

## The Evaluation of the Best Timing of Enterprise's Investment in Mainland China and Estimate Break-Even by the Combination of Scenario Analysis and FMEA Model

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**Abstract--The goal of this study is to discuss the best timing of entering China to invest and build factory. Using photomask industry of Taiwan as an example, the key variables were derived by the analysis of examining industrial environment, observing the market and technology of global photomask industry and contrasting with China's semiconductor industrial environment, and the investment strategies of important manufacturers in photomask industry in recent years; the relevant variables were obtained by consulting and interviewing with 15 experts in photomask industry. Business Failure Mode Effect Analysis (BFMEA) was used to discover the important trend of change and was integrated with scenario analysis to obtain the quantitative results as being the reference of investment strategy in decision making level. Quantitative analysis used in this study developed market and business models. Market model is based on the public information as the basis of semiconductor production and experts' consultations as the references of converting variables to develop the market model of photomask industry. This market model was used to predict future demands. Analyzed data gained from market model was applied into business model to get the relevant information about operation profit. This study found that the fourth quarter in 2003 was the best time point to invest photomask industry in China because 6-inch photomask market had significant growth in 2004 and companies investing China's photomask market will begin to make profits in 2006.**

### I. INTRODUCTION

Many scholars had deep discussions about investment issues in the areas of the border of the USA and Mexico, Easter/Western Asia, Central-South America [1], but only few discussions about China due to the slow pace of opening and political constraints. With China's opening, Taiwanese and foreign companies entering China actively to invest and build factories, and have created an obvious trend that China has become the world manufacture center. Adam Smith pointed out the cooperation and collaboration in his "the Wealth of Nations" [2]. For the purpose of survival and sustainable development, enterprise has to seek cheap labors, materials, and costs of building factory to develop potential market. Thus, it is an unstoppable trend that enterprises enter China to invest and build factory for manufacturing and production. Therefore, the evaluation of enterprises' investing and building factories in China is an interesting and valued topic.

In general, enterprises use the return of investment and simple financial reports to analyze foreign investment and building factory but the theoretical discussions in some dynamic environmental factors are little. Moreover, the application of practical business model simulation is especially lacking. Therefore, the unexpected situations that cannot be dealt with on time during the process of building

factory or at the beginning stage of production causes serious lost or failures in investment. Many scholars focused mostly on academic theories while discussing enterprise investment. For examples, using the viewpoints of option theory sees the investment of expendably flexible manufacturing system and using Net Present Value (NPV) evaluates expendably flexible manufacturing system [3]; in the investment risk prediction of regional energy market, using risk evaluation sets predicts investment risk [4]. There are few discussions integrating academic theory and application of practical business model simulation.

Because investment analysis methods in both business and academy have loopholes, this study focuses on the combination of theory and practice and integrates Business Failure Model Effect Analysis (BFMEA), scenario analysis, and expert approach to discuss the best timing of investing and building factory in photomask industry in Mainland China. At first, this study uses failure mode to analyze product design and manufacturing process planning for the advanced prevented analysis tasks; then this study uses effect analysis to predict investment performance. The original FMEA method can assist design engineers to find the weakness or potential defectiveness in products and manufacturing process design as early as possible; using the same idea can find the possible defectiveness and disadvantages in the process of building factory in foreign countries. After knowing the risks, the improved strategy can be developed, but FMEA has less discussion in analyzing investment and building factory.

Besides the dynamics and changeability of external environmental factors in China, many situations will not be predicted in the process of building factory. The goal of this study is to propose that using FMEA as the basic structure and combining with variable factors of industrial environment, called Business Failure Mode Effect Analysis (BFMEA), enhances traditional FMEA methods in the evaluation of foreign investment and building factory. Then, this study integrates scenario analysis and expert approach to consult 12 experts in photomask industry, simulates 6 business situations of initial production stage to obtain variables of BFMEA, and calculates return of investment to gain analyzed data by importing BFMEA variables into simple financial calculation mode. Through cross analysis in theory and practice, it is expected that the risk of investment and building factory will reduce to the lowest and the results of this study can be the timing reference for industry coming to invest and build factory in China.

Electronic industry plays an important role in the construction of Global Commodity Chain. IC industry is not only the heart of electronic industry but also the main power

to make technology progress. The capability of IC development and manufacture is one of the measurements of nation's technology level [5, 6]. Because of the global collaboration, China has become the world manufacture center. Production process of electronic industry includes IC design, photomask fabrication, wafer fabrication, packaging, and probing. Photomask fabrication is especially one of the important parts. According to the report "the trend of semiconductor industry in China" in IT industry Dataquest point out China will become the second largest market in semiconductor and IC in 2010 (<http://www.dqindia.com>). Where is the investment opportunity for photomask industry in this quickly growing Chinese semiconductor market? This study uses Taiwanese companies investing in Chinese photomask industry as an example to examine the industrial environment changes and to observe global photomask market and technology and the Chinese semiconductor industrial environment. First, this study made lists of production capacities, plans, and important economic activities in China in recent years and did researches in the areas of technology and demands of photomask to determine the possible technology and demands of present and future photomask market. Second, key variables were derived from above observations and analyses; BFMEA was used to find the important trends of photomask industry. Then, integrating scenario analysis, the quantitative results are to be the investment reference in management level for decision-making.

## II. LITERATURE REVIEW

Literature review of this study focuses on the review of investment evaluation method, FMEA, and scenario analysis for the convenient use of future studies.

### A. Investment evaluation

In this tiny profit era, every enterprise evaluates investment cases very carefully, especially when evaluating investment and building factories abroad. Borgonovo and Peccati [7] pointed out in the study of investment case evaluation using the sensitivity analysis that look at the investment from the view point of finance, take the maximum profit ratio of investment in one particular time point as the evaluation target, adopt the financial analysis skills - Net Present Value (NPV) and Internal Rate of Return (IRR) and integrate the sensitivity analysis to evaluate the target of special case investment. There are scholars adopted the system analysis method to discuss the foreign investment environment use environment variables - society, politics, economy, law, public service, and nature, as the five major elements of system analysis. Then, discussed some more variables, which may exist, but it lacks discussion of enterprises' operating conditions [8]. In the past, when evaluating the analysis of IT investment, scholars adopted the cost and effect analysis as the criteria of evaluating investment efficiency; took the equipment satisfaction as the evaluation criteria of technology. But, they merely discussed the whole IT environment [9]. Some scholars used the

Analytic Hierarchy Process (AHP) to discuss the foreign direct investment cases; decided each selected criteria weight using AHP, updating the new order and selecting economy factors using the simulation, adopted the simple NPV, IRR as the economical benefit evaluation of special case investment. But the risk evaluation was rarely been discussed [10]. Since there were few scholars discussed one particular enterprise that made investment and built factory in Mainland China, and the whole concept of the whole environment, industry environment, enterprise competitiveness, and enterprise failure. Therefore, this study will discuss the enterprises' investment and building factory in China through the Business FMEA Model.

### B. FMEA method

The traditional FMEA method was used by researchers in the early stage of design for analyzing the failure risks that may faced during the process of product design and production planning as the prevention analysis work; they adopted the effect analysis to predict investment effect analysis, and assisting select alternatives to raise the products' reliability and safety. All the FMEA considered the completeness of product design quality for easier conducting the producing line in the future; at the same time, clearly understood the hidden causes of failure and its effect [11, 12]. In the contrast, failure analysis is a basic analysis work. Failure analysis will define the product's necessary functions according to the acceptable standard [13]. The quality of reliability analysis depends on the ability of analysis. For the necessary function of definition, the common failure analysis needs a clear description [14], all the effects of FMEA analysis model are considering the effects of producing process, and are describing the causes and effects of failure [12].

Although FMEA has considered every aspects in the development of static product, and has been used in research and development, when evaluating enterprises' investment and building factories, the variables, which has to faced are not only the research and production, but also many active environment factors, customer relation, orders, equipment, and etc.; considering only the FMEA is not enough.

### C. Scenario Analysis

Schwartz [15] pointed out that the Scenario Analysis is used for predicting uncertain driving power which may show different situations in the future, that is the output results with different technical parameters, economy, society, politics, and political activities; it also can be used to work out individual or group behavior variables. Scenario Analysis is a describing method of predicting the unknown future. So called "scenario" is making a brave cognition assumption toward the general situation of future outside environment. It has been seen as a cognitive structure of future environment for helping decision-makers cultivating the sensibility of strategy, facing the highly uncertain world [16, 17]. Since the environment is changing very fast, the scenario analysis has to connect experts with different fields using the existing information, carrying out structure analysis with system

thinking, designing important situation development to predict the uncertainty of the future [18].

### III. BUSINESS FMEA MODEL

According to the discussion of FMEA in section 2, we found that there will be some defectiveness if apply FMEA on the analysis of investment and building factory. Therefore, this study proposes the Business FMEA model to strengthen the weakness. Below is the detailed description.

#### A. Business FMEA Model

According to the past researches, the overall environment of an investment and building factory case is related with many variables: political environment, social environment, law environment, technology environment, population environment, and etc.; in the industrial environment there are variables of self industry, relevant industry, that is competitors and hidden competitors; inside the enterprise organization the relevant variables are basic supporting functions of enterprise, organization operating function, and industrial value [19]. After the discussion in previous section, there are downsides of FMEA in analyzing investment and building factories. Therefore, this study added some overall environment variables, enterprise environment variable and scenario analysis to create the model of Business FMEA method. This study analyzed the evaluation of the photomask industry's investment in China through Business FMEA; then, used simple finance analysis method to display the return on asset, and finds the best timing for entering China to invest and build factory the financial report. At the same time, for insuring the success rate of investment and building factory in China, enterprises may use the strategy choice. Strategy choice of this study deliberates the scenario analysis of Martino [16] technique estimate to decide the final strategy choice.

#### B. Industry competitiveness analysis

The industry competitiveness analysis of Business FMEA uses the five forces, which was proposed by Porter [19] in the "Competitive Strategy". The five elements that influence industry competitiveness are: "the bargaining power of customers", "the bargaining power of suppliers", "the threat of new entrants", "the threat of substitute products", and "the intensity of competitive rivalry". Through the five forces analysis the competitive strength and profit ability of this industry can be estimated. In the traditional industrial economics, in the past, scholars had deeply discussed the influence of market structure to manufacturers' behavior and achievements; "market monopolized enterprise brings exceeded profit" has become a well-known basic theorem [20, 21].

The key of success or failure of enterprise's operation is its' competitive ability; investing new technology or new business is related with enterprise's competitive ability [21]. In the past, when scholars studied the role-play of enterprise's asset cost in investing information technology, they found that enterprise's private and public wealth have different

degree influence in enterprise's asset cost [22]. Dow and Gorton [23] proposed in a trading behavior research that uniformed and non-uniformed profit (information dissymmetry) is obvious related with the profit obtained from the trading behavior. Common investors will seek for a mode, which is more beneficial to themselves to carry on trading; even adopt the uniformed profit instead of non-uniformed profit trading. Investing and building factory in China is very difficult to raise the fund of public wealth (bank loan and public finances); it is totally different from investing in other European and American countries. The overall environment of China filled with a lot of variables, especially the information dissymmetry, it is very common. These analyses related with enterprises' competitiveness should not be ignored, especially for a new investment. Therefore, this study will carry out more detailed discuss in section 4 the industrial environment analysis of China.

#### C. Enterprise value chain

Porter [20] thought that products or services that provided by enterprises were actually created by a chain of activities. Every activity could be the final differentiation of products, and raise enterprise value. The main subject of discussion and analysis of the enterprise value chain of Business FMEA in this study is focused on investment and building factory. The final goal of manufacturing industry is to make the best arrangement of products' operation behavior and commercial flow. If the manufacturing procedure and commercial flow are under a systematic arrangement, then partial variables can be controlled in a scope [24]. The supply chain management strategy is focused on the long term parts supply management, and, at the same time, decides the planning of product line and supply chain network [25]. Analyzing enterprise's competitive condition and competitiveness under different environment, it may utilize the general strategy thinking factor, also can be limited in management domain area, obtaining resources, manufacturing and research and development, asset management and product pricing, and the vertical conformity [26]. These are the main focuses of Business FMEA.

At the same time, the value chain of enterprise itself will link with the value chain of supplier, channel and customer and form an industrial value chain. Any enterprise can use the value chain to be a analysis structure to think of how to find a strategy behavior of lowering cost or creating differentiation; furthermore, to analyze the connected relation between supplier, manufacturer and customer value chains to find possible developing chances [27, 28, 29]. According to the past researches, the characteristics of industrial value chain will influence directly on the integration efficiency of enterprise value chain [30].

It can be learned from the study of enterprise competitiveness analysis based on manufacturing that there are obvious relations between supply chain efficiency and business efficiency [31]. Thus, the Business FMEA will link supply chain, customer and customer value chain to be a competitiveness analysis structure. The analysis of value chain uses quantity method via market bases and industry

value chain analysis to judge enterprise's business ability [32]. Establishing the structure of enterprise value chain is for planning the leading time of priority order, and strengthening the time and efficiency when improving special case. Therefore, if an operation of enterprise value chain is smooth or not is closely related with the rising of the operating efficiency [29].

Under different culture and environment, the narrowed meaning of enterprise organization achievement can use financial norm to reflect actual business activities of the enterprise, for example, sales growth, profit ration, ROI, ROA, ROE, EPS. It weights the enterprise management ability using the quantification way and based on the market demand and enterprise value [21]. The Business FMEA model will use simple ROA, EPS to display the economic efficiency evaluation of investment building factory in China.

#### *D. Scenario analysis and strategy choice of the early stage*

The main goal of scenario analysis is to stimulate the participants to think about the future with a new way, and exam its own assumption to the future to indirectly inspire the viewpoint of the future [33]. When choosing a strategy case, product's life circle theory and product's innovation and development circle theory may be adopted in order to choose a proper strategy [27, 29]. The procedure of common scenario analysis has the following five steps: (1) define the problem and analysis area; (2) create system and find important variables; (3) collect data and propose assumption; (4) discuss possibility of the future; (5) select strategy choice case [34]. Common strategy choice can make the choice according to the necessity of industry scenario. Business FMEA of this study will carry out discuss base on product's life circle theory and product's innovation and development circle theory, and takes the five steps, which were proposed by Godet [34], as the reference of scenario analysis.

## IV. THE PHOTOMASK MARKET ANALYSIS OF CHINA

This section will carry out more detailed analysis and discuss focused on the market situation of photomask industry in China to be the reference information of the fifth section of this study establish marketing model and management model.

#### *A. Global IC, Semiconductor market and photomask market*

Since the manufacturing process of photomask is one of the important likes in the manufacturing process of IC and semiconductor, the market prosperity or decline of IC and semiconductor will affect photomask market. Taiwan and China play a core role in IC manufacturing, the other periphery countries are: the United States, Japan, and Germany [35]; therefore, the IC market and photomask market are vitally linked. This study collected opened data and website information (<http://www.wsts.org>; <http://www.sematech.org>) from 2000 to 2005 for the use of future analyses.

#### **1. Asian IC semiconductor market**

According to the statistic data of May 2004 from the World Semiconductor Trade Statistics, The Asian semiconductor market is the main power of impelling global semiconductor market growth. The market share of Asian and Pacific area is 40.7%, surmounted the United States 30%.

Meanwhile, the published materials of WSTS showed that because the PC changing rate is rising in the US and the strong growing power of South America and China, they are the power of impelling the growth of global semiconductor market. American Semiconductor Industry Association (SIA) pointed out that in 2002 the global major product sale grew 14.9%; in 2003 and 2004 grew even faster 23.9% and 25.6%. Therefore, Asian manufacturers are the main beneficiaries of that wave of semiconductor business recovery. The rising of Asian semiconductor market is mainly because China market is developing very fast, Taiwan, South Korea and Singapore have deep overall arrangement, and there is external environment demand; they make the development of Asian semiconductor market prospective.

#### **2. The IC, semiconductor market of China**

The great demand of investment in China is the main reason that Asian and Pacific region became the largest IC, semiconductor market demand. The demand of semiconductor in China increases every year, and it will become the largest semiconductor demand market in 2010. The factors are: (1) Chinese government gives semiconductor manufacturer favorable treatment; for example, the eight-inch wafer factory and designing industry will get the number eighteen document reward; internal sales of system products may obtain tax preferable benefit; (2) the equipment ban is lifting gradually. After China joined the WTO and obtained the most-favored nation from the US, the releasing of relevant equipment ban of eight-inch wafer factory, the processing equipment under  $0.18 \mu\text{m}$  may be lift soon; (3) due to the influence of the global trend of moving the producing line to Asia, the European telecommunication manufacturers gradually move the producing line to Asia as well, and the relevant semiconductor factories release orders to Asian semiconductor manufacturers for saving cost. Therefore, Asia is the fastest growing area of semiconductor industry in the world, and China is the gathering place of talented people and investment of Asian semiconductor market.

#### **3. Global photomask technology and market**

In 2001 global photomask industry was impacted by the falling prosperity. Because the demand of the high profit high level  $0.18 \mu\text{m}$  /  $0.15 \mu\text{m}$  photomask increased greatly in 2002, global photomask industry pursued the further refinement demand of photomask technique. Having this technique and demand, photomask manufacturers passed the low prosperity in 2001 and 2002; for the growth of photomask market from 2003 to 2005, the manufacturers should work hard to occupy the market share of photomask. For the photomask manufacturers, which would like to invest in China, it is better to occupy a spot in the market first,

seeking the technology cooperation with the local OEM factory as soon as possible; otherwise, missing the chances and it will be difficult to settle in the high level photomask market.

#### *B. The IC, semiconductor market environment in China*

Generally, environment can be divided into overall environment and industrial environment. The overall environment means the external environment: political environment, social environment, law environment, technology environment, and population environment; industrial environment can be seen as a collection assembled by various essential factors of market supply side and demand side. Below introduces each environment.

#### **1. Overall environment in China**

- (1) Political environment: since the reform and open policy that was carried out by Deng, Xiao-Ping in 1979, the economical reform rose the district administrations' influences, and formed a contradiction between central authority and district administrations. This surge of reform and open will definitely affect the development of democratic politics, but how long is needed is difficult to tell. After China jointed WTO, the uncertainty of operation environment will reduce and the cross-strait economical dealings are just like a flood can be stopped.
- (2) Economical environment: (a) finance: generally in China the financing method for Taiwanese companies can be divided into the long term financing of fixed assets, short term credit of operating capital, and the import-export trade financing; but, for companies, these three type of financing are very difficult to obtain; (b) economic development: the economic growth in China is recurrent. At the beginning of five-year plan every kind of basic construction carried out abundant, the first half of economical prosperity was rising. Then, the economy started to lose its order, and inflation pressure occurred. But Chinese authority adopted tighten policy and the speed of growth in second half was slow.
- (3) Management environment: (a) personnel: it is difficult to find Taiwanese cadre members and there are problems with adaptability. The experienced staff don't want to station in China for long. It is difficult to keep suitable personnel and increases the trouble in personnel; (b) finance: the common enterprises in China have the risk of recovering payment difficult, collecting debts not easy, and transaction risks increasing; (c) decision: information is not clear and the business information is difficult to obtain. This bothers Taiwanese companies a lot when making decisions.
- (4) Social environment: the triangle debt in China has formed a debt chain. Illegal acts, such as embezzles, bribe, smuggling, illegal drug selling, have became rampant in government and society, especially along the coastline. Because large population moved from countryside to big cities, the criminal rate is very high. According to the estimate of the Chinese Academy of Social Science that the unemployment rate has reached

10%.

- (5) Law environment: until the announcement of reform and open made by Deng, Xiao-Ping in 1979, the laws and regulations, which meet people's demand, had became exist, especially the birth of trade relevant law. There are still a lot of problems need to be solved by consoling and signing agreements from both sides; for example, the protecting area of intellectual property; the solution model of investment controversy and business dispute; the solutions of the levy, public legal proceeding and the compensation dispute; the damage compensation of the non-commercial risk, such as subrogation, war.
- (6) Technology environment: China's investment environment is not yet mature, because the personal saving ratio is not as high as in Taiwan, the enterprise profit-sharing system and venture capital are not legalized; it is difficult to gather funds form capital market. Moreover, the conditions of import semiconductor equipment are not relieved, China cannot perform the advanced manufacturing process, and the technique cannot meet the market trend. These are the two major causes of immature.
- (7) Population environment: each year there are about a million college graduates go into job market. It is not a problem to hire senior managers, but the management idea of these people needs to be recreated. This is the key factor whether the localization success or not. The localization has become a trend.

#### **2. Industrial environment**

In discussing photomask industrial environment, first, it should collect relevant information about individual events in this industry. This study categories collected information of global photomask industry as two factors, market and products, for advanced analysis.

##### a) Global photomask history

The four mainstream companies in global photomask industry have created<sup>1</sup>. After several significant changes in global photomask industry, photomask companies have gradually reduced. For instance, in the United States, photomask companies have decreased from over 20 companies to only one company, Photronics. The main reason is that the high investment creates only low profits. From the points of cost structure and global localization, big companies continued to merge small scale photomask factories and photomask department originally belonging to IDM. Less and less photomask factories do not belong to big enterprises. Almost all global photomask products are controlled by three Japanese photomask companies, DNP, Toppan, HOYA, Dupont, and Photronics. Taiwanese photomask factories can only take advantage of location to concentrate on China's domestic market but not in export market.

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<sup>1</sup> WSTS (2005) pointed out, in global photomask industry there are Dupont (24-26 %) and Photronics (15-20 %) in the U.S, DNP (18-22 %) and Toppan (14-16 %) in Japan.

b) The characteristics of photomask products

One of the characteristics of photomask industry is to keep releasing new products. The life cycle of high level photomask product has quickly become mature product. However, the following characteristics make them not easily become obsolete. (1) The bundle effects of photomask: it means that photomask product is an assembly product. In general, a  $0.18 \mu\text{m}$  photomask set, including 25 pieces of photomasks<sup>2</sup>; (2) photomask investment effects<sup>3</sup>: with the increase manufacturing capacity of IC and semiconductor, the demands of photomask also increase. Enterprises need to use merging methods to obtain more manufacturing capacities in low-level photomask. Because old machines are not enough, low-level photomask production cannot increase easily and causes the price of low level photomask increased. Its life cycle has restarted again. (3) Local effects of photomask: because of the bundle effects, low-level photomask is needed in every period of manufacturing process. Through local integration of global enterprise, photomasks produced in various levels can continue to supply global demands.

## V. PRACTICAL ANALYSIS

After the analysis of photomask market competitiveness in last chapter, this chapter describes the practical analysis. First, this study used Business FMEA model to analyze the

variables of competitive structure in photomask industry; then, market model and business model were created.

### A. Applying Business FMEA Model

In applying Business FMEA Model, photomask industry should be discussed. First, collecting relevant data from every independent industrial event, then, using Porter [20] five forces model to analyze and categorize every competitive factor, every independent event has its own items of activity which are the partial variables of Business FMEA Model. In order to have relevant variables more effective, this study interviews 15 experts in IC, semiconductor, and photomask industries. Table 1 shows the detailed information about these 15 experts. After interviewing experts, market demands were analyzed to obtain the reasonable business manufacturing planning of entering photomask industry in China. According to manufacturing planning, turnover was analyzed by prices; investment and depreciation costs of machines were obtained; the basic financial data was gained by calculating costs; these series tasks of combinations and relationships were called business model by this study. Integrating business model, competitive analysis, and enterprise activities into Business FMEA Model, the priority of investment activities were sequenced by calculation. These are the most important evaluation items for investment and building factory.

TABLE 1. DETAILED INFORMATION ABOUT 15 EXPERTS

Industries	IC design	Semiconductor Manufacturing Design	Photomask Design	Photomask Manufacturing	Photomask equipment
Numbers	3	3	3	3	3
Working years	1-3 years	3-5 years	5-7 years	7-10 years	Over 10 years
Numbers	4	3	3	2	3
Titles	Design engineer	Manufacturing engineer	Manager	Chief Technology Officer	President/Vice President
Numbers	3	4	2	2	4
Education	High school	College	University	Masters	Ph. D.
Number	1	4	5	3	2
Expertise	Manufacturing Process Design	Product Design	Factory planning	Equipment planning	Financial planning
Number	6	3	3	2	1

### 1. Reliability Examination

Using Business FMEA Model to analyze photomask market can also examine its reliability. The examined results of reliability have no large difference in comparing to results released by Dataquest. The other deviations from 2002 to 2005 are in reasonable range (Table 2). Therefore, it can be said that the Business FMEA Model satisfies reliability examination.

<sup>2</sup> A  $0.18 \mu\text{m}$  photomask set is assembled by following technological levels:  $1.2 \mu\text{m}$  (8%),  $0.8 \mu\text{m}$  (24%),  $0.5 \mu\text{m}$  (24%),  $0.35 \mu\text{m}$  (12%),  $0.25 \mu\text{m}$  (20%), and  $0.18 \mu\text{m}$  (12%). Its amounts is 25 pieces.

<sup>3</sup> The photomask investment effects is an old machine invested in 1994 is still main production machine in 2001.

TABLE 2. PRODUCTION AND MARKET'S RELIABILITY EXAMINATION

unit: Million US\$

Global IC and mask market analysis					
Items	Year→	2002	2003	2004	2005
Global IC market		151,866	197,774	244,521	256,563
China IC market		14,215	16,612	18,841	24,233
Sharing global market		(9.36%)	(8.4%)	(7.71%)	(9.45%)
China IC home make market		3,840	6,244	10,444	17,036
Sharing China IC market		(27.01%)	(37.59%)	(55.43%)	(70.3%)
China mask market		57.6	103,026	172,326	282,797
Mask share IC market ratio		(1.5%)	(1.65%)	(1.65%)	(1.66%)
BFMEA Model calculated value		59.79	107.8	164.78	262.55
Error %		3.8%	4.6%	-4.4%	-7.15%

## 2. Building Market model

In building model, the most important tasks are to summarize public data and to interview experts as planned. This study uses data obtained from interviewing experts to create market model. The amount of demand for photomask can be calculated by following formula.

$$M_T = \frac{IC_T}{(M_a) * (M_s * M_p)} \quad (1)$$

$M_T$  is the amount of demand for photomask;  $IC_T$  is the predicted amount of manufacturing of semiconductor factory;  $M_a$  is the average pieces of wafer produced by per set of photomask;  $M_s$  is the amount of photomasks in per set of photomask;  $M_p$  is the ratio of amount of photomask in various classes. The predicted amount of manufacturing of semiconductor factory is related with year and type of factory. The average pieces of wafer in per photomask are related with type of semiconductor factory and type of manufacturing line; and the number of photomasks in a set of photomask is related with design guideline. In the same set of photomasks, the ratio of photomask number in every class of photomask is related with design guideline variables.

## B. Building business model

The basic information of every factory was obtained and organized for predicted items. The unreasonable parts were consulted by experts and proved by relevant information. From 2002 market information in China, some manufacturing capacities in new factories have moved to 8-inch wafer factory. This makes obvious clustering effects; except Motorola in Tianjin, other photomask factories gather in Shanghai area and make Shanghai be the important place for photomask. This makes Shanghai increase the manufacturing capability to  $0.18\sim0.25 \mu m$ . It can be seen that Shanghai has gradually had the development capability for 12-inch wafer factory.

## 1. Manufacturing capacity planning

After predicting market to develop goals and to finish the planning of manufacturing capacity, the goals established focused on the total capacity of photomask market in China to predict market share of enterprise's investment and to estimate feasible planning for manufacturing capacity. Table 4 shows the information of calculated manufacturing capacity.

TABLE 4. MARKET SHARE FORECASTING

	2002	2003	2004	2005	2006
China total mask production	800	1935	3493	5039	7117
Share target market	0%	20%	30%	35%	40%
Production capacity	0	387	1047	1763	2846

## 2. Financial calculation

Turnover can be also gained from manufacturing plan. The estimates of fixed asset and variable costs to 2006 are about 6 writers and 12 examination machines; the total cost of equipments is \$NT 2.4 billion dollars; the investment of buildings, lands and factories are \$NT 0.3 billion dollars; in manufacturing materials, including blank photomask and mask pellicle, consumable materials, a piece costs \$NT 50 thousand dollars (Cost of goods; COG); the costs of administration and other stuffs are about \$NT 0.1 billion dollars. The financial formula could be created by simple ROA calculation. The following are formulas.

$$ROA = \frac{[S - (COG) + D_5] - (MSG \& A)}{I} \quad (2)$$

$$EPS = \frac{ROA}{10} \quad (3)$$

$S$  is the sales amount; COG is raw materials and consumable materials;  $D_5$  is the cost of 5-year depreciation;  $MSG \& A$  is the administration costs;  $I$  is the investment money;  $EPS$  is the simple  $EPS$ . This study used these simple formulas described above to calculate the price in photomask market. The estimated turnover was also obtained by integrating business plan and above formulas. Table 5 shows the detailed information.

TABLE 5. MASK PRICE

Grade	6 inch mask							5 inch mask					
	A	B	C	D	E	F	G	H	A	B	C	D	E
Design rule	2	1.2	0.8	0.5	0.35	0.25	0.18	0.15	2	1.2	0.8	0.5	0.35
Ratio of price cut (%)	0.98	0.98	0.97	0.96	0.92	0.91	0.89	0.87	0.98	0.96	0.95	0.94	0.92
Price (NT\$: K)	60	62	67	75	100	250	440	820	30	32	35	55	75

Using season as basic unit to calculate manufacturing capacity and other items, financial spreadsheet was created. Some photomask-related investment information of manufacturing capacity can be found in spreadsheet. The detailed information is shown in Table 6. The result shows that the estimated market share was set to 40 % in 2006.

However, since business environment was tough and market scale was not large enough, these caused difficulties in real business management. Thus, the EPS was still negative in 2005. From simple investment spreadsheet, it could be found that in order to increase investment EPS, reducing cost in machine depreciation is necessary to reach desired profit.

TABLE 6. FINANCE SPREADSHEET

	2002	2003	2004	2005	2006	Unit:Million \$US
Sales	0.00	4.53	16.91	30.66	48.08	
COG (including depreciation)	4.32	10.18	19.43	35.64	41.21	
Gross Profit	4.32	5.65	2.51	4.98	6.87	
MSG&A	0.29	1.91	2.34	2.63	3.24	
NP	(4.61)	(7.55)	(4.86)	(7.61)	3.63	
EPS	(1.54)	(1.16)	(0.75)	(0.12)	0.06	

### C. Scenario analysis

The item having highest risk priority (RP) in BFEMA Model is the most important problem to be the variable of

scenario assumption for advanced analysis and discussion. The six most important issues and scenario are described in Table 7.

TABLE 7. SCENARIO ANALYSIS SHEET

Item	Issues	Scenario context
1	Competing with contact customers	Lost the chance to contact with leading companies
2	Cost controlling	Acquire other companies or buying the cheap second hand equipment
3	Customers credit	Because the originally adding one third high level orders have bad quality, a company lose two third high level orders
4	Deadline issue	Yield rate of high level mask is 50% double production lines of hot run are still 50%

### 1. Competing with contact customers

In the beginning of building photomask factory period of customers' authentication, if new entrants don't have opportunity of customer's authentication, the manufacturing capacity planning will be affected significantly in the future. Therefore, for the stability of the beginning period of building

factory, the variables gained from scenario analysis should be applied into BFMEA Model to analyze the risks of factory building initial stage.

#### Scenario 1: lost the chance to contact with leading companies

TABLE 8. PARAMETER OF CUSTOMERS FOR EARLY STAGE COMPANY OF THE BFMEA MODEL

Five competitive Forces	For potential enter competitors
Competing factor	Difference of products -1
Competing variables	Factor productivity plan
Changing variables	Local IC companies/Design house don't want to joint venture with us
Business factor	Productivity plan
Business result	Result is 0.325 million US\$/month
Potential issues	No advantage to cooperate
Methods of problem controlling	Finding chances to testing products
Serious	9
Possible	9
Detectable	3
Risk priority number	243
Risk priority	87
Responsible department	High level managers
Priority	1
Action	Finding big loading companies testing products

(BZ: Business Factor; S: Serious; P: Possible; D: Detectable; RPN: Risk Priority Number; RP: Risk Priority; Pri: Priority. Others see appendix 4)

This scenario assumes that simulation parameter loses one-fifth of manufacturing capacity plan and analyzes the changes and profits. It was found from analyzed data in Table 9 that while losing chance to contact with leading companies and losing one-fifth of manufacturing capacity plan, from 2003 to 2006, every year loses \$US 3.13 million dollars in average or per share loses \$US 0.18 dollar. EPS is \$US -0.18

dollar. Thus, developing business in the beginning of building photomask factory is important. It is easy not to accomplish the planned manufacturing capacity and to cause serious damage if there is no opportunity to cooperate with upstream companies or leading companies. This is one of the key factors of having no profits in the beginning stage of building photomask factory.

TABLE 9. DATA OF EARLY STAGES COMPANY

Years→ Items	2002		2003		2004		2005		2006		Average	
	before	after	before	after	before	after	before	after	before	after	before	after
SALE *	0.00	0.00	4.53	3.63	16.91	13.53	30.66	24.53	48.08	38.46	20.04	16.07
COG *	4.32	4.32	10.18	9.91	19.43	18.68	35.64	34.37	41.21	39.10	22.16	21.28
Profit *	(4.32)	(4.32)	(5.65)	(6.28)	(2.51)	(5.15)	(4.98)	(9.84)	6.87	(0.64)	(2.12)	(5.25)
MSG *A	0.29	0.29	1.91	1.91	2.34	2.34	2.63	2.63	3.24	3.24	2.08	2.08
NP *	(4.61)	(4.61)	(7.55)	(8.19)	(4.86)	(7.49)	(7.61)	(12.47)	3.63	(3.88)	(4.2)	(7.33)
EPS (US\$)	(.092)	(0.92)	(1.51)	(1.64)	(0.97)	(1.50)	(0.15)	(0.25)	0.06	(0.06)	(0.69)	(0.87)
Result	2002		2003		2004		2005		2006		Average	
SALE *	0.00		(0.91)		(3.38)		(6.13)		(9.62)		(3.97)	
Profit *	0.00		(0.63)		(2.64)		(4.86)		(7.51)		(3.13)	
EPS (US\$)	0.00		(0.13)		(0.53)		(0.10)		(0.12)		(0.18)	

Note: \* is unit=million US\$

## 2. Cost controlling

The machine cost is one of the largest factors in the beginning of building factory. How to reduce the initial investment costs is the question that investors should consider. If per unit of machine has lower price, cost benefits will show

instantly. Some controlling variables of BFMEA related cost are shown in Table 10.

### Scenario 2: Acquire other companies or buying the cheap second hand equipment

TABLE 10. PARAMETERS OF COST CONTROLLING OF BFMEA MODEL

Five competitive Forces	For potential enter competitors 1	For potential enter competitors 2
Competing factor	Transferring cost	Cost advantage
Competing variables	The barrier of low-end product cost	Cost controlling
Changing variables	The local mask companies' equipment have finished to depreciate	The machine's depreciation number is too high
Business factor	cost	Cost
Business result	Result is 0.758 million US\$/month	Result is 0.758 million US\$/month
Potential issues	The price of machine is too high	Money of buying new is too high
Methods of problem controlling	no	Finding alternative source
Serious	9	7
Possible	9	9
Detectable	2	2
Risk priority number	162	126
Risk priority	87	63
Responsible department	High level managers	Engineering units
Priority	2	7
Action	Finding chance to acquire	No

TABLE 11. DATA OF COST CONTROLLING

Years→ Items	2002		2003		2004		2005		2006		Average	
	before	after	before	after	before	after	before	after	before	after	before	after
SALE *	0.00	0.00	4.53	4.53	16.91	16.91	30.66	30.66	48.08	48.08	20.04	20.04
COG *	4.32	4.32	10.18	8.09	19.43	11.91	35.64	21.32	41.21	26.20	22.16	14.37
Profit *	(4.32)	(4.32)	(5.65)	(3.56)	(2.51)	5.01	(4.98)	9.34	6.87	21.88	(2.12)	5.67
MSG *A	0.29	0.29	1.91	1.91	2.34	2.34	2.63	2.63	3.24	3.24	2.08	2.08
NP *	(4.61)	(4.61)	(7.55)	(5.46.)	(4.86)	2.66	(7.61)	6.71	3.63	18.64	(4.2)	3.59
EPS (US\$)	(.092)	(0.92)	(1.51)	(1.09)	(0.97)	0.53	(0.15)	0.13	0.06	(0.29)	(0.69)	(0.21)
Result	2002		2003		2004		2005		2006		Average	
SALE *	0.00		0.00		0.00		0.00		0.00		0	
Profit *	0.00		2.09		7.52		14.33		15.01		7.79	
EPS (US\$)	0.00		0.42		1.50		0.28		0.23		0.48	

Note: \* is unit=million US\$

It was found from above data that if machine costs can be reduced to one-third of original cost, the net profit increases \$US 7.79 million dollars from 2003 to 2006 every year in average, or EPS is \$US 0.48 dollar. Therefore, machine costs have obvious influence to improve the profits in the beginning period of building photomask factory.

### 3. Customers credit

In the beginning of building factory, customers are easily having doubtful attitudes to use new technologies developed by company. At this time, if expensive high-level photomask

has better performance or new technologies can reduce costs, customers will be easily to accept them. However, if the quality is not stable, company will easily lose customer's trust and cancel their orders. While company loses high level orders, not only company's reputation has been affected, but also company has uncountable lost.

### Scenario 3: Because the originally adding one third high level orders have bad quality, a company loses two third high level orders

TABLE 12. PARAMETERS OF CUSTOMER TRUST IN EARLY STAGE COMPANIES OF BFMEA MODEL

Five competitive Forces		For substitute or potential enter competitors											
Competing factor		Customers' habit behaviors -1											
Competing variables		New IC process											
Changing variables		Mask cost doesn't affect high profit. Substitute products are easy to enter this market.											
Business factor		Productivity plan											
Business result		Result is 0.1 million US\$/month											
Potential issues		Unstable quality											
Methods of problem controlling		Improving mask process											
Serious	9												
Possible	8												
Detectable	3												
Risk priority number	216												
Risk priority	72												
Responsible department	Engineering units												
Priority	3												
Action	Developing mask technology with customers												

TABLE 13. DATA OF LOSE CUSTOMER TRUST AND REDUCE 2/3 HIGH LEVEL ORDERS

Years→ Items	2002		2003		2004		2005		2006		Average	
	In. 1/3	De.2/3										
SALE *	0.00	0.00	4.54	4.51	16.99	16.77	31.17	29.64	49.33	45.55	20.41	19.29
COG *	4.32	4.32	10.18	10.18	19.44	19.41	35.70	35.52	41.40	40.82	22.21	22.05
Profit *	(4.32)	(4.32)	(5.64)	(5.67)	(2.54)	(2.64)	(4.54)	(5.88)	7.92	4.73	(1.82)	(2.76)
MSG * A	0.29	0.29	1.91	1.91	2.34	2.34	2.63	2.63	3.24	3.24	2.08	2.08
NP *	(4.61)	(4.61)	(7.54)	(7.58)	(4.79)	(4.99)	(7.17)	(8.51)	4.68	1.49	(3.89)	(4.84)
EPS (US\$)	(.092)	(0.92)	(1.51)	(1.52)	(0.96)	(1.00)	(0.14)	(0.17)	0.07	0.02	(0.69)	(0.72)
Result	2002		2003		2004		2005		2006		Average	
SALE *	0.00		(0.03)		(0.22)		(1.53)		(3.78)		(1.12)	
Profit *	0.00		(0.03)		(0.1)		(1.34)		(0.58)		(0.94)	
EPS (US\$)	0.00		(0.01)		(0.04)		(0.03)		(0.05)		(0.03)	

Note: \* is unit=million US\$

From data showing above, because the originally adding one third high level orders have bad quality, a company loses two third high level orders. Therefore, it is predicted that net profit will reduce \$US 0.95 dollars from 2003 to 2006 in average per year, and sales will also decrease \$US 1.12 million dollars, or EPS will become \$US -0.03 dollar per share. Thus, applying high technologies or products should consider their stability and continuing supply problems.

### 4. Deadline issue

Delivery on time is a very important factor in any

business and is also the key factor in photomask industry that whether customer makes orders or not. Therefore, how to make on-time delivery is a very important task. Having customers make future orders can not only insure development results but also increase reputation. The development of manufacturing process of high-level photomask is not an easy task. Enterprise going to be globalized also needs to have quality control.

### Scenario 4: Yield rate of high level mask is 50% double production lines of hot run are still 50%

TABLE 14. PARAMETER OF DELIVERY DEADLINE FOR EARLY STAGE COMPANY OF BFMEA MODEL

Five competitive Forces	For buyer
Competing factor	Quality sensitivity -1
Competing variables	0.13 and 0.15μm production combination
Changing variables	Postpone of delivering deadline
Business factor	Cost and productivity plan
Business result factor	0.077 million US\$/month
Potential issues	Cannot achieve high yield rate
Methods of problem controlling	Controlling yield rate >70%
Serious	8
Possible	9
Detectable	1
Risk priority number	72
Risk priority	72
Responsible department	R&D department
Priority	4
Action	Setup daily report of yield rate SPC (specification plan control) sheet

TABLE 15. DATA OF DELIVERING DEADLINE FOR LOW YIELD RATE

Years → Items	2002		2003		2004		2005		2006		Average	
	before	after	before	after								
SALE *	0.00	0.00	4.53	4.51	16.91	16.77	30.66	29.64	48.08	45.55	20.04	19.29
COG *	4.32	4.32	10.18	10.18	19.43	19.43	35.64	35.63	41.21	41.17	22.16	22.146
Profit *	(4.32)	(4.32)	(5.65)	(5.67)	(2.51)	(2.66)	(4.98)	(5.99)	6.87	4.38	(2.12)	(2.85)
MSGA *	0.29	0.29	1.91	1.91	2.34	2.34	2.63	2.63	3.24	3.24	2.08	2.08
NP *	(4.61)	(4.61)	(7.55)	(7.58)	(4.86)	(5.00)	(7.61)	(8.62)	3.63	1.14	(4.2)	(4.93)
EPS (US\$)	(0.92)	(0.92)	(1.51)	(1.52)	(0.97)	(1.00)	(0.15)	(0.17)	0.06	0.02	(0.69)	(0.72)
Result	2002		2003		2004		2005		2006		Average	
SALE *	0.00	(0.02)		(0.14)		(1.02)		(2.53)		(0.75)		
Profit *	0.00	(0.02)		(0.15)		(1.01)		(2.49)		(0.73)		
EPS (US\$)	0.00	(0.01)		(0.03)		(0.02)		(0.04)		(0.03)		

Note: \* is unit=million US\$

Delayed delivery happens frequently in high-level photomask because of the low yield rate and time consuming. It is usually to have two manufacturing lines running to insure to delivery on time. Table 15 shows that in the situation of two manufacturing lines working and costs increasing, net profit reduces \$US 0.73 million dollars in average from 2003 to 2006 per year; EPS is \$US -0.03 dollar, and turnover decreased \$US 0.75 million. Therefore, delivery deadline is one of the most important factors in photomask industry.

#### D. Discussions

After using Business FMEA analysis to simulate six different scenario analyses, using business model to evaluate quantitative and qualitative questions, analyzing different effects of six scenarios to financial reports, and using statistic information of real financial reports, the effects in every scenario can be clearly understood. Then, the results of scenario analysis can be used as reference in creating investment strategies in photomask industry [19, 26, 34]. Basing on this logical analytical method, photomask investors can have effective control in evaluating building factory to prevent qualitative problems that are difficult to control and to prevent to ignore effects of outside environment to enterprise itself.

In multiple investments, how to handle the market opportunity, choose correct timing, enter accurate market, and

take suitable strategy to enter are important for success [32, 36]. These issues are key factors for Taiwanese companies' successfully entering photomask market in China. Therefore, how to choose suitable timing for entering market becomes a very important task. A good entering timing can increase the success for continued development. Advanced discussions in below are focusing on the best timing for entering photomask market in China.

#### 1. Market profits

A good business opportunity should have its market profit to accommodate customers' demands and bring high-value performances to customers. Thus, while Taiwanese companies evaluate a new business opportunity, the market value of new business can be evaluated by whether market position is clear, the analysis of customers' demands is clarified, and customers' service is effective.

#### 2. Market structure

Using Porter five forces analysis evaluates market structure of new business opportunity, including entrance barrier, negotiation capabilities of upstream material companies, customers, retailers, threats of competitive products, and competitiveness of inside market. New entrants can clearly understand current market structure and future competitions and impacts. Thus, new entrants can prepare relevant solutions to increase success percentage.

### 3. Market share

The predicted market share of new business can represent the market competitiveness of new created enterprise. In general, if market share is lower than 5 %, it shows that the market competitiveness of new business is low. It also affects the enterprise's value in the future. Especially, in high technology industry, new business must have the capability of having the largest market share to be the valued target for investment.

After above analyses, this study hopes to summarize the detailed evaluation information to be the important reference for Taiwanese companies to invest photomask market in China in the right timing.

## VI. CONCLUSIONS

After above analyses, this study hopes to establish an evaluation list to be the important reference in decision making for enterprises to enter photomask industry in China.

TABLE 16. ASSESSMENT OF THE TIMING OF ENTRY TO THE CHINESE MASK INDUSTRY

Evaluation items	Checking items	Conclusions of this study	The best timing to enter China mask market
Market niche	Is that clear of market position?	Mid and low level masks are the main products in China mask market.	2003, Q4: It is the best timing for mask company entrant.
	Is that clear of customer demand analysis?	The mid level 0.25μm mask in 2002~2003 is 18% and 23%. The main profit sources of mask companies are 0.25μm and 0.35μm mask products.	
Market structure	The positions of five factors in mask market	There will be balance in demand and supply until 2005.	2004: Foreign companies and Taiwanese companies search for joint venture relationship.
Market scale and growing speed	Market scale Speed of market growing	Product value of 0.6 inch mask is 45.63 million US\$ in 2006. The forecasting increasing rate of 6 inch mask will be 200% between 2002~2005.	2004: 6inch mask product value increases fastest, the mask industry will change its quality. The most in 8-inch mask foundry.
Market share	Market share condition	The product value of Taiwanese IC companies will be 50% in 2004 and 35~40% in 2005~2006.	2004: Foreign companies and Taiwanese companies' joint venture is very important in China mask industry.
Cost structure of products	The cost ratio of products	Total costs (variable cost and fixed cost) are 85% of sales number in 2006, productivity 2900 pieces per month.	2003: 0.25 and 0.18μm make product value is 32% in all kinds of mask. High price strategy can decrease costs effectively.
Profit	Break-even	It will be break-even in 2006, Q4.	2006: It will start to make profit in 2006.
	EPS	0.06 US\$ in 2006	

### B. Strategy application of investing photomask factory in China

#### 1. Taiwanese investments having core competitive advantage to enter photomask industry in China

Taiwan IC industry has professionals, excellent industrial basis; China has advantages of large market, rich human resources, infrastructure, and efficient government to attract foreign companies. Comparing to foreign companies, Taiwanese companies have advantages of same language and culture with China; and the benefit of cooperation is larger than competitive relationship. Therefore, Taiwanese investment partners in photomask industry should take advantage of same language and culture with China to establish collaboration relationship that foreign companies

#### A. The timing of entering photomask market in China

Seoungpil and David [37] pointed out that a diversified company should break original inactive organization and should have distributed investment to improve profit. If companies can control the timing of entering market while investing photomask industry in China, it has one half opportunity of success in new investment. Table 20 is the summarized results analyzed by this study.

In Table 16, it shows that 2003 is the best year to invest in China; the development of photomask industry in Shanghai area focused on OEM model until 2004; photomask companies in Beijing area mainly provide services to designing companies because clustering relationship has not established; Guangzhou area having no clear development plan should focus on consumable electronics. It became apparent that China's semiconductor industry basing on Taiwanese companies as development core has established and it is the best time to invest China's photomask industry for Taiwanese companies.

cannot develop. The core competitive value of same culture in collaboration relationship is that foreign companies cannot imitate.

#### 2. Collaborating with local industry in China

At present time, Taiwanese companies can grow in Chinese photomask market because of the establishment of partnership. The networking relationship with other IC companies in communication and information exchange helps to reach customers' demands effectively. Collaborating with Chinese companies to become industrial army to enact cooperation rules, share infrastructure and market information, and establish functions of development and exchange core technology, Chinese companies can gather to

produce stronger clustering effects and enhance long term competitive advantages in international market.

#### C. suggestions for following researchers

With the quick change and complexity in environment, the factors of evaluating a new business to enter a new market have become more complicated. This study just used Porter's five forces analysis, Business FEMA, and scenario analysis. However, facing present complicated environment, more evaluation methods could be consider, for example, multiple targets and attributes decision making, growth curve method and etc. while Taiwanese companies faces multiple choices, they can evaluate from wider angle to prevent ignorance and use growth curve method to predict the industrial growth in the future.

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