Operational implications of early supplier involvement in semiconductor manufacturing firms

A case study

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Abstract

Purpose – Existing earlier supplier involvement (ESI) models mostly emphasize the product development perspective with limited attention to the process development dimension. Towards this end, this paper aims at a tailored framework for semiconductor manufacturing firms by taking into account the implementation of ESI in process development as well as product development.

Design/methodology/approach – A number of well-recognized propositions are examined through a case study of MIC Semiconductors Asia. Based on observations from the case study, the problems of existing frameworks are analyzed and accordingly possible solutions are explored.

Findings – The case study reveals the importance of process development in ESI implementation. It is imperative to build up on some fundamentals of the company before ESI can be carried out successfully. Also observed is that the effectiveness of a supplier selection criterion should be gauged from the performance of the suppliers. It is also found out what type of relationships with suppliers are favorable to ESI, regardless whether the length of the relationship can be translated to trust in technical capability in practice.

Originality/value – Examining existing ESI models through a real case study sheds light on the practical application of ESI. In particular, the semiconductor manufacturing process is emphasized in addition to the general ESI focus on product development.

Keywords Suppliers, Supplier relations, Semiconductors, Operations management

Paper type Research paper

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1. Introduction

In Porter's (1980) model of competitive forces, buyers and suppliers were described as adversaries who could improve their respective positions by increasing their power relative to each other. This means that the profits lost by one could be gained by the other. Hence, a buyer would be unlikely to actively involve their suppliers in product development for fear that increasing their capabilities or knowledge would increase the suppliers' relative power. Nevertheless, researchers have recently paid increasing attention to the effects of buyer-supplier relationships as a form of competitive advantage.

In recent years, the focus has shifted to integrating suppliers' capabilities into the firm's supply chain system and operations management. Partnerships are forged with suppliers to take advantage of their technological expertise in design and manufacturing. This is termed as earlier supplier involvement (ESI). The reason why suppliers are gaining such increased importance lies in the large proportion of production costs that are attributed to raw materials. Burton (1998) and Naumann and Reck (1982) estimated that the suppliers account for 30 percent of the quality problems and 80 percent of the product lead time problems. Clark and Fujitmoto (1991) reported that an automotive assembler could reduce the engineering hours and lead time required for new model development by delegating part or the entire engineering responsibility to selected suppliers.

Many researchers have explored the advantages of involving suppliers early in product development. Some of these advantages include shorter product development cycle time, better quality of the products and lower input and production costs. For example, the advantages of practicing ESI are well observed in major US corporations such as Whirlpool, Lockheed McDonnell Douglas, Boeing, and Daimler Chrysler. These companies have shifted many of their design activities to key suppliers. Raia (1992) stated that Chrysler Viper was advanced from concept to production in 36 months against an industrial norm of 60 months. The supplier's assistance was instrumental in this process.

On the other hand, there have also been studies that have failed to find a statistically significant relationship between supplier involvement and product development time (Zirger and Hartley, 1996). Eisenhardt and Tabrizi (1995) found out that increased supplier involvement was related to slower development. Although the payoffs from implementing ESI are great, however, there are numerous obstacles that must be confronted and overcome to deploy such a strategy.

One of these obstacles is the unwillingness of suppliers to participate in the company's ESI efforts. Supply chain professionals have long suspected that true collaboration with their suppliers involves more than just having the latest technology in place. A study by Council of Logistics Management has justified this intuition by indicating that the enablers and impediments to collaboration have more to do with management style and interpersonal relationships than with technologies (www.cscmp.org/).

The length of the relationship may be one of the factors leading to ESI success. Stinchcombe (1965) addressed the reason why long inter-firm links may outperform shorter ones. Owing to the learning requirements inherent in developing efficient coordination and knowledge exchange between a buyer and a supplier, it is time-consuming and costly to develop the familiarity and expertise required for each partner to know when and how to draw on the other's resources. Hence, companies without a long and stable relationship with their suppliers may face problems in implementing ESI.

In addition, past research has mainly focused on ESI as applied to product developments. Leseter and Ramdas (2002) empirically examined whether suppliers for different sourced products play distinctly different roles in product development, by analyzing survey data on a wide range of sourced automotive products. McIvor and Humphreys (2004) employed a case study research methodology to analyse the dynamics of ESI in the product development process, with regard to buyer-supplier relationships, cost reduction programmes, senior management involvement and the extent of supplier involvement. Petersen *et al.* (2003) revealed that customer/supplier integration on a new product development project requires a detailed formal evaluation and selection of potential suppliers prior to consideration for involvement. Only trusted suppliers with a proven track record should be approached, at least initially, to participate.

In practice, suppliers may also be involved early in process developments as well as in other areas such as the procurement of materials. Petersen *et al.* (2005) observed that early supplier integration is an important coordinating mechanism for decisions that link product design, process design, and supply chain design together. Several elements of ESI act as coordinating mechanisms in this context.

However, few studies go into any detail in examining the obstacles to supplier involvement and providing recommendations to managers with regard to facilitating ESI (McIvor *et al.*, 2006). Dowlatshahi's (1999) model probably is so far the most comprehensive framework for implementing ESI. However, it has not been untested practically under different industries. It is thus imperative that the highly competitive nature of the semiconductor market should create greater motivation for the semiconductor manufacturers to form strategic partnerships with their suppliers.

Towards this end, this research aims to evaluate the existing ESI conceptual framework as applied to a semiconductor manufacturing firm. A case study of MIC Semiconductor Asia is reported involving MIC semiconductor's overseas assembly and test operation and product distribution hub in Southeast Asia. Besides applying the framework to MIC, their supplier selection criterion is evaluated and the type of relationships that it holds with its suppliers is studied. This helps to understand the relationship that MIC holds with its suppliers and how these relationships can be useful to ESI success.

2. Research methodology

2.1 Dowlatshahi's model

Most of the ESI programs developed so far are geared towards meeting the specific needs of a particular company and mainly in the area of product developments instead of process developments. Process-development projects are more prevalent in an assembly and testing plant than are product development projects. Process development refers to procedures that guide the conceptualization, design, engineering, manufacturing and implementation of changes to production/operations processes while product development refers to the procedures that guide the conceptualization, design, engineering, production and sourcing of a new product. So far Dowlatshahi's ESI conceptual framework probably provides the most comprehensive list of areas of collaboration, though his framework focuses more on ESI in product development (Dowlatshahi, 1999).

Dowlatshahi's model encompasses four components, including design, procurement, supplier and manufacturing, where the components of design, procurement and manufacturing are internal departments of the company while the component of supplier is external. Changes have been made to the component of design so that it focuses more on process-development projects rather than on product development projects. The four components of ESI are interrelated to one another. This means that some of the tasks are performed with aid from other components and information should flow freely between each component in order to form a seamless integrated supply chain. The model consists of a list of propositions, as summarized in Table I.

Propositions for design	D(1): conceptualization designs for manufacturing process
	D(2): define process function and usage
	D(3): conduct cost analysis
	D(4): determine material requirements for the new/improved process
	D(5): discuss auxiliary functions of process operations
	D(6): determine number and type of standard parts, materials used for improvements. Standardize raw materials
	D(7): develop material specifications and tolerances for the new/improved process
	D(8): determine quality targets
Propositions for procurement	P(1): negotiate overall price
	P(2): negotiate transport cost and terms
	P(3): determine order frequency, inventory costs and safety stock levels
	P(4): negotiate lead-times
	P(5): determine order frequency, inventory costs and safety stock levels
	P(6): set incoming quality inspection standards
	P(7): determine order frequency, inventory costs and safety stock levels
Propositions for suppliers	S(1): determine number and type of standard parts, materials used for improvements standardize raw materials
	S(2): improves quality control at supplier's factory
	S(3): troubleshoots problems/rejects
	S(4): investigates pricing and cost improvements
	S(5): determine delivery standards and goals
	S(6): determine technical capabilities
	S(7): determine R&D investments
Propositions for manufacturing	M(1): define and discuss manufacturing process
	M(2): review/update production schedules
	M(3): determine size of production runs
	M(4): set inventory turnover goals
	M(5): determine throughput costs
	M(6): evaluate set-up times
	M(7): determine production capacity
	M(8): set production efficiency goals
	M(9): define material handling goals

Table I.
Propositions of Dowlatshahi's ESI model

2.2 Research methodology

Based on Dowlatshahi's ESI conceptual framework, surveys are formulated and interviews are structured to study each proposition in the framework and to understand the constraints that may be faced when applying this conceptual framework. Interviews are conducted with the purchasing manager, planning manager, a production planner and five engineers from MIC, three from the test department and two from the assembly department. Surveys are also conducted with 21 engineers, 16 from the test department and five from the assembly department. Key aspects of study include the following:

- In order to carry out most of the propositions effectively, it is dependent upon the capability of its suppliers. Hence, it is important to have a good set of supplier selection criteria that focuses more on the technical capability instead of the cost of engaging the supplier. However, the framework did not emphasize on the need for supplier reviews and having an effective supplier selection criterion.
- Dowlatshahi's model proposes involving suppliers as early as possible in the conceptualizing stage of the product development process. In the modified framework, this proposition was changed to "conceptualizing design for process-development projects" so as to be more applicable to a manufacturing environment. However, not all projects may be suitable for collaboration as early as in the conceptualizing stage. The suppliers may be unwilling to be that involved in the first place because it means increased responsibility. Therefore, there is a need to look at the presence of any risk/reward sharing agreements and the usefulness of such agreements. The factors affecting the timing and degree of supplier involvement should be also studied.
- Having a long-term relationship with its suppliers can be as important as selecting competent suppliers. Past research has indicated that the length of the relationship with suppliers can have a positive effect on the success of collaboration efforts. Hence, establishing long-term working relationships can be one of the propositions in the conceptual framework.
- Increased collaboration with suppliers in process-development projects may bring about disputes over the ownership of the design and a possible leakage of proprietary information. Hence, the ESI conceptual framework should have a proposition that allows both the suppliers and the company to safeguard their proprietary information and to determine in advance as to who will have the ownership to the eventual design.

In view of the possible problems and areas of improvements to the ESI conceptual framework, the case study also addresses such issues as:

- the company's relationships with their suppliers;
- the company's supplier selection criteria and the quality of current suppliers;
- the presence of any risk/reward sharing agreements;
- the length of relationship with its suppliers; and
- the timing and degree to which suppliers are involved.

3. Case analysis

3.1 Problems in implementing Dowlatshahi's ESI model

In the case study, although the company has satisfied most of the proposition testing, it does not mean that the company has implemented ESI successfully. This is mainly due to the following reasons.

3.1.1 The dependency on reliable and technically competent suppliers to satisfy completely the objective of a proposition. This is seen in propositions D(1), D(5), S(2), S(3) and M(1). All of the above propositions require suppliers to be technically competent enough because the major responsibility of the design problem is shifted to the suppliers. To be aware of the suppliers' capabilities is not enough (proposition S6), the company has to select the competent suppliers. Therefore, competent and capable suppliers must be chosen to ensure that any problems can be resolved efficiently.

The company may attempt to involve their suppliers in the early stages of conceptual design; however, their suppliers may not be competent enough to provide the best suggestions. In one instance, the vendors were approached to improve on their electrical connector head designs for the burn-in boards because the pins are easily bent. The bent pins often produce error reports for that board of tested DRAM. However, after a few months, this issue was still not resolved. This could be due either to the incompetence of the supplier or that the supplier simply had no incentive to do that for the company.

3.1.2 Unwillingness of suppliers to provide the increased level of support. Early involvement of suppliers in a company must come with the support from the suppliers. This can be seen in propositions D(1), D(4), D(7), P(3), P(7) and M(1). In providing the necessary level of support so as to satisfy the above propositions, the suppliers have to assume increased responsibility. Eventually, the increased risk that they have to take may outweigh any increase in potential earnings. The reasons that prevent the suppliers from committing their services to their customers in ESI efforts may be due to:

- bearing greater risk/increased responsibility;
- commitment from the buying company;
- company size of the suppliers; and
- supplier-buyer relationship (supplier goodwill).

3.1.3 Lack of motivation from the staff of the company. Even if there have been formalized efforts to integrate suppliers to bring about ESI, the eventual success is still dependent on how the employers are willing to engage themselves in such process-development projects. Improvements usually imply changes to the existing process and increased efforts and responsibilities for the engineers. Furthermore, a lack of motivation in the technical staff of the company may also make them more resistant to any changes in the manufacturing line. Early involvement of suppliers may bring with it improved but unknown technology. This fear of the unknown may create reluctance to involve their suppliers earlier.

3.1.4 Problems relating to the ownership of the jointly developed design/product. This ESI framework did not address the need to first rectify the problems related to the ownership of the design so that any future disputes/law suits can be avoided. A design jointly developed by the suppliers and the buying company will eventually face the problem of ownership. It can be difficult to write a definitive contract for design work and R&D activities, in which the resources used and the results they obtain may be highly unpredictable. An unexpected technological breakthrough from a jointly developed project may be of high-potential earnings, however, since it is jointly developed, it is difficult to agree upon on who should have the major rights.

3.1.5 Poor communication between the suppliers and the buying company. Almost all of the propositions in the framework are dependent on how effective communication is between the suppliers and the various departments in the buying company. Engaging the help of competent suppliers may still not bring about reduced development cycle, especially when the suppliers are based overseas.

3.1.6 Fear of leaking proprietary information. Some propositions in the framework may cause proprietary information of the company to be lost. These propositions are D(1), M(1) and D(7). The sharing of proprietary information is often necessary in involving suppliers earlier in its operations and development projects. However, proprietary information such as demand figures, detailed material specifications and equipment information is often highly confidential. By passing such information to suppliers, the company takes a risk of losing its competitive advantage to rival companies. This is particularly true for companies who hope to gain the “first-mover” advantages. Critical information may be leaked out to competitors when the same supplier utilizes the design for its rival company. Though most companies exchange confidentiality agreements with their suppliers, eventually, the buying company will have to rely upon the suppliers’ moral integrity not to divulge commercial secrets. To avoid exposure to such opportunistic behaviour from the suppliers, a buying company may prefer to keep any critical design work in-house instead.

3.1.7 The perceived higher cost in involving their suppliers earlier. Involving suppliers earlier in any process-development projects can be costly due to such reasons as:

- cost incurred in setting up common information systems;
- cost incurred to provide training to the suppliers so that the quality control of materials can be improved at the suppliers’ plants;
- rewards and incentives to motivate the suppliers;
- co-design expenses incurred; and
- investments in supplier’s plants so as to improve on materials at the source.

Hence, some companies may only see the short-term costs incurred but fail to see the long-term benefits and cost-savings of involving their suppliers earlier in their process-development projects. Before using the framework to implement ESI, the company has to make sure that the whole company from the top management to the engineers and technicians understand that the long-term benefits can outweigh the short-term costs incurred. For instance, suppliers may be asked to provide recommendations for improvements to existing processes (proposition M1), however, if the engineers are overly concerned with the short-term cost incurred, they may attempt to bring about the improvement themselves, hence, the suppliers’ expertise are not tapped on.

3.1.8 Involving suppliers too early in the development process. In the ESI framework, proposition (D1) advocates involving suppliers as early as in the conceptualizing stage of the design. However, the timing of supplier's involvement leading to a successful collaboration varies with the situation. Suppliers can be involved as early as in problem identification and as late as during the final stages of part ordering. The advantages of involving supplier as early as possible has been discussed earlier, however, it is not easy to determine when exactly to involve their suppliers. In fact, a few studies have indicated that involving suppliers earlier does not mean reduced product development time. Zirger and Hartley (1996) pointed out that involving suppliers too early may result in integration problems and increased cost.

3.2 Solutions to the observed problems in implementing ESI

3.2.1 The dependency on reliable and technically competent suppliers to satisfy completely the objective of a proposition due to lack of effective and consistent supplier selection criteria, time constraint, or budget constraint. To deal with this problem, a well defined set of supplier selection criteria that assess not only the technical capabilities of the suppliers but also their reliability in delivering goods on time and in the promised quality.

MIC has a good set of supplier selection process and criteria that a company can follow in selecting their raw material suppliers, though the company is still overly concerned with price in the selection of suppliers for process-development projects. The importance should still be on the total cost of ownership instead of just focusing on price. It should include quality, supplier reliability and financial strength, warranties, ability to meet/satisfy schedules, management depth, pricing, and close match in technology and growth plans.

Alternatively the company can keep a list of useful and assessed suppliers, because of the time constraint in assessing suppliers for process-development projects. In SGST Microelectronics Pte Ltd, there are two programmes for their suppliers. One is the Ship-to-Stock Certification programme, aimed at certifying suppliers' control methodologies and procedures to meet or exceed the internal control requirements. The other is the Supplier Partnership programme, which has various sub-programmes that are jointly managed by the organisation and the supplier to achieve common interests and objectives. Examples of such sub-programmes are ecology awareness, process improvement, team-oriented problem solving and statistical process control.

MIC can try to adopt an approach that is similar to the Supplier Partnership programme used by SGST to identify suppliers that can be engaged in process-development projects. Hence, it can lessen the problem of not having sufficient time to identify competent suppliers.

3.2.2 Unwillingness of suppliers to provide the increased level of support, such as bearing greater risk/increased responsibility, commitment from the buying company, company size of the suppliers, or supplier-buyer relationship (supplier goodwill). A possible solution is to use reward/risk sharing agreements. A lot of companies, especially small and medium-sized enterprises, do not have sufficient resources to complete the innovation project on their own. They need to find a way to cover the existing innovation deficits, e.g. know-how lack, missing own capital, etc. Hence, it is believed that with the agreement to share in risks, the suppliers have the capacity to carry out the project. Furthermore, a clause in the contract can allow the buying company to provide rewards for their suppliers involved in a joint process-development project, by including a profit-sharing agreement when a solution performs above pre-set margins. In this way, the vendor will be encouraged to deliver optimal service to the client, by implementing cost-efficiencies, for instance.

However, risk/reward-sharing agreements will incur short-term increases in costs and careful selection of suppliers to have such agreements is needed. Not every supplier can be involved in such agreements due to the different importance of each development project. It is not possible for the company to finance all development projects when the supplier gets to have ownership to the design.

In MIC, the company does not form formal risk/reward-sharing agreements with their suppliers because they tend to increase the liability of the company. The company will consider investing in their suppliers' products if the suppliers do not have sufficient funds to carry out the improvement. In most other cases, a design fee or non-recurring expense is charged to the company instead, while the supplier retains ownership to the design. The company also does not have to resort to the use of any reward sharing agreements to motivate their suppliers since it has stronger bargaining power than their suppliers do.

MIC is also involved with KMT, which used to be a joint venture between MIC and KSL. In April 2001, the company acquired the remaining interest in KMT. Similarly to its relationship with TECH, it also forms various agreements with KMT whereby MIC provides technology, engineering and training support to KMT.

3.2.3 Lack of motivation from the staff of the company. The suggested solution is profit-sharing. Most companies overcome this problem by having profit sharing with their employers, and better worker benefits in the form of subsidized medical expenses, more off days, etc. Top management also plays an important role in creating a motivating and competitive environment to encourage their workers to put in their best efforts. They should always push for improved manufacturing process, reduced lead-time and reduced manufacturing cost. MIC motivates its workers by implementing profit sharing and the option to purchase shares of the company. Awards and recognition can also be given to staff who have performed well and who have served the company for a long period.

3.2.4 Problems relating to the ownership of the jointly developed design/product. This problem may be solved through reaching an agreement in advance. These problems are difficult to resolve once co-operation starts. This is the reason why MIC prefers to either pay a design fee while the supplier gains ownership to the design or designs any products likely to give a competitive edge in-house. Hence, this issue should be addressed and agreed upon by both parties before any collaboration starts.

However, ownership problems of jointly developed products can be resolved if companies form joint ventures or are able to reach an agreement eventually. Perhaps, the supplier will be allowed to claim ownership to the design, but the company that was involved in joint development of the product can pay a much lower price. In any way, this should not be the hindering block that keeps companies from involving their suppliers earlier.

3.2.5 Fear of leaking proprietary information. This suggests making use of non-disclosure agreements. Companies can pursue two possible legal remedies for disclosure breaches: monetary damages and injunctive relief. Court-awarded monetary damages are extremely difficult for a company to prove and almost impossible to quantify because it is tough to show what future profits or benefits a company would have received from the confidential information had it not been disclosed. A court may also grant injunctive relief, in which the vendor is ordered by the court to cease disclosing; again, the damage has already been done.

3.2.6 The perceived higher cost in involving their suppliers earlier. By convincing those dealing directly with the suppliers and the top management that the benefits arising from ESI in the long-term can offset the initial increases in cost. This change in perception can sometimes be difficult since the top management is often too concerned with incurring any additional expense. The top management has to understand that no company can exist on its own. Its survival is directly dependent on its suppliers. Hence, investing in their suppliers will eventually benefit them in the form of better technologies and greater security in the procurement of good quality materials.

3.2.7 Involving suppliers too early in the development process, including the cost of engaging suppliers earlier, the time taken for gaining the approval to the development project, or the complexity in communicating the requirements of the project. This suggests that when determining when to involve the suppliers, the company should take the above factors into consideration. The cost of engaging suppliers need not always be higher when the suppliers are involved earlier. If they are merely consulted to give suggestions, this is part of the suppliers' customer service to provide support for their products. It is only when the suppliers are engaged earlier to help in designing a certain part of the product/process, then the company has to pay a design fee for their effort. Hence, the company need not feel obligated when the suppliers are not engaged eventually even though they are involved in the conceptualising stage.

Furthermore, the company should not be overly concerned about the higher cost involved in engaging suppliers' help in design. For instance, in subcontracting the control of an automated BIB cleaning machine to the more experienced suppliers, though the company has to pay a design fee, it frees the engineers and technicians to attend to other more important issues.

The usefulness of each solution as perceived by the 21 of the company's staff are shown in Figure 1. The most useful approaches to effective ESI include:

- formalised process to select and review capable suppliers;
- formalised process for considering suppliers for partnership;
- forming a multi-disciplinary team to aid in communication;
- establishing long-term relationships to gain co-operation;
- setting of goals and objectives in working with suppliers; and
- presence of common or linked information systems.

Some of the unexpected results are also revealed. Since the company's policies and goals are set by the top management, if they are not convinced by the benefits of ESI, it is quite difficult for the company's staff to convince them. This may explain for the lower than expected results for "convincing top management". Ownership problems are also not as easily rectified by an agreement before hand due to the high uncertainty in any development projects. Suppliers will not want to commit themselves to such agreements early in the development efforts. Risk/reward sharing agreements are not viewed as useful solutions because it was generally felt that the potential increase in business dealings should serve as a sufficient means of motivation for the suppliers.

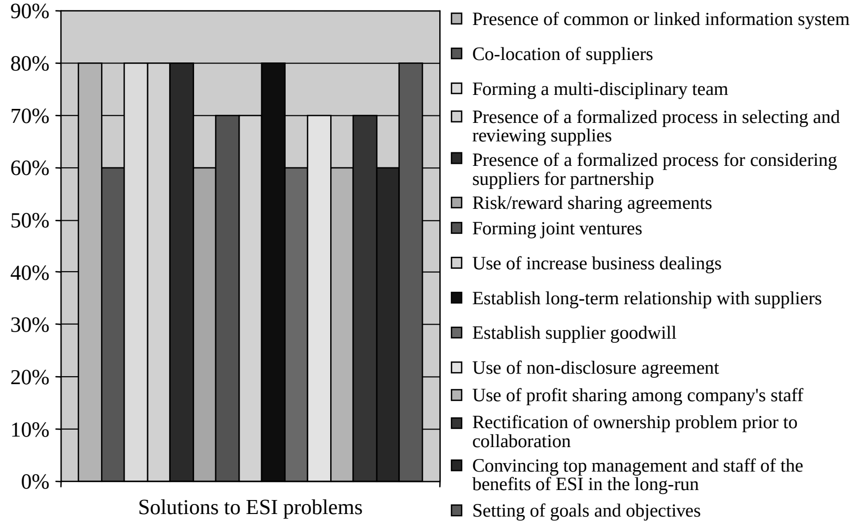


Figure 1. Usefulness of solutions to problems encountered in ESI

This may be due to the fact MIC is a big company with lots of potential business deals. The co-location of suppliers is also seen as not very useful because the suppliers are usually unwilling to commit their company staff to serving a single company.

3.3 Important factors for effective ESI

3.3.1 Management. The management mostly refers to the motivation and commitment for continuous improvement. The company must have a top down commitment to the critical success factors, with strategy and vision translated into action. Commitment must not stop at the top but must cascade down throughout the organization to the production areas. Main issues include structure of development team, support from senior management, and attitude towards suppliers.

3.3.2 Suppliers:

- *Capability of suppliers.* Since ESI requires close cooperation from the suppliers, a systematic and formal approach has to be taken to ensure that the best suppliers are selected. Supplier selection criteria should focus on not just cost but on other factors such as reliability of delivery and product quality. For instance, Intel considers both the traditional criteria such as quality, delivery predictability/reliability and worldwide cost competitiveness, as well as the strategic criteria related to technology, productivity, process control, innovation/new ideas, financial stability, service, management philosophy and training programs.
- *Commitment from suppliers.* The commitment from suppliers to be involved in the company's ESI project may be lacking due to the increased responsibility of the supplier. Hence, the company has to come up with ways of encouraging suppliers to be more actively involved in the company's developments.
- *Confidence and trust in suppliers.* Since the company cannot validate the suppliers' recommendations every time, trust and confidence in the suppliers' capabilities are important.

3.3.3 Collaboration with suppliers:

- *Communication.* Proper means of communication must be established so that any ESI efforts will not be hindered by the miscommunication of information. The importance of communication has been discussed earlier.
- *Setting goals and objectives.* Goals concerning issues such as capacity, profit, quality and ownership of design should be agreed and understood early in the collaboration with suppliers. It is important to recognise that often two organisations can work closely together but become undone because the objective of one did not fit with the ability of another. For instance, the objective of the company may include growth in capacity but this was not matched by the supplier's ability to supply.

3.3.4 Inherent factors:

- *Type of industries.* The type of industries is likely to affect the structure of the development process. For stable and relatively mature products (e.g. cars), thorough planning may be more useful as compared to products with more uncertainty in a rapidly changing industry (e.g. semiconductors). In rapidly changing industries, it may be more applicable to have a development process based on frequent iterations, extensive testing and short milestones. Hence, the successful implementation of ESI should take into account the type of industries in which ESI is to be implemented.
- *Company size.* For most companies in the manufacturing industry, the bigger the company size, the stronger its bargaining power and the easier it gains support from their suppliers in any of their development projects.

3.4 Product vs process-development projects regarding ESI

In terms of improvement or new product or process identification, the company's product engineers, marketing team gets feedback from their customers for improvements to their products. The company's process engineers and suppliers help to identify possible improvements. The suppliers update the company on new technology. Since the suppliers involved in process-development projects help to identify new technologies, they can help in identifying improvements earlier than the suppliers involved in product developments. Hence, the ESI framework for process development should try to involve suppliers even earlier, bearing in mind that not all projects need ESI.

Regarding the identification of suppliers, product development emphasizes more on the identification of suppliers. In process development, emphasize is placed both on identifying important technology as well as important suppliers. McGinnis and Vallopra (2001) found out that in process development, less emphasis appears to be placed on the evaluation of whether to use a supplier or not as compared to new product development. This is perhaps due to the fact that a supplier may hold a certain technology not possessed by another supplier. Hence, the selection of suppliers for process development should place greater emphasis on the technical capability of the suppliers.

As for groups of people involved in ESI, suppliers, product engineers, manufacturing, marketing and purchasing are involved during product development. In process development, suppliers, purchasing and manufacturing area are involved during development. Process development involves representatives from fewer departments than product development; hence, the co-location of team members and sharing of information is a less-daunting task.

As for signal of the competitiveness, customers' feedback on a product can be relatively easier to obtain through market surveys in product development. However, at process development, no direct market feedback to signal that a process is falling short. Also, it is more difficult to gain market information about competitors' process capabilities. Market feedback is not as timely or effective in providing guidance on process development than product development. Therefore, it is much more difficult to benchmark what competitors are doing inside their factories than to benchmark products that are available on the open market. Hence, motivation from the company's staff and dependency on the suppliers to provide "intelligence" about their competitors' process capabilities is even more important for ESI in process development.

With regard to ease of justification, product development is much easy to justify since its rewards usually comes in the form of greater sales. Process development however rewards are more difficult to quantify due to the lack of observability and market feedback, though they yield lasting competitive advantages. Many companies tend to focus more directly on product developments than process developments (Bowen *et al.*, 1994) because their benefits are usually more tangible, hence the ease to justify the required investments. Therefore, implementing ESI in process-development projects may be more difficult than implementing ESI in product development due to the increased difficulty in convincing top management of its benefits.

Figure 2 compares ESI implementation with focus on product development and process development. Therefore, a few issues deserve attention when managing ESI in process-development projects. Supplier selection criteria for process development have to emphasize more on technology capability of the supplier rather than total cost of ownership. Even though a supplier may have a higher total cost of ownership, the company is forced to engage it when it is the only company with the technical expertise. In addition, obtaining suppliers' feedback regularly is important because they are the company's "informants" on new technology. Furthermore, process developments are more dependent on the OEMs because they produce the equipment. The buyer has less-bargaining power.

4. Characteristics of ESI in the semiconductor industry

4.1 Emphasis on both product and process development

The semiconductor industry is not like the steel or the food-processing industry, which focuses mainly on process simplification only so as to achieve higher throughput per dollar spent. Neither is it similar to the equipment design companies, which focus mainly on product development only.

The characteristics of the semiconductor industry – active patenting, large R&D expenditures, rapid price declines – reflect the frequent introduction of new production processes and products. Given this high frequency, it is necessary for companies to focus on both process and product development at the same time. The companies' efforts alone are usually insufficient especially when high-R&D investments are required and the payoffs are subjected to high uncertainty. Hence, practicing ESI and forming strategic alliances are necessary in the industry. One such partnership is between MIC and Infineon, who are co-developing a family of reduced latency DRAM

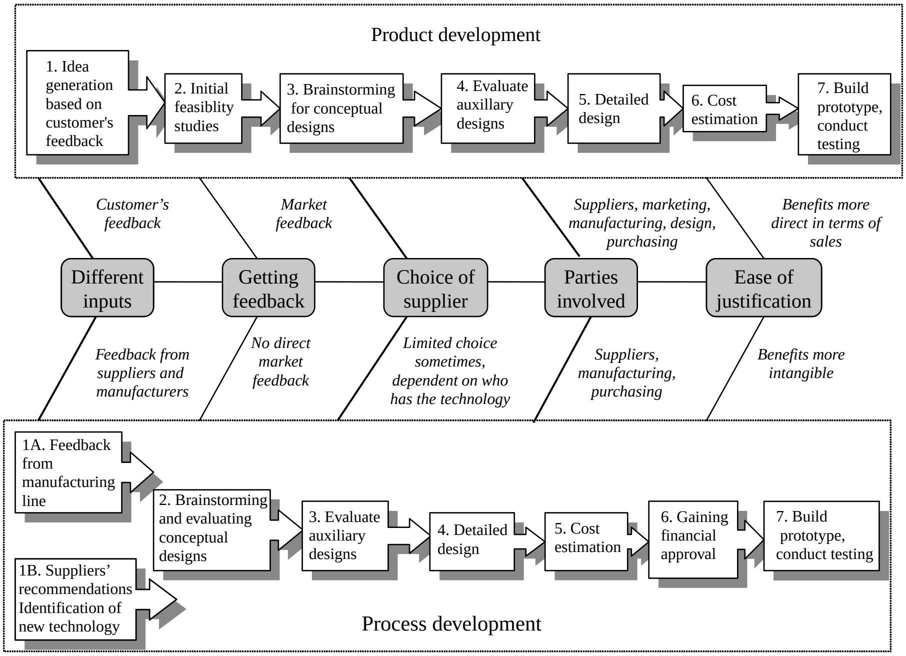


Figure 2.
Process development vs product development for ESI

devices for networking applications. MIC also forms joint venture with TECH for the supply of wafers. Since implementing ESI in the semiconductor industry involves both product and process development, the ESI framework should take into account the differences in practicing ESI in both types of developments, instead of just focusing on one as is the case in most research.

4.2 Emphasis on protecting proprietary information

The highly competitive nature of the industry and the high level of uncertainty that surrounds the payoffs to a particular piece of knowledge meant that companies in the semiconductor industry have to take greater care in protecting their knowledge. Involving suppliers earlier may require the sharing of proprietary information, thereby exposing themselves to the risk that these suppliers may divulge this confidential information. Hence, before implementing any ESI program, the company has to take steps to ensure that their proprietary information and trade secrets are secured. These can be achieved through the filing of patents and the use of non-disclosure agreements.

However, a study have shown that the use of patents is not so much as to prevent their competitors from getting hold of the knowledge, rather patents are used as "bargaining chips" in negotiations with other patent owners (Hall and Ham, 2001). Broad, cross licensing of patent rights among manufacturers characterizes the semiconductor industry. Hence, a firm has to keep a strong patent portfolio of its own so as to ensure that its profits are not corroded away by the outflow of royalty payments to owners of semiconductor-related patent rights. Basically, companies "race to patent" so as to secure the right to exclude others before they are excluded.

In contrast, in slower paced industries, such as the steel industry, technological change is characterized by the accumulation of numerous incremental improvements over a long-time horizon; hence, there is a smaller need in "racing to patent".

4.3 Different roles of suppliers in product development

The semiconductor industry is not like the automotive industry where products can be divided into many subassemblies and eventually combined together. For instance, DRAM or modules are manufactured through a series of processes, to be carried out in a particular order. For product development in the semiconductor industry, suppliers contribute mainly in the area of material developments while in the automotive industry; suppliers contribute more extensively in the production of an entire subassembly. This means that suppliers play a more extensive role in product development in the automotive industry as compared to the semiconductor industry. Since suppliers in the semiconductor industry are required to produce new materials, hence in the selection of key material suppliers, it is important to focus on their technical capability. This is in line with the supplier selection criteria used by MIC.

4.4 Focus of supplier-buyer collaboration on process development

Suppliers are involved to a greater extent in process rather than product development in the semiconductor industry. Companies such as MIC, who manufacture semiconductor devices, are thus very much dependent on the semiconductor equipment manufacturers for process developments rather than product development. The company can attempt to develop new materials through extensive research with their suppliers but they cannot produce the manufacturing equipment on their own.

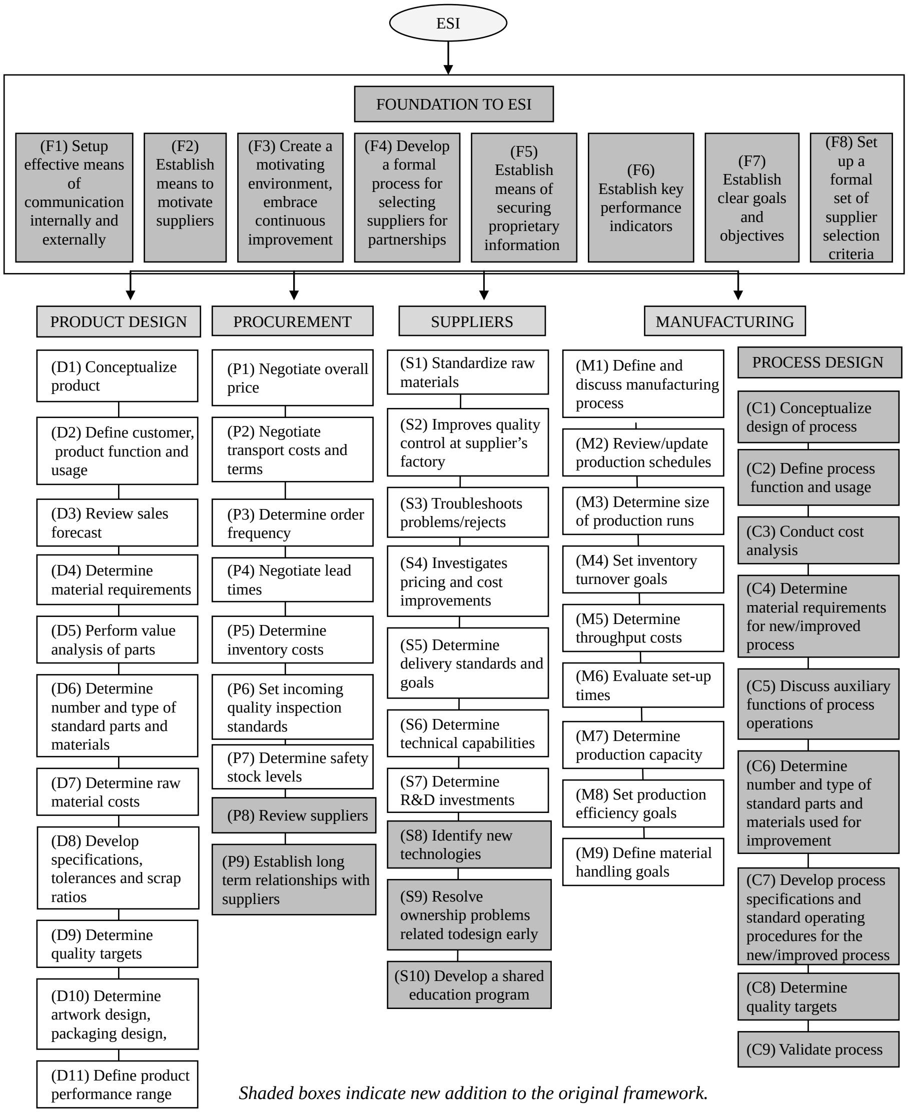
5. A framework of ESI for the semiconductor industry

Figure 3 shows a modified framework for implementing ESI in the semiconductor industry, where the shaded boxes indicate the addition to the original Dowlatshahi's model. The propositions of this framework refer to the need to satisfy the ESI fundamentals before the rest of the propositions in the framework can be implemented effectively. These propositions are to be achieved by the top management of the company. These propositions are established so as to overcome the problems faced in implementing the framework.

5.1 Procurement

Proposition P8. Review suppliers. Suppliers should be reviewed based on a formal set of criterion at least annually. This helps to assure the quality of the materials and provide feedback on the capability of the suppliers. The review on the suppliers will require cooperation from the suppliers to provide the relevant information. These reviews can then be communicated to the top management of their suppliers so that follow-up action can be taken.

Proposition P9. Establish long-term relationships with suppliers. Owing to the highly competitive nature of the semiconductor industry, it is increasingly important to form strategic alliances with their suppliers so as to ensure a continuous supply of materials. Instead of having a lot of competing suppliers, the number of suppliers can be reduced so that the company can focus on developing a long-term relationship with them. The feasibility of a partnership with the suppliers can be discussed once the



Shaded boxes indicate new addition to the original framework.

Figure 3.
A modified ESI framework for semiconductor manufacturing

company is satisfied with the performance of the supplier. For instance, MIC forms a joint venture with TECH so as to secure a continuous supply of wafers.

5.2 Suppliers

Proposition S8. Identify new technologies. The main difference in ESI between process and product development projects lie in the identification of new technology. The semiconductor industry is fraught with fast evolving technology; hence semiconductor manufacturers need to keep themselves updated on the latest technology. The easiest way of updating themselves is by keeping close contact with their suppliers.

Proposition S9. Resolve ownership problems related to design early. Any ownership problems related to a jointly developed product or design have to be resolved as early as possible. Although the idea may originate from the buying company, the suppliers may assume that since they provide most of the design work, they are free to use the design for other customers. Hence, by discussing such issues with their customers early, the suppliers avoid any legal disputes in future.

Proposition S10. Develop a shared education program. The suppliers and the buying company should work closely to develop a shared education and training program. In MIC, the suppliers are the only ones providing training for use of their products. However, the company's engineers can also provide training to their suppliers on quality control methods so that the quality of the supplied materials can be improved at the source.

5.3 Manufacturing-process design

The propositions are similar to the propositions under product design, though they are designed more for process developments. They are included in the ESI framework because in the semiconductor market, it is important to focus both on improving the product as well as the manufacturing process. In the semiconductor industry, manufacturers such as MIC depend heavily on the OEMs. If the manufacturing process has to be customized or improved, help from the OEMs are essential since they understand the workings of their equipment better.

Figure 4 shows a formal plan of systematic implementation of ESI. This procedure helps:

- resolve ownership problems;
- enable linked information systems to assist in more frequent communication, which is essential for the purchasing department in vendor managed inventories than the manufacturing department;
- provide motivation to the suppliers to be involved in the company's ESI efforts;
- establish means of securing proprietary information;
- measure performance feedback indicators; and
- assess suppliers' capabilities so as to match them with suitable tasks.

6. Discussions and conclusions

This study has tested the propositions of an ESI conceptual framework produced by S. Dowlatshahi with a case study. It suggests the inadequacies of the framework for process-development projects. It is imperative to explore how the implementation of ESI in process development differs from that of product development. Also observed from the case study is the need to build up on some fundamentals of the company before ESI can be carried out successfully, such as means of communication, protecting proprietary information, capability of suppliers, etc. Accordingly, the supplier selection criteria used by the company for selecting both raw material suppliers and process suppliers are studied. The effectiveness of a supplier selection criterion is gauged from the performance of the suppliers. Though a good rating may be given, it may not be extensive enough at the first place. It is thus necessary to look at suppliers' level of

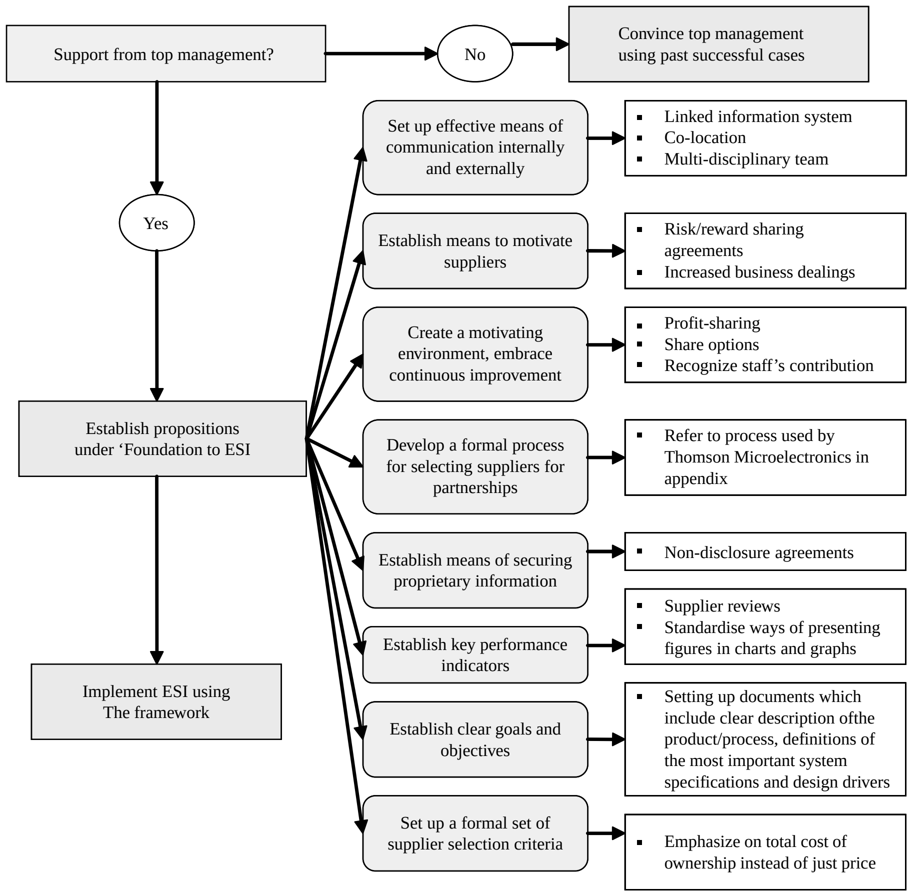


Figure 4.
ESI implementation procedure

involvement and to understand why suppliers' are not involved earlier in the first place. In addition to the effectiveness of non-disclosure agreement, the means of improving communication, whether co-location of suppliers is useful, and how practical it is in reality are investigated. It is also found out what type of relationships with suppliers are favorable to ESI, regardless whether the length of the relationship can be translated to trust in technical capability in practice.

Since the survey results are obtained based on a single case study only, it should be noted that they are not to be taken as conclusive findings. The usefulness of the added propositions is to be further tested using a bigger sample of companies in the semiconductor industry before they are used as a formal framework for implementing ESI. Nevertheless, it helps to gain insight into the actual practices likely to be adopted by a company in dealing with suppliers earlier. It is through the application of these conceptual ideas to a real-life practical case that the inadequacies surface.

Throughout this research, the propositions proposed in the original framework for product development have not been further applied to this case study. This is partly due to the fact that the company's design facilities are not accessible. Nevertheless, the choice of the company as a case study can still be considered valid because by being one of the leading companies in DRAM production, it will be interesting to explore its practices, which are likely to be emulated by others. Furthermore, since process development is likely to involve suppliers more than product development in the semiconductor industry, the lack of opportunity to test the propositions for product design should not be a major setback in this research. With the highly competitive nature of the semiconductor industry, it is believed that the formation of strategic alliances in the supply chain will become even more common in the future. Hence, this research has taken the first step to explore a possible way of collaboration by involving suppliers earlier.

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