

# The Simulation and Forecast Model for Human Resources of Semiconductor Wafer Fab Operation

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**Abstract.** The efficiency of fabrication (fab) operation is one of the key factors in order for a semiconductor manufacturing company to stay competitive. Optimization of manpower and forecasting manpower needs in a modern fab is an essential part of the future strategic planning and a very important to the operational efficiency. As the semiconductor manufacturing technology has entered the 8-inch wafer era, the complexity of fab operation increases with the increase of wafer size. The wafer handling method has evolved from manual mode in 6-inch wafer fab to semi-automated or fully automated factory in 8-inch and 12-inch wafer fab. The distribution of manpower requirement in each specialty varied as the trend of fab operation goes for downsizing manpower with automation and outsourcing maintenance work. This paper is to study the specialty distribution of manpower from the requirement in a typical 6-inch, 8-inch to 12-inch wafer fab. The human resource planning in today's fab operation shall consider many factors, which include the stability of technical talents. This empirical study mainly focuses on the human resource planning, the manpower distribution of specialty structure and the forecast model of internal demand/supply in current semiconductor manufacturing company. Considering the market fluctuation with the demand of varied products and the advance in process technology, the study is to design a headcount forecast model based on current manpower planning for direct labour (DL) and indirect labour (IDL) in Taiwan's fab. The model can be used to forecast the future manpower requirement on each specialty for the strategic planning of human resource to serve the development of the industry.

**Keywords:** semiconductor, wafer fab, human resource, headcount model, simulation, forecast model

## 1. INTRODUCTION

As the semiconductor manufacturing technology has entered 8-inch wafer era, the complexity of fab operation increases as the increase of wafer size. The wafer handling method has evolved from manual mode in 6-inch

wafer fab to semi-automated or fully automated factory in 8-inch and 12-inch wafer fab. Therefore, the distribution of manpower requirement in each specialty varied as the trend of fab operation goes for downsizing manpower with automation and outsourcing maintenance work. This paper is to study the specialty distribution of manpower

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from the empirical study of requirement in a typical 6-inch, 8-inch to 12-inch wafer fab. The human resource planning in today's fab operation shall consider many factors, which include the stability of technical talents. The turn over ratio of employees is relatively high as the industry migration to Asia in recent years that impact the long-term competitive advantage of the company due to the difficulty in knowledge management. This study is to discuss the optimization of manpower structure for modern fabs by considering the internal resources, automation, maintenance outsourcing, redundancy of key technology talents etc. The model can be used to forecast the future manpower requirement on each specialty for the strategic planning of human resource to serve the development of the industry.

This study mainly focuses on the human resource planning, the manpower distribution of specialty structure and the forecast model of demand/supply in current semiconductor manufacturing industry. Considering the market fluctuation with the demand of varied products and the advance in process technology, the study is to design a headcount forecast model based on current manpower planning for direct labour (DL) and indirect labour (IDL) in Taiwan's wafer fab. The manpower requirement affected by wafer size, ramping schedule, capacity, technology, the degree of tool automation and product mix is also mentioned.

From this study, we define so called IDL as of an exam-worker who is responsible for the fab operation related stuff and directly report to a fab operation organization. And the definition of DL is responsible for wafer handling, operating tools and the related stuff regarding to wafer moving.

Decision-makers tend to give assessments based on their past experiences and knowledge (Baksi, 1995). We take the process of arriving at a consensus based upon the reaction of multiple individuals, which has merit in that group interaction may facilitate the exchange of ideas and information whereby an acceptable judgment may be obtained. To deal with the vagueness of human thought and expression in making decisions; efficiently resolve the ambiguity arising in uncompleted information and the uncertainty in human judgments, to employ the expert group discussion is necessary and important.

## 2. HUMAN RESOURCE PLANNING IN SEMICONDUCTOR INDUSTRY

The semiconductor industry has been ingenious at continuing to make things work, and has been critical in the continued growth in the industry on a global basis. The ever-changing dynamics of the industry have created an interesting and unique, which also challenge the company in which to do strategic business. Among the

more notable of these dynamics has led human resource planning for companies of the tendency to spin off business units or ancillary divisions in efforts to concentrate resources on core markets. Another distinct trend has been the focus on multinational expansion, particularly in Asia, where China has become fertile ground for new subsidiaries. And, not surprisingly, talents and investment capital have also weighed heavily on the development of the semiconductor industry.

Semiconductor companies have always required a fair amount of capital investment and talent to enable the manufacturing of wider and more powerful electronic devices. With the rate of technological change accelerating and more semiconductor manufacturing moving to a foundry model, mostly the challenge will be to increase the return of investment capital by raising yields and lowering costs, while maintaining the flexibility to satisfy a variety, even a proliferation, of sophisticated new products demanded by consumers. Therefore, many organizations have professed to view human resources as valued assets as incubating talent pools to adapt the needs of market and technology innovation; and the investment in human resources as strategically imperative to corporate competitiveness (Harrell-Cook and Ferris, 1997).

### 2.1 The Headcount Planning of Fab Operation

The purpose of this headcount planning is to provide useful information for a variety of organizational purposes ranging from human resource planning to streamline manpower requirement in fab operation. It is also the foundation of forecasting the need for human resources as well as the plans for such activities as training, transfer, or promotion. Frequently job analysis information is incorporated into a human resource information system. Moreover, some combination of existing job analysis methods should be used (i.e. job performance observation, interviews, critical incidents, structured questionnaires) to weight the advantages and disadvantages. Selection, training, and pay systems are often keyed to job analysis and classification systems, without the information, it is impossible to determine reliably the structure of the relationships between jobs in an organization (Cascio, 1989).

Although headcount planning of fab operation, it involves the ideas on: (1) to maximise the operator workload; (2) manage the extra hours; (3) manage sub-contracting; (4) manage the assignment of the operators from one workshop to another; (5) assign to a job the operator who has the best skill; (6) have a better view on the global capacity in operators required to perform a planning; (7) have a better view on the capacity per competence required to perform the planning; (8) have a better view on individual assignments; (9) manage continuous training (Grabot and Letouzey, 2000). Thus, management of manpower can be modelled by a reasonable and flexible

thinking logic and go through the points as group expert's discussions.

The impact to headcount modeling, which setting human resource objectives is art as much as it is science. It requires conscious forethought based on the kind of future the firm wants to create for itself.

## 2.2 Impact on Business Cycling

The cycling changed the way many companies do business. It has also changed how their customers do business. Many of the customers have undergone tremendous pressures in downsizing their structures. Thus, their expectations toward suppliers and partners in terms of equipment and process technology are higher. There is more of a need to limit risk, changes in commitment, and a stronger push to fix costs. This leads to the outsourcing of different functions which not just the equipment but some of the research expertise, process technology, everything that's eventually incorporated into the package that the company deliver. This could be a major driver behind the business model.

To be competitive in the global business environment, organizations must build competence in their human resource as well as forming a demand/supply model, because such resources will be a vital determinant for survivability in a changing environment. During the downturn, companies are generally looked at acquisition possibilities as of a strategic alliance - joining forces with some of their long-term customers. It may have strengthened both capabilities in terms of leading technology, as well as other competencies. Besides, there are always looking for new applications for the core technologies as well as new business strategies. As predicting the future manpower planning with variety external factors (eg. technology, outsourcing etc.) could be risky and changeable (Woods, 1999). Hence, the business cycling have impacted the rule of human resource planning to new insight of manpower allocation as sticking to the core technologies and recomposition the capability of workforce as of the business model requires focus and careful choices.

## 3. METHODOLOGY

In general, a company tends to be two basic trends in manpower planning research: (1) a normative approach which emphasized mathematical programming models; (2) a comprehensive planning process which uses methods like job analysis, work study, factor analysis, organization structure, performance appraisal etc. (Purkiss, 1981). Nevertheless, human judgements for deciding the relationship between departments or groups are usually given by crisp values for establishing a structural model.

In many cases, crisp values are an inadequate reflection of vagueness in the real world; the fact that human judgements with preferences are often unclear and hard to estimate by exact numerical values (Tau et al., 2001).

In practice, to achieve effective and reasonable decision-making for solving complicated problems with multiple criteria, it is usually necessary to gather group knowledge and employ experts' experiences and opinions.

Therefore, a suitable strategy would be to perform a methodological analysis of historical data generated during the capacity expansion, seeking to find empirical relationships among the history of product, technology, manpower status, etc. to create the needs from experts discussion and group decision making for handling problems with the vagueness and imprecision can be the most direct and efficient way.

### 3.1 Group expert decision-making

To gain a solution for the problem solving, group expert decision-making is important to any organization, because it usually impacts upon those decisions that affect organizational performance. Group expert decision-making is a way to draw from varying degrees of experience, opinions, ideas, and motivations; facilitate learning for a broad range of informants in terms of their own perceptions and it can also be helpful in identifying variables, issues, and hypotheses. From the study, we take the process of arriving at a consensus based upon the reaction of multiple individuals, which has merit in that group interaction may facilitate the exchange of ideas and information whereby an acceptable judgment may be obtained (Cheng and Lin, 2002).

However, judgments for decision-making are often given by crisp values, though crisp values are an inadequate reflection of situational vagueness. In fact, many decisions involve imprecision since goals, constraints, and possible actions are not known precisely (Bellman and Zadeh, 1970). When making decisions in an uncertain environment, the result of decision-making is highly affected by subjective judgments.

Decision making is the process of defining the decision goals, gathering relevant information, generating the broadest possible range of alternatives, evaluating the alternatives for advantages and disadvantages, selecting the optimal alternative, and monitoring the results to ensure that the decision goals are achieved (Hess and Siciliano, 1996; Opricovic and Tzeng, 2004). To further the practicality of the group decision making in an uncertain environment, the analytical procedure of our proposed methodology is explained as follows: Step1: identifying the decision goal and forming a committee for gathering group knowledge for problem-solving; Step 2: information collection and developing evaluation criteria; to have sufficient data to help establishing sets of requi-

rement by ramping milestone which exist the nature of causal relationships and are usually comprised of many complicated aspects; Step 3: acquiring and aggregating the assessments of decision makers; Step 4: establishing and analysing the structural model; simply draw up a trend chart can help to visualize the complicated causal relationships of criteria into a visible structural model, providing valuable insight for problem-solving.

Decision-makers tend to give assessments based on their past experiences and knowledge, and also their estimations are often expressed in equivocal linguistic terms. To deal with the vagueness of human thought and expression in making decisions; efficiently resolve the ambiguity arising in uncompleted information and the uncertainty in human judgments, to employ the expert group discussion is necessary and important. Thus, the group decision-making in a real operation environment have experienced the wave of demand/supply and created a need to employ the logic of those uncertainties, and require effective aggregation methods to cope with group decision-making problems. In the following, we briefly review some essential terminologies of manpower specialty.

### 3.2 Manpower distribution of specialty structure

Human resource must be consistent with the planned future direction of the organization as well as with long-rang strategic plans. In order to run a fab efficiently, an effective headcount model with measurable indices is necessary for optimizing the manpower allocation. Generally, the headcount of fab operation is divided into two categories that are IDL and DL. The IDL includes equipment engineer (EE), process engineer (PE), manufacturing supervisor (Mfg IDL) and facility engineer (FE). The DL is responsible for operating tools and handling wafers (Huang and Wu, 2002).

Assessment of engineering manpower plays a very crucial role in running the company. There are different ratios of internal/external talent for DL and IDL due that the latter may need more skilled engineers to utilize their experience for solving the technical issues quickly and avoid possible delay and mistake along the way. Also experienced employee usually may use resources efficiently and create a continual research environment for knowledge accumulation. IDL have higher technical requirement and it is more likely to broaden the experience gradually in every operation stage. In general, DL tends to work in regular work content which is gradually displaced by tools running in automation condition. As the manufacturing technology advance to 12-inch wafer era, the tools become more difficult in operation by manual and require more precise and careful operation since the tools are getting more expensive and much more complex than those of 8-inch and far further from 6-inch.

As for recruitment, the most used to select or promote applicants must be based on a keen, meaningful forecast of job performance. Therefore, the orientation and development for training a worker can be very costly. To perform a specific task reliably and efficiently, engineers must understand exactly the capabilities of the operator and what he or she is expected to do. Similarly, any improvements or proposed new working methods must be evaluated relative to their impact on the overall job objectives.

## 4. FORECAST MODEL OF DEMAND AND SUPPLY

For the forecast model of manpower requirement as well as job analyses have always been done for providing a deeper understanding of the behavioural requirements of jobs (Choudhury et al., 2002). This in turn creates a solid basis on which to make job-related personnel decisions. Generally, job analyses are often done for a specific purpose (e.g., training design, manpower allocation and support program) with consideration of the many other uses of the information.

### 4.1 Affect Factors on Modelling

The development or trend on wafer fab with the consideration of wafer size, as it is a competitiveness of technology and capital. The development of wafer fab from early stage's small size of 3-inch, 4-inch to 5-inch, then to make progress to the year 1990's 6-inch and 8-inch wafer fab, as well as the future trend to 12-inch fab. Wafer fab could be meant as of economic scale, technology and cost competitiveness. As for first tier wafer manufacturer, new fab build or fab expansion represents to stretch and extend of contention power. For running of fair business, it could be a long-term racing, continuing to struggle on higher technology exploration, feasible capital budgeting and time-to-market.

A well manpower planning as well as a study on the headcount modelling is quite useful for a wafer fab's operational efficiency (Tzeng et al., 2004). Therefore, the related effect factors on the forecast model are considered: (1) the differences of organization structure; (2) familiarity on the technology and equipments; (3) work function and scope differences; (4) ramping milestone; (5) production capacity; (6) utilization and efficiency indices.

### 4.2 Headcount Planning

The headcount planning which includes internal transfer, training and recruitment (Lo et al., 2003). Also, it requires certain reasonable percentage on external recrui-

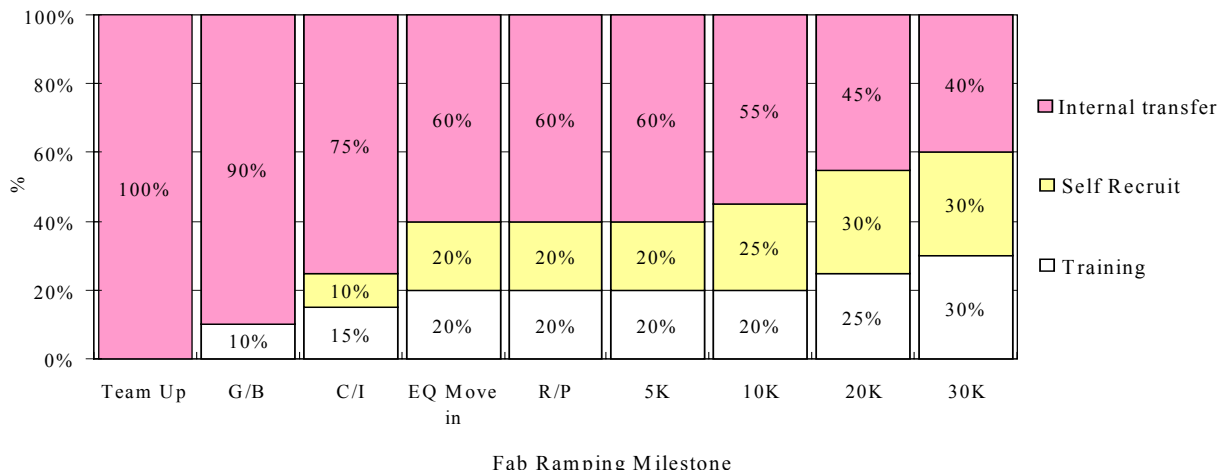


Figure 1. Assumption Pattern of Headcount Requirement by Ramping Milestone

Table 1. New Fab Ramping Milestone

Fab	Q4-99	Q1-00	Q2-00	Q3-00	Q4-00	Q1-01	Q2-01	Q3-01	Q4-01	Q1-02	Q2-02	Q3-02	Q4-02	Q1-03	Q2-03	Q3-03	Q4-03	Q1-04
A	EQ Move-in	R/P	5K	20K	30K													
B					EQ Move-in	R/P	5K	10K	20K	30K								
C	EQ Move-in	R/P	5K	10K	15K	20K	25K	30K										
D			C/I	EQ Move-in	R/P	0.3K		3K	4.7K									
E	G/B							C/I	EQ Move-in	R/P	5K	10K	15K	20K	25K			
F	G/B							C/I	EQ Move-in	R/P	5K		10K	15K	20K	25K		
G								G/B						C/I	EQ Move-in	R/P	5K	10K
H												G/B						C/I

ting task. The recruitment begins with a clear statement of objectives, based on the types of knowledge, skills, abilities, and other characteristics that an organization needs. Objectives are also aggregated on a consideration of each well-trained individual and accustom in ultra-clean environment of fab clean room condition, related to that of the surrounding complexity rule and cleanliness requirement (see as Figure 1).

The actual process of the planning begins with a specification of human resource requirements-numbers, skills mix, levels, and the time frame within which such needs must meet. In order to make the operations successful, consideration should be given to the cost of operations and the analysis of the performance from existing fabs. Since the activities success is determined by the approved numbers of function which actually perform the jobs.

As the empirical study to view a new wafer fab project which usually starts from teaming up, ground breaking (G/B), clean room installation (C/I), equipment move-in, pilot run, wafer ramping-up (R/P) to full capa-city (e.g.

30Kpcs/month), sufficient manpower is a must to fulfil each stage requirement (see as Table 1). For an existing semiconductor manufacturing company, it initially needs certain percentage of the senior talents through internal transfer to help establishing each function related to operation in keeping up with ramping schedule.

According to the study objectives, the headcount supply indicates the available manpower in mature fab which operation has reached full-scale. As for the demand shows the requirement from ramping stage of fab operation that needs expertise to involve in the initial stage for urging the ramping schedule can be made on time. For the sake of operation balance, the support from internal resources can be transferred, training and new recruitment, but it have to keep in certain percentage to make sure each supporting fab can afford to own production load and still can make the effort on this support staff as well as get the backup from other fab (refer to Figure 2).

Therefore, this study take the contribution on setting a model to figure out how the fabs to find a way to provide their fair support in time to new-build-wafer fab by using this simulation rule to reduce any possible risk.

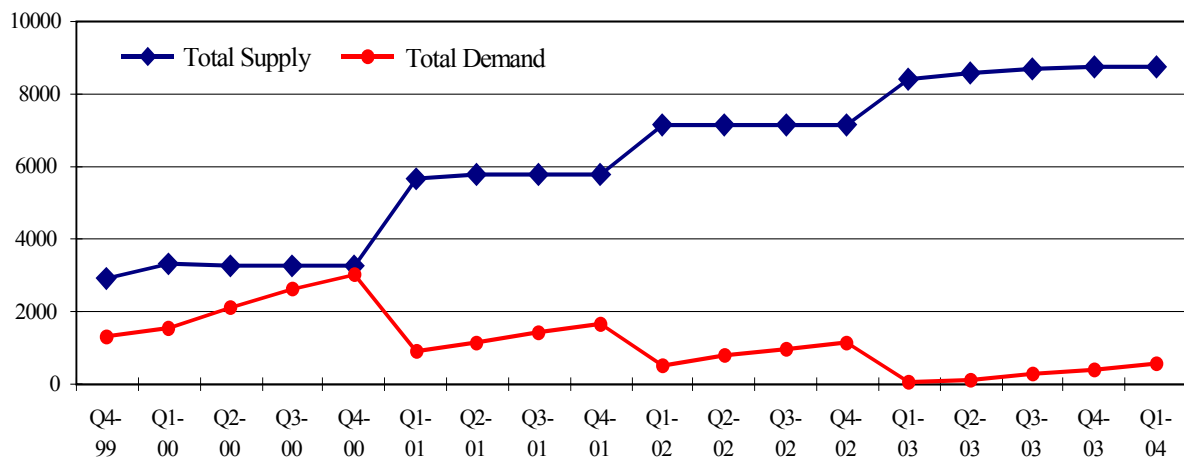


Figure 2. Headcount Total Demand versus Supply

## 5. DISCUSSIONS AND SUGGESTION

This is an advantage of a wafer fab with a lot of talents to work together. It also allows for recruiting sustainable of long-term planning. Talents with the flexibility and the capability move the operation faster. In general, company remained certain rate for seeking the talent in the silicon arena when everybody thought that it might develop into a profitable industry. The same thing with wafer foundry manufacturing company, due to the necessary intellectual and electrical engineering skills, foundry manufacturing company with their talents provide all the support that their users require, as well as own expertise.

A key dynamic aspect of the model is the relation between market condition and managerial strategies. When market competition is severe, top managers will move towards conservative by using headcount freeze strategies and will try to reduce the proportion of central staffs compared with full capacity running situation. This paper provides not only a simple concept on the headcount estimation at different wafer fab ramping stage but also useful information for the headcount planning in existing fab (supply) and new start up fab (demand).

Since the semiconductor manufacturing industry has become mature, the global manufacturing strategies tend to go for cost reduction and production efficiency in terms of migrating manufacturing base to lower cost regions for maintaining their business in profitable. Thus a new start up fab may be able to reduce the labour cost and sharing limited experiences from existing fabs. This paper provides an outline on headcount ramping modelling for the help of management on headcount allocation and human resource planning. Especially, in this economy down turn period, cost control and talent recruiting policy may impact the business directly and bring the chance to win in next up turn.

This model wouldn't work for every company in the world, but it's a perfect fit with the industry's particular culture and strengths - the evidence is in its stable revenues (outcome) and profitability, and its excellent position in the markets.

However, the study demonstrates the sophisticated headcount planning with empowered and intelligent workers to achieve productivity and respond quickly to customer needs for a variety of innovative and high quality product. It is suggested that the historical data is used coping with its productivities trend as the basis of typical fab headcount during wafer ramping.

## 6. CONCLUSION

The role of semiconductor company in the delivery higher operation efficiency and outcome in those of competitive environment must see the talent planning to be a crucial staff. Therefore, the human resources of a company those are mostly to supply the core competencies which will be the source of sustained competitive advantage. In such industry, well-planned manpower demand and supply can smoothen the business operation; the acceptance of headcount forecast model might be well helpful toward changeable market situation.

Within 10 years, as the trend of manufacturing technology advances to larger wafer size, functional outsourcing and fab automation, it is expected that the manpower of the future advanced fab will be much reduced from today's fab.

For future study, this paper will review the typical manpower requirement of 6-inch, 8-inch and 12-inch wafer fab for semiconductor manufacturers as the reference of managerial guidance in human resource planning.

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