Oracle E-Business Suite
High-Tech Semiconductor Industry Solutions

Achieving Excellence in
Manufacturing Execution and Customer Response
Through
Oracle Shop Floor Management

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**Target Audience:**
a. Managers involved in semiconductor manufacturing and supply chain operations
b. Oracle Sales Managers/Partners involved with selling or implementing Oracle Shop Floor Management (OSFM)
EXECUTIVE SUMMARY

Today’s semiconductor industry is being revolutionized! But unlike other changes in the industry such as larger wafers or new lithography tools, this revolution is not only about technology but also about how companies need to do business. Staying competitive requires that companies change both their business and operations practices to stay ahead of the competition. Shorter time-to-market, higher scheduling stability, better profit margins, higher number of products and product developments, and of course minimized costs together with top quality are essential.

The successful semiconductor manufacturer has to accommodate these complex, sometimes opposed and contradictory, requirements to fulfill the customer demands as well as to ensure their own profitability. Thus the optimization of the wafer fab performance while enabling a highly flexible manufacturing and enterprise strategy plays a major role.

Semiconductor firms are also increasingly finding that they must be involved on a timely basis with not only their own business but their customer’s business as well. IC companies must provide their products and services to customers quickly and with the highest quality while reducing the turnaround time between order and delivery. Lead times that were formally measured in days in the past are now expected to be measured in hours. Customer responses are fast becoming real-time, and timely manufacturing and delivery becomes a worldwide concern.

Few systems other than Oracle, deliver such information for any of the semiconductor manufacturers. Most Business enterprise and manufacturing operations remain predominately autonomous and site-specific. Moreover, neither one is coordinated with the supply chain on an “instantaneous” basis. Specialized software at each fab will always exist, but competition will force the adoption of a flexible, integrated information system that sees a company as a single entity worldwide.

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Oracle Shop Floor Management (OSFM) helps semiconductor companies in achieving excellence in manufacturing execution and customer response. It achieves this through adoption of a flexible, integrated information system that sees a company as a single entity worldwide. OSFM is a part of overall Oracle E-Business Suite that provides extended shop floor control by providing real-time status information on work orders, support for advanced shop floor WIP Transactions, dynamic routings, reduced lead time, detailed lot tracking and many other capabilities. This enables fast manufacturing turnaround to the customer through a real-time system that looks worldwide at all possible sites for wafer capacity, assembly and test, and inventory/distribution, and link these, also in real-time, to global supply-chain planning.
This convergence of customer responsiveness along with manufacturing excellence is clearly an effective way to add new customers, build the revenue base, and increase throughput above and beyond heavy capital investment in new fabs and equipment. Many Oracle customers use this convergence of customer responsiveness and manufacturing excellence as a key differentiator for their positioning in the semiconductor industry.

Finally, the paper describes capabilities and architectures of the currently available OSFM software and its alignment with agile manufacturing execution. Oracle has developed this industry specific solution along with some of its key customers – Lucent Microelectronics (currently Agere Systems) and Level I (currently a division of Intel).

Today, Oracle has more than 75 customers of OSFM in semiconductor industry worldwide. Most of these customers are also active members of Oracle’s customer advisory board and work as solution design partners with Oracle. Over the last 4 years, these design partnerships have resulted in significant enhancements in Oracle’s offerings for the industry’s key issues. As the industry adapts to 300 mm wafer manufacturing, additional enhancements continue to be made in line with the recommendations and prioritizations set by its annual Customer Advisory Board meetings.
Semiconductor Industry – Current State

The rise of global competition and improvements in technology is enabling companies to break away from an insular approach to manufacturing and be more responsive to customers. These developments have raised the stakes for IC manufacturing putting new emphasis on reduced cycle times, and increased product yield in addition to advancing process technology. However, the core of this revolution is the supply chain requiring visibility of manufacturing products worldwide, and complete integration of demand and order entry with all manufacturing execution systems. This virtually puts the customer interests directly onto the fab floor, which then fans out to every downstream member of the chain. It puts an end to older stand-alone supply chains that supported local make-to-planfabs, and rarely had real-time visibility in company’s global operations. This revolution is also redefining customer relationships by including up-to-the-minute information via the Internet on order status, yield, quality and costs in addition to commitment on delivery. In addition, semiconductor manufacturers expect this data to be timely since market, demand and supply events cannot wait for batch updates that are often too late for an appropriate response. To provide this capability, today’s business environment requires a single repository for business and production.

These requirements make the integration between corporate enterprise and manufacturing the cornerstone for future success. Most semiconductor companies use MES systems from a third-party vendor but not all sites within a single company use the same MES supplier. In fact, it is common to find that fabs may also differ on toolsets used, and other data collection systems for test, yield, business and quality analysis. It is imperative then that a product be able to transgress such disparities as serial flows, batch and discrete processes, and variances in tools bringing them together in a simple and effective manner. To bridge this gap between ERP and disparate MES systems requires a methodology that addresses differences in routing, shop floor transactions handling, “life cycle” or “end-to-end” product genealogy of products, yield-based operations costing, and WIP. All of these are included in OSFM. But why are they so important?

Enterprise software manages production costs and computes manufacturing targets but was never intended to have lot genealogy or lot tracking capability. Even within the fab specialized data, material control (MCS) or document management (PDM) systems (often unique to that fab) may handle changing product specifications and lot process instructions but not always follow variations in lot routing and recipes so such information is still left un-automated. MES systems often facilitate lot movements but are ill equipped for special dispatching to keep equipment utilization and WIP volume high. What exists presently are local, co-existing systems such as MES, MCS, PDM & ERP that independently collect and analyze particular sets of fab data with little collective interaction. Each has its important role to fill and is important to fab management. Currently, global allocation of resources and transactions, intra-fab capacity planning, sophisticated lot moves, product binning, and automated dispatching are beyond the capabilities of such systems. However, since most are well ingrained into the production processes, fabs will be reluctant to replace them. These software tools are still important to existing semiconductor business. What is needed is a new approach that optimizes these tools but not at the expense of interrupting production.

OSFM – A Killer Application

OSFM meets this need by understanding that MES and ERP systems are interdependent and must work with each other to satisfy customer demand. Integration is necessary to track occurrences in the fab that will impact the entire supply chain process. Events such as bottlenecks (i.e. a lack of key pieces of equipment due to downtime), lot mis-processing, re-routing of lots, customer demand changes, or unexpected fab downtimes are all “supply-chain sensitive”
events that affect both customer and manufacturer. The core capabilities within OSFM were designed to handle exactly these kinds of events. They easily fit with standard MES systems from many reputed vendors systems to vertically integrate multiple fabs at different locations at an enterprise level using real time data. These modules also provide the ability to input customer orders directly onto the “shop floor” (i.e. fab), do costing/operational yield analysis, and reduce inventory and working capital. In addition, OSFM compliments existing systems so replacement of current MES & ERP infrastructures under most cases is not required.

The impact of OSFM can be seen clearly in an example from a recent installation at a major semiconductor manufacturer. This customer projected that the total time from customer order entry to delivery (to the customer) was 95-146 days. Even a theoretical model, which assumed that initial testing of the customer design was a re-order and therefore not required, estimated that about 24 days would be needed with no front-end order processing. Using OSFM, the entire process reduced to less than 7 days with no initial design qualification. The order process cycle alone predicted to be about two weeks long became a succinct 15 hours. All of this included order entry of the customer’s latest demand, match to global capacity, identification of which factory was optimal for this order, and input of the order into the specific factory build schedule. This completed in less than a day. All of this is valuable today not tomorrow.

In summation, the key to better planning, increased profits, and strong customer partnerships within the semiconductor sector over the next decade will depend on a strong, global supply chain and integrated execution systems. As the market evolves to a make-to-demand economy and a lower dependence on computer-based products, successful companies will have optimized enterprise and manufacturing infrastructures over all of their manufacturing and distribution sites. This puts the ERP/MES interface at the center, and all progress in this area for any firm must begin there. The OSFM platform is an excellent place to start.

Business Values derived from OSFM

OSFM is a single vendor solution that either provides comprehensive shop floor functionality or enables the integration of third party Manufacturing Execution Systems (MES) packages. By extending Oracle Manufacturing’s core functionality through OSFM, Oracle empowers the enterprise through an extensive, real time integrated ERP/MES environment. Customer and shop floor transactions are captured in a single repository, facilitating customer demand and supply synchronization, supply chain planning and analysis. Oracle Shop Floor Management also provides for most MES functionality. If manufacturing operations, however requires a third-party MES product, OSFM provides hooks into its functionality via APIs, mirroring shop floor transactions within Oracle ERP in real time. OSFM is a standard software package, eliminating the need for custom MES solutions or minimizing the effort of designing and integrating MES systems with the Oracle ERP environment.

Meanwhile, the semiconductor industry has, in recent years, gone through a paradigm shift that has grown beyond the capabilities of traditional manufacturing. One of the major shifts relates to customer intimacy. Customer intimacy means having a real-time, accurate perspective of the enterprise at any given moment. Several examples portray this perspective. The salesperson is now required to give on the spot accurate information about his/her customer’s manufacturing lots and their status. Semiconductor companies’ customers are requiring detailed information about whether their lots went through certain pre-qualified manufacturing facilities/equipment. Production planning managers need genealogy snapshots to proactively isolate potential shrinkage problems due to faulty lots moving downstream and spreading through the manufacturing space. Oracle Shop Floor Management (OSFM) is a collection of enhancements to Oracle Applications that fulfills and enables each of these scenarios and more. By the simple act of allowing the integration of the data at each shop floor back to the enterprise, OSFM enables the synchronized and event-driven enterprise.
Process transparency and data sharing in the design house / foundry model are a significant step towards better managing the supply chain for the semiconductor industry. For the fabless company, this equates to being able to readily access data pertinent to them from their foundries. Although transparency of data may not be the major roadblock here (these were made available through technologies such as EDI), there certainly can be improvements made in the speed and accuracy of the data. OSFM permits the fabless company to receive data from their foundries on a real time basis.

For the semiconductor company that owns the privilege and responsibility of having its own manufacturing facilities (i.e. fabrication), OSFM strives to achieve real-time synchronization across the entire corporation at any given time. This means that for the innovative market leader who owns multiple front end facilities and multiple assembly and test facilities spread out around the world, a user based at headquarters in the U.S. is able to have adequate visibility into every aspect of manufacturing for a given sales order. The sales person is able to respond in real time to a customer about the status of his/her order, and also is able to commit with confidence to any change in demand the customer may require. In the semiconductor enterprise we strive for corporate-wide manufacturing synchronization and a level of transparency throughout demand to fulfillment, which facilitates better customer care and, ultimately, intimacy. OSFM is the cornerstone to data synchronization, an IT aspect of infrastructure that is essential in succeeding about such a model.

**OSFM Functional Specifications**

OSFM is a package of extensions to core manufacturing. These extensions include extensive modifications to the WIP, BOM, Inventory and Cost Management modules. The following table describes in overview the added features made available through OSFM.

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<th>Dynamic Routing</th>
<th>Allow super user operation “Jump”</th>
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<td>Complex Lot Transactions (WIP/INV)</td>
<td>Split a lot into multiple lots Merge multiple lots into one resulting lot Change assembly, lot name, lot quantity or routing on a lot Bonus in lots beginning at any operation sequence</td>
</tr>
<tr>
<td>Lot Genealogy</td>
<td>Trace lots throughout entire manufacturing process Perform “genealogy surfing” forwards and backwards through manufacturing lot genealogy Determine detailed lot information at any point in genealogy</td>
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<td>Yield-Based Operational Costing</td>
<td>Define operational level yields on the routing of a product Provide for calculation of cumulative, reverse cumulative yields and factored usage Collect actual yields for all required operations at WIP move Build in the yield loss into the cost of the product</td>
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<tr>
<td>Co-Products</td>
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**Dynamic Routings**

OSFM provides an ability to determine routings on the fly responding to process needs or resource availability. Users can specify operation relationships (for example, going from operation A to either B or C), which are subsequently enforced by OSFM as routings and are executed by the operator on the factory floor. Under some circumstances, OSFM also provides an ability to “jump” to any operation outside this dynamic routing.

**Shop Floor Move Transactions**

OSFM offers more detailed tracking of the shop floor/ WIP. Whereas standard Oracle WIP did not provide the flexibility to track all the various transactions that happened on the shop floor (e.g. WIP split/ merge, re-works), the added types of transactions and robustness of OSFM enable more detailed tracking of every transaction.
During shop floor move Transactions, OSFM enforces intra-operation steps, collects engineering data, and specifies resources used. Along with the flexibility provided by OSFM must come measures to more strictly control and monitor the kinds of transactions made on the shop floor. In view of this, OSFM WIP Move Transactions Form has been enhanced and some of the major features include the following:

a. Users can now specify mandatory intra-operation steps. One can specify as to which intra-operation steps (queue, run, to move and scrap) are mandatory at each move transaction.

b. The dynamic routing definition is enforced. Specifically, the list of values in the “to operation” field will read the dynamic routing definition and give the operator the choice to move only to operations to which he/she can move based on the current operation.

c. A super user “Jump” feature has been made available. When the jump feature is enabled (set by a profile), the operator is able to move “in to” any standard operation in the inventory organization, regardless of the specifications set by the dynamic routing.

Complex Shop Floor Transactions

OSFM extends the standard Oracle Manufacturing functionality to accommodate complex lot related transactions and process models commonly found in high-tech shop floor environments such as semiconductor fabs. Through OSFM an enterprise’s capabilities are expanded by the following functions: maintain lot names when part numbers change, split and merge lots, update lot names, routings and quantity, manage bonus lots and model co-products. Depending on business models, OSFM can be used in automated shop floor environments as well as in interactive systems, which require manual interventions. Leveraging the Oracle Applications Internet based architecture; OSFM provides user friendly, browser based interfaces:

Lot Genealogy

Proactive customer responsiveness to product quality issues is a function of tracing raw materials and lots through manufacturing processes. Unlike traditional manufacturing environments, which have limited capabilities of tracing finished goods from raw material at the ERP level, OSFM provides complete lot genealogy for backward and forward visibility across the enterprise. Product defects can be quickly traced to lots and processes. Also, OSFM helps in the identification of affected lots (forward explosion) so that customers can be proactively notified. By leveraging OSFM generated information, processes can be improved across a multi-fab enterprise environment.

Yield Based Operational Costing

Within OSFM, yield-based costing is determined by multiplying the actual costs at an operation by the reciprocal of the expected yield at that operation. It is based on the underlying concept that if one expects to have a percentage shrinkage at an operation, your costs will multiply by the inverse of that percentage. As a simple example, expecting a yield of 50% (0.5) at a given operation means that for every 2 units put in, one good unit will come out. Conversely, in order to get one good unit out, one would expect to have to put in 2 units. Essentially, the
expected cost of manufacturing doubles. Accordingly, with a more complex example (e.g., 80% or 0.8), expected costs would multiply correspondingly. OSFM costing tracks yield-based costing at an operational level. Expected yield rates are defined for each operation on the routing for an item, and at each move the costs are adjusted according to the yield-based logic. Of course, these additional costs are tracked separately, a sixth cost element if you will, and are later flushed out as job close variances. Provided with the OSFM costing solution is a reconciliation report which will, at the operation level, report expected scrap dollars versus actual scrap dollars, and therefore favorable or unfavorable gain in actual production costs (variance).

### Co-Product Definitions

The co-products concept has already been described earlier. It can best be illustrated through a simple example, consider that a single die (an unpackaged chip) for a CPU can be sold at many different grades, such as 400, 500 or 600 MHz. Depending on test results, the same die will be packaged and marked as completely different finished goods and priced as such. The three items we would define in Inventory, one for each grade, would then be co-products, sharing a common component, the die. The bill of material structure for such an assembly relationship would be an inverted bill. A separate form is provided with OSFM for definition of co-products. For a given component, the user specifies the co-products that it yields. The form will then generate the corresponding bills of materials definitions.

### Supply Chain Optimization

The OSFM modules are multi-purpose and can be used to optimize supply-chain issues as well as control or track them. For example, lot genealogy, WIP tracking, and yield-based costing could be applied to maximizing and controlling manufacturing asset utilization along with Oracle APS Solution. More details on these can be obtained from the specifications of Oracle APS offerings.

### Business Models using OSFM

Having described the business values and the functional specifications for OSFM, this section now describes as to how some of the existing customers have modeled OSFM in their business processes. OSFM is being used today by Fabs, fabless design houses, assembly & test houses as well as several IDMs.

#### Design House/ Foundry Relationships

In the design house / foundry relationship, OSFM strives to make the two act as one company, rather than carrying on a customer / vendor relationship. Through open data transparency and true synchronization across that particular link in the partial supply chain, there are benefits that are realized by both parties.

For example, imagine a scenario where an ASIC design house outsources front-end fabrication to a foundry. Typically the level of information exchange between the two would be lot starts and lot completes, followed by a matching invoice and receipt. Through OSFM, the added level of competitive information comes in through more insight in cost of manufacturing (or outsourcing), and lot genealogy. While the foundry typically wouldn’t disclose information about details into operational yields and manufacturing cost by operation, the yield for the entire assembly in the foundry may be represented by a single
outsource processing operation in Oracle WIP. With the ability to do yield-based operational costing in OSFM, the design house is now able to have much insight into exactly where in manufacturing most costs are being accumulated. For a design house, the vision is to do only what they do best – design chips and market/sell them. Manufacturing planning and execution are beyond the scope of the design house’s core competency, and OSFM allows the design house to minimize that area of making and selling chips. OSFM provides a level of integration that is transparent and real time. Oracle envisions a centralization of information where all manufacturing entities and design houses come together so as to create a single virtual enterprise that is the well-managed supply chain.

**IDM Model**

True synchronization between the enterprise level and the manufacturing levels is essential to create customer intimacy. In the integrated device manufacturer (IDM) environment, OSFM affords the level of detail necessary to move up to the next level of operations.

**Summary**

What is the cost for an IC company to make the move towards this integrated, global supply-chain system and the new business environment that comes with it? Conversely, what is the cost of not doing anything at all and keeping the present mode of doing business? The answer is twofold. First, in terms of dollars, the OSFM system described is on a par with a 200mm wafer stepper. The stepper allows for more wafers to be run in one fab, and may increase throughput. OSFM on the other hand can increase efficiency, throughput, and customer responsiveness for the entire company. The ROI on a stepper is likely to be modest. OSFM is a tool that can significantly increase profits and lower operating costs. High equipment utilization is fine but it is not a substitute for timely market response. Secondly, no IC producer or foundry can afford not to transition itself into a worldwide, E-business company because the competition will. The old methods and information infrastructures are no longer satisfactory. Maintaining them is costly, manpower-intensive, and time-consuming. Simply adding equipment to make profit is no longer optimal. Internal strategies based on extensive runs and large inventories are things of the past. External, customer-centered strategies focused on short runs on a wider mix of products with quick turnarounds based on customer demand is the new paradigm. The economics are changing and success in the future semiconductor marketplace will belong to those who are prepared.

**About the Author**

Rakesh Kumar works for Oracle Corporation and has previously managed globally diverse manufacturing/supply chain operations for more than 20 years in various senior management capacities at a Fortune 50 Transnational. He holds a B.Tech in Mechanical Engineering from Indian Institute of Technology (IIT), New Delhi and MBA in Finance & Marketing from University of Chicago’s Graduate School of Business.