses: daily, weekly, event-based, and no-response.

***Question 6. What unit of measure does your company use to aggregate forecasts? Please indicate all that apply.***

**Table 3: Units of Measure used in Aggregation**

| Response | Frequency |
|---|---|
| Cost, in Dollars | 1 |
| Revenue, in Dollars | 3 |
| Units | 3 |
| Wafers | 0 |

***Question 7. What information is used to generate forecasts. How important is it and at what level of aggregation is it used?***

*We define a "New Product" to be a product which is in the early stages of its life cycle, when demand is growing strongly. A "Mature Product" is past the initial stage of rapid growth, and has stable, continuing demand. For a "Sunsetting Product" one expects future demands to be significantly lower than current demands.*

For each of the data sources listed in Table 4, and for each of the three Product Life Cycles defined in the previous paragraph, companies were asked to state whether they use the data source or not, and to rate its importance. One company rated most data sources and did not indicate which ones they use. Respondents were encouraged to rank data sources that they do not use, and one company did so.

**Table 4: Use and Importance Ratings for Different Data Sources**

Importance ratings are 1-7 with 1 denoting Not Important and 7 denoting Extremely Important.

| Data Source | # of Known Users | | | Average Importance Rating by Known Users | | | | # Ratings by Others | | | Average Importance Rating by Other Companies | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | New | Mature | Sunsetting | All Parts | New | Mature | Sunsetting | New | Mature | Sunsetting | All Parts | New | Mature | Sunsetting |
| Historical demand for this product | 2 | 3 | 3 | 4.88 | 4 | 6.33 | 4 | 2 | 1 | 1 | 2.75 | 1.5 | 6 | 2 |
| Historical shipments for this product | 2 | 3 | 3 | 4.88 | 4 | 6.33 | 4 | 2 | 1 | 1 | 2.75 | 1.5 | 6 | 2 |
| Planned Demand for this product (created by a corporate planning process) | 1 | 2 | 3 | 5 | 5 | 4.5 | 5.33 | 2 | 1 | 1 | 4.5 | 5 | 6 | 2 |
| Backlog (demand that should have been shipped and has not) | 1 | 3 | 3 | 5 | 3 | 5.67 | 5 | 1 | 0 | 0 | 1 | 1 | n.a. | n.a. |
| Historical demand for similar or related products | 2 | 3 | 1 | 4.5 | 6 | 4 | 3 | 2 | 1 | 1 | 3.5 | 3 | 6 | 2 |
| Turns (orders that we expect to receive before this period ends) | 0 | 2 | 1 | 5 | n.a. | 5.5 | 4 | 1 | 1 | 1 | 3.33 | 2 | 4 | 4 |
| Design Wins (clients who have designed our product into theirs) | 2 | 3 | 1 | 5.5 | 5.5 | 5.33 | 6 | 0 | 0 | 0 | n.a. | n.a. | n.a. | n.a. |
| Historical shipments of similar or related products | 2 | 3 | 3 | 4.25 | 6.5 | 4.33 | 2.67 | 2 | 1 | 1 | 4.5 | 5 | 6 | 2 |
| Planned demand for similar or related products | 1 | 1 | 1 | 4.33 | 5 | 4 | 4 | 2 | 1 | 1 | 4.5 | 5 | 6 | 2 |
| Information from your sales organization that is not quantified | 1 | 1 | 2 | 4 | 5 | 3 | 4 | 2 | 2 | 2 | 4.83 | 5.5 | 5.5 | 3.5 |
| Other: New Part Number Forecast | 1 | | | 7 | 7 | | | | | | | | | |
| Forecasts provided by customers | 1 | 3 | 3 | 5.14 | 3 | 5 | 6 | 2 | 1 | 1 | 4.25 | 6 | 3 | 2 |
| Orders from customers | 2 | 3 | 3 | 6.13 | 5.5 | 6.33 | 6.33 | 2 | 1 | 1 | 3.75 | 5 | 3 | 2 |
| Current market conditions | 2 | 2 | 1 | 3.6 | 3.5 | 4 | 3 | 2 | 2 | 2 | 4 | 4.5 | 4 | 3.5 |
| Market forecasts | 2 | 2 | 0 | 3.75 | 3.5 | 4 | n.a. | 2 | 2 | 2 | 4.33 | 5.5 | 4 | 3.5 |
| Seasonality | 0 | 2 | 0 | 3 | n.a. | 3 | n.a. | 2 | 2 | 2 | 3.67 | 5.5 | 3 | 2.5 |
| Informally gathered market intelligence; hearsay | 2 | 1 | 1 | 2.75 | 3.5 | 2 | 2 | 2 | 2 | 2 | 3 | 3.5 | 3 | 2.5 |
| Degree of Customer satisfaction | 0 | 1 | 0 | 4 | n.a. | 4 | n.a. | 2 | 2 | 2 | 2.83 | 3 | 3 | 2.5 |
| Personal Judgment | 0 | 2 | 2 | 3 | n.a. | 3.5 | 2.5 | 2 | 1 | 1 | 2.75 | 3 | 3 | 2 |
| Executive Decision | 1 | 2 | 2 | 4.4 | 4 | 4.5 | 4.5 | 2 | 1 | 1 | 3.5 | 4.5 | 3 | 2 |
| All Data Sources Rated | | | | 4.61 | 4.64 | 4.79 | 4.36 | | | | 3.68 | 4.03 | 4.22 | 2.61 |

As one might expect, the data sources used are different for products in different life cycle phases. Mature products are more similar to Sunsetting products than New products are. On average, users think that data is slightly more important than non-users do.

'Forecasts provided by customers' are viewed by users as being very important for Mature and Sunsetting products, but not for New products. Other respondents have the opposite view. For New products, 'Historical demand for similar or related products' are viewed as being very useful by users, but not by other respondents. 'Historical shipments of similar or related products' exhibits a similar, but less dramatic, trend.

Each company gives a wide range of importance ratings to different data sources. However from one company to another, the importance ratings are quite consistent.

**Table 5: Use of Data Sources by Companies**

Notes: Total count – each life cycle phase and data type counted separately.

| Company | A5 | B5 | C5 | Total |
|---|---|---|---|---|
| Total # Data Sources Used | 25 | 38 | 40 | 103 |
| # Data Sources Used Market Forecasts and Current Market Conditions | 0 | 4 | 5 | 9 |
| # Data Sources Used information that is not quantified* | 2 | 7 | 5 | 14 |
| # Data Sources Used indicating integration with other business processes** | 6 | 1 | 7 | 14 |
| # Data Sources Used New | 2 *** | 14 | 13 | 29 |
| # Data Sources Used Mature | 12 | 14 | 16 | 42 |
| # Data Sources Used Sunsetting | 12 | 10 | 11 | 33 |

* Includes the following data items
  Information from your sales organization that is not quantified
  Informally gathered market intelligence; hearsay
  Degree of Customer satisfaction
  Personal Judgment
** Includes the following data items
  Planned Demand for this product (created by a corporate planning process)
  Planned demand for similar or related products
  Executive Decision
*** One of these data sources is "Other: New Part Number Forecast". This seems to be the result of an internal business process, and may itself depend on some of the other data sources listed above.

The average importance rating for Market Forecasts and Current Market Conditions in Table 4 is moderate, but a remarkably wide range of ratings was provided by users. That may reflect the manner in which they are used.

The third and fourth rows indicate that companies use (or do not use) certain types of data differently. The fifth row may indicate that the way in which the forecasting process is integrated with other business processes is different in different companies. In fact, one company indicated that the only data they use to forecast new parts is “Design Wins” and a “New Part Number Forecast”. The New Part Number Forecast is presumably generated by a different business group (see Table 5).

**Table 6: Avg Importance Rating of Data Sources Used by different Companies**

| Company | A6 | B6 * | C6 | D6 |
|---|---|---|---|---|
| All Life Cycle Phases | 3.37 | 3.60 | 5.16 | 5.35 |
| New Products | 3.27 | 4.50 | 7 | 5.62 |
| Mature Products | 3.29 | 4.31 | 5.08 | 5.88 |
| Sunsetting Products | 3.6 | 2.00 | 5.08 | 4.27 |

* Company B6 ranked all sources and did not indicate which sources they used.

Company A6 is less satisfied with the data they are using than companies C6 and D6. However the types of data they use for forecasting are similar to that of the other companies.

***Question 8. Do forecasters in your company generate only point forecasts (i.e., a single number) or do they also create some indication of the anticipated forecast accuracy, such as an interval?***

Three companies do only point forecasts. One company provide an interval when the degree of uncertainty is unusually high.

## *Part 2: Forecast Quality*

***Question 9. 9a. What do you consider to be an acceptable percentage error in forecasts at the following levels of aggregation and the following lead times? (For example, if the forecast is 60 and the actual demand is 80, then the percentage error is |60-80|/80=25%.) The lead time is how far into the future you are forecasting. Respond only for the levels of aggregation that apply, and only for those lead times that are important to your company's operations.***

In question 9 a small number of responses at the "device-package-region" level of aggregation was treated as "part-region". A response for "Mask Set" was treated as "Product Family".

Respondents were invited to rate acceptable errors for each of the 9 levels of aggregation listed in Table 8 below, for each of 3 phases of the product life cycle, and for each of 3 different forecast lead times (1-2 months, 3-5 months, 6+ months). A total of 181 entries, or an average of 45 per company, were provided.

By far, the most noticeable trend in the data is that different companies report very different standards for what constitutes an acceptable forecast error. To illustrate the dramatic nature of these differences, we statistically fitted the reported data to the model described in Table 7.

**Table 7: Trends in Acceptable Percentage Forecast Errors via Statistical Regression**

Model: $A = L \times P \times G \times T \times C$ $(R^2=0.70)$

| Symbol | Description | Estimated Coefficient |
|---|---|---|
| A | Acceptable Percentage Error | n.a. |
| L | Factor for life cycle phase | 0.97 for New, 1.0 for Mature, 1.21 for Sunsetting |
| P | Factor for degree of Product Aggregation | 1.28 for Part, 1.0 for Family, 1.0 for Total |
| G | Factor for degree of Geographical Aggregation | 1.49 for Customer, 1.0 for Region, 0.76 for Worldwide |
| T | T = Forecast Lead Time | T = 1.0 for 1-2 months, 1.50 for 3-5 months, 1.93 for 6+ months. |
| W | Factor for Company | 0.14, 0.21. 0.94, 1.0 |
| C | Constant | 26.9 |

According to this model the life cycle phase (New, Mature, Sunsetting) influences acceptable errors by as much as 22% (1.21/0.97 - 1). The corresponding numbers are 28% for product aggregation, 96% for geographical aggregation, 93% for forecasting lead time, and 600% for different companies. No data differentiating acceptable errors for product-family demand from acceptable errors for total demand was reported.

Two out of three companies have lower values for acceptable forecast errors for New products than for Mature products. One has higher values and the fourth did not differentiate. Similarly, two out of three companies have a lower targets for forecast error for Mature products than for Sunsetting products, and one had higher tsrgets. The regression averages these disparities and produces coefficients that asre more uniform than the individual company resonses (the 'L' row above). These responses may reflect some combination of the economic implications of forecast errors for different types of products, and the difficulty of obtaining accurate forecasts. No one reported acceptable errors at the mask set level of aggregation.

***9c. How satisfied are you with the overall quality of your forecasts at the following levels of aggregation? (Respond only for the levels of aggregation that apply.)***

Table 8 gives summary results, by level of aggregation and by phase in the product life cycle. Satisfaction with forecast accuracy is generally low. There is a clear trend of more satisfaction with forecasts for more highly aggregated demand streams.

**Table 8: Degree of Satisfaction, by Level of Aggregation and by Product Life Cycle Stage**

Satisfaction ratings are 1-5 with 1 denoting Strongly Dissatisfied and 5 denoting Very Satisfied.

| | Average Satisfaction Rating | Spread of Satisfaction Ratings | Satisfaction Rank (from Pairwise Comparison; 1 is least satisfied) |
|---|---|---|---|
| **Level of Aggregation** | | | |
| Part – Customer level | 2 | 0 | 1 |
| Part – Regional level | 2.67 | 1 | 4 |
| Worldwide demand for part-number | 2.33 | 3 | 5 |
| Product family – Customer level | 2.33 | 1 | 2 |
| Product family – Regional level | 3 | 2 | 6 |
| Worldwide demand for Product family | 3 | 3 | 8 |
| Total Customer demand | 2.5 | 1 | 3 |
| Total Regional demand | 3 | 2 | 7 |
| Total Worldwide demand | 3.5 | 3 | 9 |
| **Product Life Cycle Stage** | | | |
| New Products | 1.5 | 1 | 1 |
| Mature Products | 2.75 | 3 | 3 |
| Sunsetting Products | 2.5 | 2 | 2 |

The degrees of satisfaction are quite low, across the board. Average satisfaction and the rank by pairwise comparison differ because not all respondents rated every category. The Spread of satisfaction is the difference between the highest and the lowest scores reported.

As one would expect, there is a higher degree of satisfaction with aggregate forecasts than with disaggregate forecasts. Also, the degree of satisfaction with forecast accuracy is consistent with the common perception that New products are the hardest to forecast and Mature products are the easiest. One company is a strong exception to the second trend, being happiest with forecasts for Sunsetting products and least happy with forecasts for Mature products. Also see the Table 9.

**Table 9: Level of Satisfaction, by Company**

Responses are quantified as 1-5 with 1 denoting Strongly Dissatisfied and 5 denoting Very Satisfied.

| Company | | A9 | B9 | C9 | D9 |
|---|---|---|---|---|---|
| **Levels of Aggregation** | # Levels reported question 1 | 1 | 4 | 4 | 9 |
| | # Levels reported here | 2 | 4 | 9 | 9 |
| | Average Satisfaction Rating | 1.5 | 2.5 | 2 | 3.67 |
| | Spread of Satisfaction Ratings | 1 | 1 | 0 | 3 |
| **Product Life Cycle Stage** | Average Satisfaction Rating | 1.33 | 1.33 | 1 | 1.33 |
| | Spread of Satisfaction Ratings | 3 | 3 | 0 | 3 |

**Table 10: Relationship between Standard for Forecast Accuracy and Satisfaction with Current Forecast Accuracy**

| | | Company | | | |
|---|---|---|---|---|---|
| **Happy with your Forecast Accuracy?** | Less Happy | A9, C9 | B9 | D9 | Happier |
| **What is an Acceptable Forecast Accuracy** | Expect More | C9, D9 | A9, B9 | | Expect Less |

In row 2 of Table 10 companies A9,C9 are quite close to each other in the degree of satisfaction, but B9 and D9 are spread (see rows 4,6 of Table 9). In Table 10 row 3, companies C9,D9 are close to each other in 'What is an Acceptable Forecast Accuracy', as are companies A9,B9 (see the 'W' row of Table 7). Overall, there appears to be little relationship between the standard that a company has for forecast accuracy and their satisfaction with their current performance.

***Question 10. What quantifiable measures does your company use to assess the accuracy of a demand forecast? How useful are these measures? (For example, standard deviation of forecast error, average percentage error, etc.)***

The standard measures reported are the following.

[Actual Demand] / Forecast
Absolute error
Forecast - Supply
MAPE: Mean Absolute Percentage Error.

Two companies mentioned interesting variations on typical approaches. Suppose that the manufacturing lead time is L. Instead of measuring the error in a forecast for the demand in a given month, one company recommends measuring the error in the current forecast of the total demand that will occur in the next L months. This is consistent with the theory of base-stock inventory systems with backorders, which indicates that the inventory in the pipeline should cover the total demand that will occur in the next L time periods.

Another company tracks forecast stability over time (i.e., how much the forecasts for the demand in a given month change as the month gets closer).

## *Part 3: Software and Statistical Tools in Forecasting*

***Question 11. What software tools and statistical methods does your company use for forecasting purposes? How satisfied is your company with the results of the tool?***

**Table 11: Satisfaction with Forecasting Tools and Statistical Methods**

Satisfaction ratings are 1-5 with 1 denoting Strongly Dissatisfied and 5 denoting Very Satisfied.

| **Tool** | **Satisfaction Scores** | | | |
|---|---|---|---|---|
| i2 | 3 | 3 | | |
| Manugistics | 3 | | | |
| SAP | 3 | 3 | | |
| Software developed by another company specifically for your company | 3 | | | |
| Software developed by your company | 4 | 4 | | |
| Spreadsheets | 3 | 4 | | |
| SPSS | 4 | | | |
| **Methods** | | | | |
| Moving Averages or Exponential Smoothing | 2 | 2 | 3 | 4 |
| Regression or other trend-following methods | 3 | 4 | | |
| Winter's method or other methods that capture Seasonality | | | | |
| Autoregressive methods (ARMA, ARIMA, etc.) | 3 | 3 | | |
| Statistical methods that capture ramp-up patterns for new or fashion goods | 3 | 4 | | |
| Statistical methods that capture ramp-down patterns for end-of-product-life goods | 3 | | | |

**Table 12: Use of Tools and Methods by Companies**

| **Company** | **A12** | **B12** | **C12** | **D12** |
|---|---|---|---|---|
| **Tools** | | | | |
| Number of Tools Used | 2 | 2 | 3 | 4 |
| Number of Major Software Vendors used | 0 | 1 | 2 | 2 |
| Number of Other Software Tools used | 2 | 1 | 1 | 2 |
| Average satisfaction score for Tools | 2.5 | 2.5 | 2 | 2.5 |
| Spread of satisfaction scores for Tools | 1 | 1 | 0 | 1 |
| **Methods** | | | | |
| Number of Methods Used | 1 | 2 | 5 | 3 |
| Number of methods for New and Sunsetting used * | 0 | 1 | 3 | 1 |
| Average satisfaction score for Methods | 3 | 2 | 2 | 2 |
| Spread of satisfaction score for Methods | 0 | 2 | 0 | 2 |

* This refers to three categories, “Statistical methods that capture ramp-up patterns for new or fashion goods”, “Statistical methods that capture ramp-down patterns for end-of-product-life goods”, and “Autoregressive methods (ARMA, ARIMA, etc.)”, which are capable of modeling exponential growth and exponential decay.

Satisfaction is quite low, for both tools and methods. “Moving Averages or Exponential Smoothing” received the lowest satisfaction scores, but it is also the only method used by all companies. The company that likes it the most (satisfaction 3) is the company that uses it exclusively. There is a higher degree of satisfaction with Software developed by the client, spreadsheets and SPSS than there is with i2, Manugistics, SAP or Software developed for the client. There are many possible explanations for this – cost, the amount of thought that was given to how the products should be customized to the client’s needs, how well the user understands and can alter the software, and the “not-invented-here” syndrome.

Seasonality is interesting. Table 4 indicates that either 2 or 3 of the 4 companies use data on seasonality to generate forecasts for mature products. However according to question 11, formal statistical methods for seasonality are not used.

## *Part 4: Training and Evaluation of Forecasters*

*By “forecaster” we mean the persons responsible for producing demand forecasts.*

***Question 12. How do forecasters in your company learn how to generate forecasts? How useful/applicable are these sources of knowledge? Please rate each item even if it is not currently used.***

The usefulness ratings are 1-5, with 5 being the most satisfied. Three companies rated the sources that they used. One company provided ratings for selected sources, but did not indicate which ones they used. Consequently the number of companies using a source of knowledge can be less than the number of usefulness ratings.

**Table 13: Use and Ratings of Sources of Knowledge on Forecasting**

| Source of Knowledge | # Companies Using It | Company D14 Ratings | Other Ratings | | |
|---|---|---|---|---|---|
| Formal training by your company | 1 | 5 | 2 | | |
| Formal training from outside of your company | | | | | |
| Learn from peers | 3 | 5 | 2 | 3 | 4 |
| Learn from customers | 2 | 4 | 3 | 4 | |
| Learn from supervisors | 2 | 4 | 2 | 4 | |
| Learn by doing | 3 | 2 | 4 | 4 | 5 |
| Other: Geogr Supervisor | 1 | 5 | | | |
| Other: Worldwide Team | 1 | 5 | | | |

**Table 14: Average Usefulness Scores by Respondent**

| Company | A14 | B14 | C14 | D14 |
|---|---|---|---|---|
| Number of Sources of Knowledge Used | 3 | 3 | 5 | 7 |
| Number of Types of Formal Training * | 0 | 0 | 1 | 3 |
| Average Satisfaction Rating | 2 | 4 | 3.2 | 4.7 |
| Spread in Satisfaction Ratings | 0 | 0 | 2 | 1 |

* Includes “Formal training by your company”, “Other: Geogr Supervisor”, and “Other: Worldwide Team”.

There is a noticeable difference in the number of sources of formal knowledge used. Most of that comes from differences in the amount of formal training that takes place. Company D14 uses the most comprehensive list of sources of knowledge, and they expressed the greatest degree of satisfaction. With the exception of company D14 there do
es not appear to be a lot of formal training.

***Question 13. Who provides input in evaluating a demand forecaster's performance? Briefly, what is the company trying to learn about the forecaster from each of the relevant evaluating personnel? How useful is each input?***

In this question the usefulness scores range from 1 to 7. Other than the entry marked with an asterisk, the methods rated were the methods used.

**Table 15: Usefulness Ratings of Input from Evaluators of a Forecaster's Performance**

| Evaluating Employee | Usefulness Ratings | | | |
|---|---|---|---|---|
| Subordinates of the Forecaster | 5 | | | |
| Co-Workers of the Forecaster | 5 | 6 | | |
| Supervisors of the Forecaster | 3 | 5 | 6 | 7 |
| Senior Management | 4 | 6 | 7* | |
| Customers | 5 | 6 | 6 | |
| Self-evaluation | 7 | | | |
| Quantified Measures of Forecast Accuracy | 5 | 6 | 7 | 7 |

**Table 16: Average Usefulness Scores by Respondent**

| Company | A16 | B16 | C16 | D16 |
|---|---|---|---|---|
| Number of Evaluators | 3 | 3 | 5 | 7 |
| Average Satisfaction Score | 5.33 | 6 | 4.8 | 6.14 |
| Spread in Satisfaction Scores | 4 | 0 | 1 | 2 |

Input from all sources is apparently valuable. There are clear differences among companies in the number of evaluators used and in the perceived usefulness of the evaluations, but these differences do not appear to be related to each other. For each company, average usefulness ratings fall within a fairly narrow band.

***Question 14. How does your company use the information obtained from the employee evaluations?***

**Table 17: Ways in which the Companies Use Evaluations of Forecaster Performance**

| Use | # of companies |
|---|---|
| Feedback for employee self-improvement | 4 |
| Guidelines for training | 2 |
| Employee recognition & promotion | 2 |
| Employee compensation | 2 |

**Table 18: Number of Ways that Companies Use the Evaluations**

| Company | A18 | B18 | C18 | D18 |
|---|---|---|---|---|
| Number of Ways Evaluations are Used | 1 | 2 | 3 | 4 |

For the most part, the companies that obtain evaluations from a lot of different sources (question 13) use those evaluations in more different ways (question 14).

### Other Comments

In several tables companies give ratings for usefulness, importance or degree of satisfaction (see Tables 6, 9, 12, 14, 16). When the differences appear to be significant there is a clear trend. Companies that are more satisfied on one of these ratings are likely to be more satisfied on the others (the correlation is far from perfect). To a substantial extent these differences may reflect different ways of calibrating responses rather than a real difference in performance.

Rows 2,3 of Table 14, row 2 of Table 16, and row 2 of Table 18 are all related to the scope of training and evaluation efforts for forecasters. The rankings of different companies in these rows are quite consistent.

# III. Conclusions

In this section we review our most important findings.

The number of different levels of aggregation at which companies generate forecasts varies from 1 to 9 (see question 1). This may reflect a different architecture for business processes in different companies. For example, in Company 1 the forecasting organization might aggregate and evaluate forecasts as an inherent part of the forecasting process. In Company 2 the forecasting organization might produce forecasts at a single level of aggregation, and pass them to a different part of the corporation for aggregation and analysis. This hypothesis is compatible with the fact that there is a positive relationship between the company responses in Table 2 column 2 and in Table 5 row 5.

A number of interesting observations can be made regarding the sources of information that are used to generate business processes (see question 7). Companies use an average of 9.7 data sources for New products, 14 data sources for Mature products, and 11 data sources for Sunsetting products. (The 9.7 is probably artificially low.) As might be expected, different data sources are used to predict demand for products in different phases of their life cycles (New, Mature, Sunsetting). Different companies follow fairly consistent patterns in the data sources that they choose to use for products in different life cycle phases. The biggest differences are for New products. Users rate the importance of different sources of information more highly than non-users do.

The forecasting process produces an estimate of the degree of uncertainty inherent in a forecast in only one company, and they do it only for forecasts that are subject to an unusually high degree of uncertainty (see question 8). This is just one indicator of a larger opportunity. Much of the semiconductor industry could derive major benefits from a consistent effort to quantify the uncertainty that exists in their planning processes.

The data reported on acceptable forecast errors is remarkable in that the differences from one company to another are dramatic (see Table 7). Another surprising fact: most respondents give different values for acceptable forecast errors for New, Mature and Sunsetting products, but they do not agree on which set of products should have the more stringent targets.

Respondents express a fairly low degree of satisfaction with current forecast errors, and an even lower degree of satisfaction with statistical methods (see Table 8). Not surprisingly, respondents are happier if the forecasts are more highly aggregated. Also, respondents are happier with forecast accuracy for Mature and Sunsetting products than for New products.

Respondents express a fairly low degree of satisfaction with software tools, and an even lower degree of satisfaction with statistical methods (see Tables 11,12).

The respondents seem to vary significantly in the extensiveness of corporate programs for training forecasters, for evaluating them, and for making use of the results of those evaluations. Companies with programs that are more comprehensive in one of these three areas tend to have comprehensive programs in all of them. Companies are quite satisfied with the usefulness of different sources of training, both formal and informal (Tables 13-14). They are very happy with the value of different sources of feedback on forecaster performance (Tables 15-16).

### Acknowledgement

The author is indebted to a number of anonymous members of the semiconductor community who made very useful comments on the orientation and content of the survey, to those who responded to the survey, and to the Semiconductor Research Council for the financial support that enabled this survey.

# APPENDIX: The Original Survey`

## Survey on Practices Related to Demand Forecasting for Semiconductor Products

**Topic of the Survey:** This survey addresses issues relating to short-term demand forecasting (typically, 1-9 months) in the semiconductor industry. Included among those topics addressed are:

- How forecasts are produced
- How part-number-level forecasts relate to forecasts for product families
- How regional forecasts relate to worldwide forecasts
- How companies use demand forecast information
- How forecast accuracy is defined and measured
- How forecasters are trained and evaluated

**Goals:** The goals of this survey are to understand and facilitate benchmarking of current practices relating to short term demand forecasts in the semiconductor industry. Specifically, this survey focuses on forecasts for part-number-level demand forecasts; we consider those forecasts that are generated in sufficient detail to drive product production.

**Distribution:** This survey is being distributed to major manufacturers of semiconductor products who are members of the Semiconductor Research Council (SRC).

**Who should respond:** This survey should be completed by a first-line supervisor of the people who generate short-term, detailed part-number-level demand forecasts.

**Dissemination of Results:** Summary results from all respondents will be published in a report that hides individual company responses. Each respondent, if identified in part 5 of the completed survey, will receive a draft of the report before it is released and will have an opportunity to request revisions. Identified respondents will also receive a confidential document that contrasts their responses to the full range of responses from all participating companies.

**Estimated time to complete the survey:** About 90 minutes. Need not be completed in a single sitting.

### Schedule:

- Please complete and mail your survey back to Professor Roundy no later than May 5, 2001.
- A draft of the report will be disseminated to identified respondents no later than May 20, 2001.
- Requested revisions to the draft report are to be received by Professor Roundy no later than June 1, 2001.
- Publication of the final report, no later than June 15, 2001.

**Affiliation:** This survey is partially funded by the Semiconductor Research Council through Research Grant 830, "Forecasting and Demand Management in the Semiconductor Industry".

**Questions:** Contact Robin Roundy, contact information below.

### Reply to:

Professor Robin Roundy
Phone: 607-255-9137
FAX: 607-255-9129
Email: robin@orie.cornell.edu

Operations Research and Industrial Engineering
216 Rhodes Hall
Cornell University
Ithaca NY 14853

### Identification of Respondent and Company (optional)

Note: We cannot provide you with either a draft of the report or a confidential comparison of your responses to the range of all responses without this information.

Name of respondent (optional) _____
Title (optional) _____
Company (optional) _____
Email (optional) _____
Phone (optional) _____
Address (optional) _____
_____

# Part 1: Practices for Generating Forecasts

By a "short-term demand forecast" we mean a demand forecast that is used to drive production planning and related short-term tactical decisions. These forecasts are typically made at the part-number level, and usually have planning horizons of approximately 9 months. *All questions in this survey refer to short-term forecasts.*

***Question 1.*** At what levels of aggregation are demand forecasts generated in your company? Please check all that apply.

- ☐ Part-number - Customer level
- ☐ Part-number - Regional level (Size of a typical region: _____)
- ☐ Worldwide demand for part-number
- ☐ Mask set – Customer level (provide an example and approximate number of parts in a family below)
- ☐ Mask set – Regional level
- ☐ Worldwide demand for Mask set
- ☐ Product family – Customer level (provide an example and approximate number of parts in a family below)
- ☐ Product family – Regional level
- ☐ Worldwide demand for Product family
- ☐ Total Customer demand
- ☐ Total Regional demand
- ☐ Total Worldwide demand
- ☐ Other: _____

Forecasts are typically generated in time buckets (i.e. total demand for 1 week or 1 month) and with a given time horizon (i.e., we create forecasts for all demands occurring in the next 6 months). They are typically re-generated on a calendared basis. Some companies perform minor updates to forecasts in between major forecast generation cycles. The next four questions address these issues.

***Question 2.*** What time horizon do you use when demand forecasts are generated?

***Question 3.*** What time bucket(s) do you use for your forecasts?

***Question 4.*** How often are forecasts generated?

***Question 5.*** How often are minor updates to forecasts formed?

***Question 6.*** What unit of measure does your company use to aggregate forecasts? Please indicate all that apply.

- ☐ Cost, in Dollars
- ☐ Revenue, in Dollars
- ☐ Units
- ☐ Wafers
- ☐ Other : _____

***Question 7.*** What information is used to generate forecasts. How important is it and at what level of aggregation is it used? Provide your answers in the tables below.

We refer the respondent to question 1 for a list of aggregation levels that might be used.

*We define a "New Product" to be a product which is in the early stages of its life cycle, when demand is growing strongly. A "Mature Product" is past the initial stage of rapid growth, and has stable, continuing demand. For a "Sunsetting Product" one expects future demands to be significantly lower than current demands.*

*In following tables, please provide importance rankings for all information sources listed, even if they are not currently used.*

7a. **New Products**

| | Used? Y or N | (1) Not Important | (2) | (3) | (4) | (5) | (6) | (7) Extremely Important | At what level of aggregation is the information used? |
|---|---|---|---|---|---|---|---|---|---|
| **Information generated by your corporation** | | | | | | | | | |
| Historical demand for this product | | | | | | | | | |
| Historical shipments for this product | | | | | | | | | |
| Planned Demand for this product (created by a corporate planning process) | | | | | | | | | |
| Backlog (demand that should have been shipped and has not) | | | | | | | | | |
| Historical demand for similar or related products | | | | | | | | | |
| Turns (orders that we expect to receive before this period ends) | | | | | | | | | |
| Design Wins (clients who have designed our product into theirs) | | | | | | | | | |
| Historical shipments of similar or related products | | | | | | | | | |
| Planned demand for similar or related products | | | | | | | | | |
| Information from your sales organization that is not quantified | | | | | | | | | |
| Other A (describe below) | | | | | | | | | |
| Other B (describe below) | | | | | | | | | |
| **Information from sources outside of your corporation** | | | | | | | | | |
| Forecasts provided by customers | | | | | | | | | |
| Orders from customers | | | | | | | | | |
| Current market conditions | | | | | | | | | |
| Market forecasts ` | | | | | | | | | |
| Seasonality | | | | | | | | | |
| Informally gathered market intelligence; hearsay | | | | | | | | | |
| Degree of Customer satisfaction | | | | | | | | | |
| Personal Judgment | | | | | | | | | |
| Executive Decision | | | | | | | | | |
| Other C (describe below) | | | | | | | | | |
| Other D (describe below) | | | | | | | | | |

7b. Description of other information sources from the table above (Other A,B,C,D):

7c. **Mature Products**

| | Used? Y or N | (1) Not Important | (2) | (3) | (4) | (5) | (6) | (7) Extremely Important | At what level of aggregation is the information used? |
|---|---|---|---|---|---|---|---|---|---|
| **Information generated by your corporation** | | | | | | | | | |
| Historical demand for this product | | | | | | | | | |
| Historical shipments for this product | | | | | | | | | |
| Planned Demand for this product (created by a corporate planning process) | | | | | | | | | |
| Backlog (demand that should have been shipped and has not) | | | | | | | | | |
| Historical demand for similar or related products | | | | | | | | | |
| Turns (orders that we expect to receive before this period ends) | | | | | | | | | |
| Design Wins (clients who have designed our product into theirs) | | | | | | | | | |
| Historical shipments of similar or related products | | | | | | | | | |
| Planned demand for similar or related products | | | | | | | | | |
| Information from your sales organization that is not quantified | | | | | | | | | |
| Other A (describe below) | | | | | | | | | |
| Other B (describe below) | | | | | | | | | |
| **Information from sources outside of your corporation** | | | | | | | | | |
| Forecasts provided by customers | | | | | | | | | |
| Orders from customers | | | | | | | | | |
| Current market conditions | | | | | | | | | |
| Market forecasts ` | | | | | | | | | |
| Seasonality | | | | | | | | | |
| Informally gathered market intelligence; hearsay | | | | | | | | | |
| Degree of Customer satisfaction | | | | | | | | | |
| Personal Judgment | | | | | | | | | |
| Executive Decision | | | | | | | | | |
| Other C (describe below) | | | | | | | | | |
| Other D (describe below) | | | | | | | | | |

7d. Description of other information sources from the table above (Other A,B,C,D):

7e. **Sunsetting Products**

| | Used? Y or N | (1) Not Important | (2) | (3) | (4) | (5) | (6) | (7) Extremely Important | At what level of aggregation is the information used? |
|---|---|---|---|---|---|---|---|---|---|
| **Information generated by your corporation** | | | | | | | | | |
| Historical demand for this product | | | | | | | | | |
| Historical shipments for this product | | | | | | | | | |
| Planned Demand for this product (created by a corporate planning process) | | | | | | | | | |
| Backlog (demand that should have been shipped and has not) | | | | | | | | | |
| Historical demand for similar or related products | | | | | | | | | |
| Turns (orders that we expect to receive before this period ends) | | | | | | | | | |
| Design Wins (clients who have designed our product into theirs) | | | | | | | | | |
| Historical shipments of similar or related products | | | | | | | | | |
| Planned demand for similar or related products | | | | | | | | | |
| Information from your sales organization that is not quantified | | | | | | | | | |
| Other A (describe below) | | | | | | | | | |
| Other B (describe below) | | | | | | | | | |
| **Information from sources outside of your corporation** | | | | | | | | | |
| Forecasts provided by customers | | | | | | | | | |
| Orders from customers | | | | | | | | | |
| Current market conditions | | | | | | | | | |
| Market forecasts | | | | | | | | | |
| Seasonality | | | | | | | | | |
| Informally gathered market intelligence; hearsay | | | | | | | | | |
| Degree of Customer satisfaction | | | | | | | | | |
| Personal Judgment | | | | | | | | | |
| Executive Decision | | | | | | | | | |
| Other C (describe below) | | | | | | | | | |
| Other D (describe below) | | | | | | | | | |

7f. Description of other information sources from the table above (Other A,B,C,D):

***Question 8.*** Do forecasters in your company generate only point forecasts (i.e., a single number) or do they also create some indication of the anticipated forecast accuracy, such as an interval? _____

_____

_____

## Part 2: Forecast Quality

***Question 9.*** 9a. What do you consider to be an acceptable percentage error in forecasts at the following levels of aggregation and the following lead times? (For example, if the forecast is 60 and the actual demand is 80, then the percentage error is |60-80|/80=25%.) The lead time is how far into the future you are forecasting. Respond only for the levels of aggregation that apply, and only for those lead times that are important to your company's operations.

**Acceptable Percentage Errors**

| Level of Aggregation | New Products | | | | | Mature Products | | | | | Sunsetting Products | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lead Times | | | | | Lead Times | | | | | Lead Times | | | | |
| | 1-2 | 3-5 | 6+ months | Other D | Other E | 1-2 | 3-5 | 6+ months | Other D | Other E | 1-2 | 3-5 | 6+ months | Other D | Other E |
| Part-Customer level | | | | | | | | | | | | | | | |
| Part-regional level | | | | | | | | | | | | | | | |
| Worldwide demand for Part | | | | | | | | | | | | | | | |
| Mask set – Customer level | | | | | | | | | | | | | | | |
| Mask set – Regional level | | | | | | | | | | | | | | | |
| Worldwide demand for Mask set | | | | | | | | | | | | | | | |
| Product family – Customer level | | | | | | | | | | | | | | | |
| Product family – Regional level | | | | | | | | | | | | | | | |
| Worldwide demand for Product family | | | | | | | | | | | | | | | |
| Total Customer demand | | | | | | | | | | | | | | | |
| Total Regional demand | | | | | | | | | | | | | | | |
| Total Worldwide demand | | | | | | | | | | | | | | | |
| Other A | | | | | | | | | | | | | | | |
| Other B | | | | | | | | | | | | | | | |
| Other C | | | | | | | | | | | | | | | |

9b. Please explain levels of aggregation (Other A,B,C; may be the same as 1) and other forecast lead times (Other D,E).

9c. How satisfied are you with the overall quality of your forecasts at the following levels of aggregation? (Respond only for the levels of aggregation that apply.)

| Level of Aggregation | Strongly Dissatisfied | | | | Very Satisfied |
|---|---|---|---|---|---|
| Part-Customer level | ○ | ○ | ○ | ○ | ○ |
| Part-regional level | ○ | ○ | ○ | ○ | ○ |
| Worldwide demand for Part | ○ | ○ | ○ | ○ | ○ |
| Mask Set - Customer level | ○ | ○ | ○ | ○ | ○ |
| Mask Set regional level | ○ | ○ | ○ | ○ | ○ |
| Worldwide demand for Mask Set | ○ | ○ | ○ | ○ | ○ |
| Product family – Customer level | ○ | ○ | ○ | ○ | ○ |
| Product family – Regional level | ○ | ○ | ○ | ○ | ○ |
| Worldwide demand for Product family | ○ | ○ | ○ | ○ | ○ |
| Total Customer demand | ○ | ○ | ○ | ○ | ○ |
| Total Regional demand | ○ | ○ | ○ | ○ | ○ |
| Total Worldwide demand | ○ | ○ | ○ | ○ | ○ |
| New Products | ○ | ○ | ○ | ○ | ○ |
| Mature Products | ○ | ○ | ○ | ○ | ○ |
| Sunsetting Products | ○ | ○ | ○ | ○ | ○ |
| Other A | ○ | ○ | ○ | ○ | ○ |
| Other B | ○ | ○ | ○ | ○ | ○ |
| Other C | ○ | ○ | ○ | ○ | ○ |

9d. Description of other levels of aggregation from the table above (Other A,B,C):

***Question 10.*** What quantifiable measures does your company use to assess the accuracy of a demand forecast? How useful are these measures? (For example, standard deviation of forecast error, average percentage error, etc.)

_____

_____

_____

## Part 3: Software and Statistical Tools in Forecasting

***Question 11.*** What software and statistical tools does your company use for forecasting purposes? How satisfied is your company with the results of the tool?

| 11a. **Software Tools** | **Used?** | **Strongly Dissatisfied** | | | | **Very Satisfied** |
|---|---|---|---|---|---|---|
| GAINSystems | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| i2 | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Manugistics | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Oracle | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Prescient Systems | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| SAPAmerica | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Spreadsheets | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Software developed by your company | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Software developed by another company specifically for your company | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Other A | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Other B | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |

| 11b. **Statistical Methods** | **Used?** | **Strongly Dissatisfied** | | | | **Very Satisfied** |
|---|---|---|---|---|---|---|
| Moving Averages or Exponential Smoothing | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Regression or other trend-following methods | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Winter's method or other methods that capture seasonality | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Autoregressive methods (ARMA, ARIMA, etc.) | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Statistical methods that capture ramp-up patterns for new or fashion goods | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Statistical methods that capture ramp-down patterns for end-of-product-life goods | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Other C | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Other D | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |

11c. Please explain the other software tools (Other A,B) and statistical methods (Other C,D).

## *Part 4: Training and Evaluation of Forecasters*

*By "forecaster" we mean the persons responsible for producing demand forecasts. If there is more than one group of forecasters, and the responses differ for the different groups, please indicate.*

***Question 12.*** 12a. How do forecasters in your company learn how to generate forecasts? How useful/applicable are these sources of knowledge? Please rank each item even if it is not currently used.

| **Sources of Knowledge** | **Used?** | **Not Useful** | | | | **Very Useful** |
|---|---|---|---|---|---|---|
| Formal training by your company | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Formal training from outside of your company | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Learn from peers | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Learn from customers | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Learn from supervisors | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Learn by doing | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Other A (explain below) | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Other B (explain below) | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |

12b. Descriptions of other sources of knowledge (Other A,B).

***Question 13.*** 13a. Who provides input in evaluating a demand forecaster's performance? Briefly, what is the company trying to learn about the forecaster from each of the relevant evaluating personnel? How useful is each input?

| **Evaluating Employee** | **Used? Y or N** | **Input Provided** | **(1) Not Useful** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7) Very Useful** |
|---|---|---|---|---|---|---|---|---|---|
| Subordinates of the Forecaster | | | | | | | | | |
| Co-Workers of the Forecaster | | | | | | | | | |
| Supervisors of the Forecaster | | | | | | | | | |
| Senior Management | | | | | | | | | |
| Customers | | | | | | | | | |
| Self-evaluation | | | | | | | | | |
| Quantified measures of forecast accuracy | | | | | | | | | |
| Other A: (explain below) | | | | | | | | | |
| Other B: (explain below) | | | | | | | | | |

13b. Please describe other evaluators (Other A,B).

***Question 14.*** How does your company use the information obtained from the employee evaluations? Please check all that apply.

- ☐ Feedback for employee self-improvement
- ☐ Guidelines for training
- ☐ Employee recognition & promotion
- ☐ Employee compensation
- ☐ Other (explain): _____