DECISION MODEL FOR SEMICONDUCTOR PROCESSOR MANUFACTURING

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ABSTRACT

Semiconductor industry is a complex industry wherein Companies need to keep on investing in R&D to introduce new products every year and stay competitive. Technologies are changing so fast that majority of the companies cannot afford to develop and implement new technologies alone. Product Design and Process Design are two main areas of investments in this industry. Semiconductor companies are at crossroads whether to make huge investments in setting up new FABs or use Foundry services to get their chips manufactured. Some semiconductor companies manufacture their own devices, while some others only design their products and outsource the manufacturing to foundry companies.

INTRODUCTION

New FABs require investments of billions of dollars every few years which is not an option for a large number of semi conductor companies. Many IDMs are now rethinking their business models in view of changes to the structure of the industry [1]. Decision to go Fabless or keep on investing in new FABs could be a make or break decision for these companies. Moreover, these decisions depend on a large number of factors which could be Strategic, Technical, Economic, Political etc. Majority of these criteria are subjective criteria which are difficult to score. Therefore, how do semiconductor companies decide their future operating model and what factors should they consider when evaluating these decisions. In order to answer these questions, we made a study of different decision models. We used Hierarchical Decision Model for semiconductor processor manufacturers to define their future business model.

METHODOLOGY

A hierarchical decision model has a goal, criteria that are evaluated for their importance to the goal, and alternatives that are evaluated for how preferred they are with respect to each criterion. The goal, the criteria and the alternatives are all elements in the decision problem, or nodes in the model. The lines connecting the goal to each criterion means that the criteria must be pair-wise compared for their importance with respect to the goal for that criterion. Similarly, the lines connecting each criterion to the alternatives mean the alternatives are pair-wise compared as to which is more preferred shown there are six sets of pair wise comparisons, one for the criteria with respect to the goal and 5 for the alternatives with respect to the 5 criteria.

Overall key decision - In order to determine the overall key decision, the team evaluates several of the company's overall objectives. The indication to go Fabless may be unlikely given the advance and leadership in its technologies and development. The determination relating to the key objectives are based on several factors and research articles indicated in the references and personal opinion within the team's decision [2].

Different criteria - Criteria are subjective, team members are representative of their professional experience and vote on the most reasonable and value to the company.

Different alternatives - The alternatives are fairly straight forward, given the objective of this paper is to determine the decision process of Fabless model; we decided to build our alternatives around that, which includes Fabless, new FAB, hybrid (some foundry and some self-manufacture) and keep current FAB(s).

Pair-wise comparisons to measure the relative weights - Using Pair-wise comparison, each team member assigns a value to each system compared to the other systems. Each criteria is then compared that with the other criteria under the given system. Each alternative is then compared in the context of all criteria.

Conclude with the best possible business operating model for a semiconductor company - The best possible alternative will have the highest weight.

In addition to the overall objective indication, the team has researched several other companies such as Intel, AMD, LSI and IBM to evaluate the decision for each criterion. The process of identifying the final criteria and sub-criteria is to choose the most logical and advantageous to any semiconductor company that would want to use or adapt this model for their decision making process [3, 4]. Technology selection is a crucial step in the design of new complex systems in the semiconductor industry. This is especially true considering the enormous cost factors of bringing a single new device to market. When manufacturing technologies are to be selected from a large pool of available technologies, it is very important that the interactions among these selected technologies are accounted for while assessing their impact on the system. Design of any complex system entails many objectives to reach and constraints to satisfy. This multi–objective nature of the design/manufacturing problem ensures that the technology solution is always a compromise between conflicting objectives such as maintaining technology leadership and rapid time to market. For this discussion, many of the technologies that are under consideration may include processes and techniques that are not widely available commercially, either because they are proprietary or because there is limited experience with their deployment by service providers. In this case, there may be the need to involve vendors and/or service providers at some level in the selection process to determine if a prospective alternative is even viable. The technology selection system utilized by the team was defined by technical information about the alternatives based on industry expertise of the respondents. The objectives, strategic direction and the culture of the organization were utilized as the measurements to evaluate the alternatives as they relate to the specific business. In order to provide an overview of the complex relationships inherent in the semiconductor business model, the team assessed whether they were comparing issues of the same order of magnitude. The hierarchy of technology is required to include enough detail to properly define the problem as thoroughly as possible as well as try to balance other features such as the ease of use and operating cost of the model. During this step, the organizational information regarding company mission, objectives, goals, technology alternatives, and degree of interaction among them were defined to insure that reverent technologies were selected.

Subsequently, the alternatives were arranged in the hierarchy. An element in a hierarchy at a given level serves as a criterion for the elements in the level below. With the implied knowledge of the semiconductor industry, the team quantified the weight of importance for each element in the hierarchy. Group consensus was reached for assigning the weight to each criterion and alternatives.

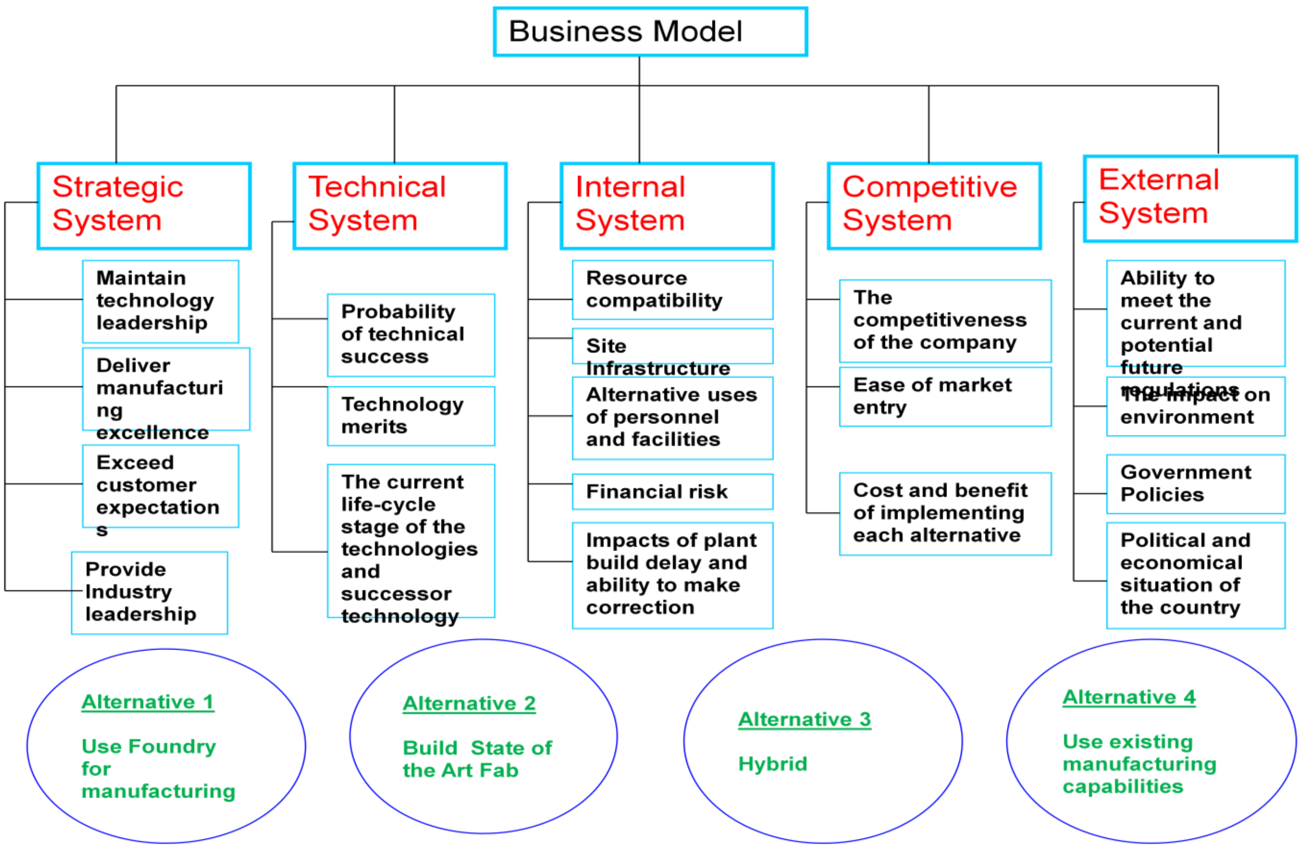

Figure 1 – Decision Model

RESULTS

Evaluating the corporate overall performance is observably a multifaceted multi-criteria dilemma. However, to resolve this multifaceted multi-criteria dilemma, a solution process is conducted with a unique approach. In addition, under the multi-criteria evaluation, no single criterion can dominate all other alternatives. Instead, each criterion may have a unique advantage towards its favor. Therefore, the conclusion would be the result of the "optimal" decision. The problem to be addressed in this research - evaluating a corporation's decision to go Fabless; under current difficult economic and market conditions is a suitable application for the Hierarchal Decision Model or HDM approach. However, some concerns have arisen regarding HDM for the illogical ranking when two or more alternatives have similar or related characteristics. These undesirable effects, however, do not; invalidate the HDM method, states Harker & Vargas [5] and Saaty & Vargas [6]. It will not be a problem in real world applications because it is very rare to encounter two alternatives with very similar characteristics, and special precautions (e.g., grouping similar alternatives) can easily be taken to avoid it [7]. Pair-wise comparison is a key step in the HDM model to determine priority weights of factors and provide a rating for alternatives based on qualitative factors. The procedure focuses on two factors at a time and their relation to each other, so decision makers will be more comfortable to offer relative (rather than absolute) preference information. The relative importance of each factor is rated by a measurement scale to provide numerical judgments corresponding to verbal judgments.

Systems	Factors	System Weight	Factor Weight	Combined
S1: Strategic System		**0.26**		
	F1: Maintain Technology Leadership		0.57	0.15
	F2: Deliver Manufacturing Excellence		0.21	0.05
	F3: Provide Industry Leadership		0.22	0.06
S2: Technical System		**0.26**		
	F4: Probability of Technical Success		0.47	0.12
	F5: Technology Merits		0.33	0.09
	F6: Current Lifecycle Stage of the Technologies and Successor Technology		0.20	0.05
S3: Internal System		**0.18**		
	F7: Alternative uses of personnel and facilities when below capacity or product design is terminated		0.29	0.05
	F8: Impacts of plant build delay and ability to make correction		0.35	0.06
	F9: Financial Risk		0.36	0.06
S4: Competitive System		**0.21**		
	F10: The competitiveness of the company		0.46	0.10
	F11: Ease of market entry		0.27	0.06
	F12: Cost and benefit of implementing each alternative		0.27	0.06
S5: External System		**0.09**		
	F13: Political and economical situation of the country		0.59	0.05
	F14: The impact on environment		0.41	0.04

Table 1 – Decision Model Weights

Step one, executive objectives are defined; step two, the HDM model starts identifying all significant and vital performance criteria. Step three; criteria are then structured into a hierarchy descending from an overall objective to various criteria and sub-criteria in successive levels. Important guidelines for selecting criteria and constructing the hierarchy structure have been recommended: first, represent the problem as thoroughly as possible; second, considering the environment surrounding the problem; third, identifying any issues or attributes that contribute to the solution, and finally clarify the necessary participants associated with the problem [7]. Organizing the criteria in a hierarchy serves two main purposes: first, it provides an overall view of the complex relationship inherent in the situation; and secondly it helps decision makers evaluate whether the issues in each level are of the same order of magnitude. Step four, the priority weights of structured criteria are then determined through pair-wise comparison to reflect the judgments and relative preferences of specialized decision makers. Not surprisingly, the priority weights may vary from one person to another. When there are several levels of criteria and sub-criteria, the weight of higher-level criteria are first computed. The weight of the corresponding higher-level criteria is then used to weight the criteria at the lower level in the hierarchy (i.e., composite weight). Step five, the procedure is repeated by moving downward along the hierarchy, computing the weight of each criterion at a particular level and using these to determine composite weights for succeeding levels. When multiple decision makers are involved in developing priority weights, achieving an agreement may be complicated. Weight analysis can then be used to assess the extent of differences and the potential impact on final decision. For instance, the means and variances can be calculated and the significance of the differences among sets of weights can be statistically tested. In the final step of the proposed HDM model; the criteria, which have the relative higher overall priority scores, will be identified as the corporations' most imperative enduring overall performance measures and to be analyzed and integrated into the corporations' long-term strategic planning process.

A1	**A2**	**A3**	**A4**
20%	**36%**	**23%**	**21%**

Table 2 – Results

Experts completed pair-wise comparison survey in order to evaluate the relative importance of decision factors under each main system with respect to their impacts on that system. PCM software was used to calculate the final relative weight for each factor while maintaining the same inconsistency level. After that, the final weight for each decision factor was derived by multiplying the weight of each factor by the relative weight of each corresponding system. In order to determine the relative importance of each alternative, experts performed a pair-wise comparison of the alternatives among themselves with respect to their impacts on the decision factors. PCM software was used to calculate the weight of each alternative with regard to each decision factor. Both technical and strategic systems hold the highest weight with equal score of 0.26. Both internal and competitive systems came next with approximately equal weight while the external system has the least weight. Few factors carry the highest relative weights which indicate the importance and impact of these factors according to the experts. In addition, the highest scoring decision factors belong to systems highest weighted systems. The second alternative scored the highest among all alternatives with respect to majority of decisions factors.

Building state of the art Fab (alternative 2) scored the highest with approximately 40%. Adopting the hybrid model (alternative 3) came second with a score of 22% which is significantly lower than the highest scoring alternative. The other two alternatives were the lowest with an equal score of 19%.

CONCLUSIONS

The semiconductor industry is a very complex business landscape where multiple manufacturing options exist which can drive a variety of business models. These models are driven by multiple criteria's and rapid technological advances in both product design and manufacturing process. The effect of this ever changing landscape is that an analysis performed at one given time for one given product will not necessarily be valid for similar products. For example, at one time all microprocessors were driven to be built with the absolute newest manufacturing technology in order to achieve the maximum performance. Due to the shift if the product landscape you have seen a shift to more purpose built devices that often are "good enough" for the specific task and do not require the utmost in process technology. However the technology used was at one point pinnacle of state of the art. It is clear that process development must always continue but is costly. The decision to choose a specific business model has thus become extremely complex. The 4 options we proposed are all very valid business models, however upon examination they do not form a good list of alternatives for the a generic semiconductor industry in that depending on the company and product they may not really be options at all due to barriers to entry such as cost (building a FAB), or the fact no facilities currently exists (use existing FABs). Even with a specific case study which could support all the options it became clear that the model was not well suited without more focus on the specific product being considered rather than a class of products such as microprocessors. For high end products will always require new and innovative processes which cannot be supplied by other alternatives. This focus is critical to better align the categories and define the criteria which can lead to a simplified model.

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