Adexa / *Adexa in the Semiconductor Industry White Paper*

Introduction to Adexa

Adexa helps companies excel in today's fierce marketplace by making supply chain and operations planning a competitive differentiator. Adexa delivers an integrated collaborative planning and performance management solution that maximizes the use of assets within and beyond the four walls, to help companies design, source, make and deliver products faster and more profitably.

Adexa delivers a synchronized, global view of supply, demand and production information, optimized against constraints and monitored against unforeseen events. A manufacturer can connect customers to automate the order and demand management process, resulting in better forecasts and delivery performance with lower inventory levels. Similarly, on the supply chain back end, automatic replenishment alerts can be sent to suppliers when safety stock is diminished.

Suppliers can then respond to new demand signals, with their responses triggering a remodeling of the extended supply chain and/or just alerting all those impacted by the response. Adexa enables, and even automates, intelligent decision making across the enterprise and throughout all levels of multi-tiered supply chains.

Adexa's Enterprise Global Planning System (eGPS) is a portfolio of open, scalable and adaptable technology solutions. A multi-threaded architecture with open communication standards and integration, security and personalization are part of the inherent design of the system. Adexa utilizes an efficient unified data model that tightly integrates modules in the solution-set, and delivers exceptional speed and scalability for both planning and collaboration. Adexa provides a pragmatic approach to maximizing business performance on a global scale and to achieving immediate ROI without lengthy, expensive, or volatile deployments.

Adexa in the Semiconductor Industry

Adexa is the industry leader in advanced planning and scheduling solutions for the semiconductor industry. Semiconductors represent one of the most difficult environments for planning and scheduling. Characterized by long lead-times, interplant dependency, high occurrence of breakdowns and scraps, and notably expensive equipment, wafer fabrication lines and back-end manufacturing present a very challenging job-shop environment for planning and scheduling. In addition, the industry faces highly fluctuating demand changes, variable mix of end-items, and vigorous competition internationally.

Most of the world's top 25 semiconductor manufacturers use Adexa applications. Adexa has customers that represent every segment of the semiconductor industry from wafer ingot manufacturers to fabless semiconductor companies. At this time Adexa has greater than 125 live deployments of our applications at Semiconductor companies. Some of these companies are illustrated in the table on the next page of this document:

Customer	Available to Promise	Strategic Planning	Supply Chain Planning	Plant Planning
Advanced Micro Devices	✓	✓	✓	✓
ASE Test Limited			✓	✓
Agere Systems			✓	✓
Chartered	✓		✓	✓
Conexant Systems	✓		✓	✓
Hitachi Semiconductor			✓	✓
Matsushita Electronics			✓	✓
Philips Semiconductor				✓
Sanyo Electric			✓	✓
Sharp Device Division			✓	✓
Toshiba Semiconductor				✓
TSMC			✓	✓
UMC				✓

Adexa's Position in the Market Place

Adexa is the only provider of collaborative planning solutions that were built from the ground up to model the complexity of the semiconductor industry. Other vendors were first to market back in the early 1990's with a generic solution designed with a one size fits all mentality.

These applications were designed to fit a generic set of planning processes applying the 80/20 rule, not to meet the complex requirements of the Semiconductor industry.

Why have so many semiconductor companies turned to Adexa?

In short, because we are the best. When put head-to-head with our competitors Adexa wins hands-down due to our semiconductor specific functionality, the speed and flexibility of our solving algorithms and our ability to rapidly deploy our solutions.

Here are the three main areas that differentiate Adexa solutions for their ability to deliver quality planning results for the semiconductor industry:

1. Unified Data Model (UDM)
2. Semiconductor Specific Functionality
3. Ease of Implementation

Unified Data Model

Our data model was developed with the semiconductor manufacturing process paramount in the design. Our software designers concentrated on building a data model that could model the very complex movement of product through the shop floor and be able to model the actual resources that the lot would be processed upon. The intention was to be able to handle the details of the environment but also be able to solve much faster than our competition. Speed is the result of an efficient data representation!

Adexa applications are designed to model the reality of how products move through either the supply chain or shop floor. The result from an Adexa application can be executed to and does not require additional planning and the use of Excel like those other guys.

An advanced planning system is not advanced if the result cannot be executed to. The basis behind the model reality concept is that data held in the ERP and MES system is the starting point for building a planning model.

Adexa applications must be able to handle real products, the actual resources they are processed upon and real product routings through the supply chain that come straight from those source systems. We do not create dummy routings or dummy resources or monster translation tables because to do that gets us away from a result that we can execute to and also adds complexity to the implementation.

Our result is therefore more accurate and delivers a real return on investment to our clients in a reasonable time frame. A typical Adexa wafer fabrication plant implementation takes less than four-months to complete.

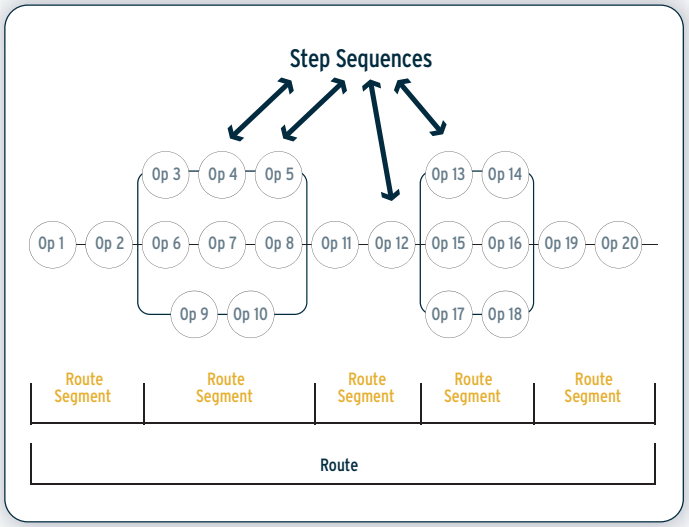
There are two main reasons why other vendors cannot take data straight from these systems:

1. Data model design
2. Speed of solving

Adexa breaks down the product routes into four definable steps; routes, route segments, step sequences and operations.

Operations are the manufacturing steps that a product goes through. Step Sequences are a combination of operations. A Route Segment encompasses many step sequences. Routes are a combination of many route segments.

The following diagram illustrates these key components of the data model:

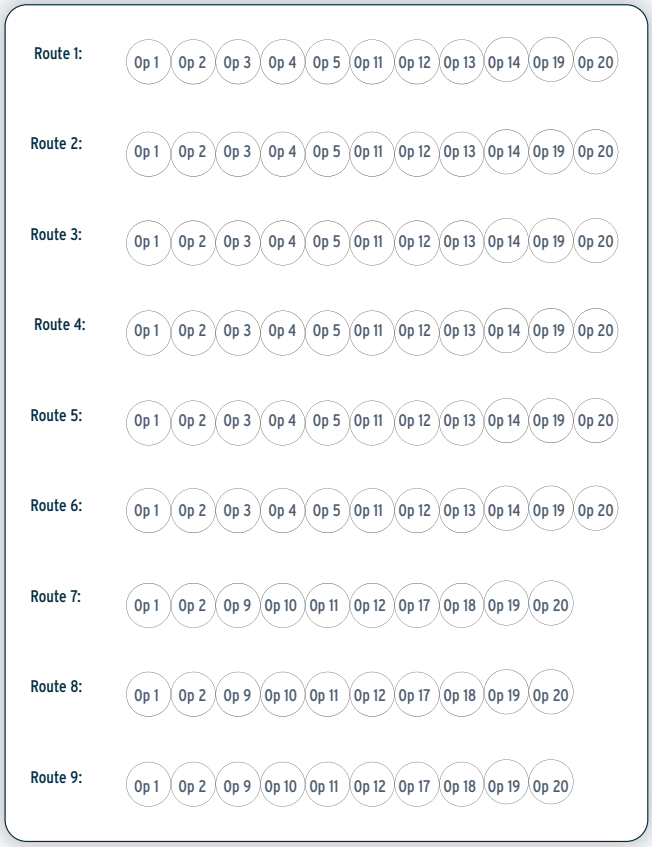


In semiconductors, Adexa tends to compete with one vendor. Its data model was designed using the one-size fits all approach. It only has two levels within its data model that would correspond to Route and Operation. This prevents it from being able to model the accurate routings for complex manufacturing, especially the semiconductor industry.

Since our competitor's software only has the Route and Operation level in its data model, the practical effect of this is that in order to model the above routing structure using its software, we have to create a series of linear routes.

In the above example Adexa creates only one route with multiple route segments and these objects become reusable, therefore, keeping the model size small but still being able to model the reality of the semiconductor manufacturing process. The corresponding route structure from our competitors is illustrated on the next page:

In the below example our competition would have 9 routes to just the ***ONE*** route in Adexa. Therefore, the other data model is very inefficient and will lead to an exponential increase to model size and solve time.



At the Toshiba Semiconductor plant in Iwate, Japan after spending nearly 18 months trying to implement someone else's Factory Planning product, Adexa was given an opportunity to showcase our application. We went live at that facility in less than five months. The competitors' tool was running during tests at over 22 hours where as the Adexa tool solved in well under one-hour.

Adexa applications get their speed from two key architecture advantages:

1. Adexa data model is tuned to the needs of complex manufacturing environments such as semiconductors.
2. Our applications are memory resident.

If we refer back to the example where our competition had 10 or 11 operation steps per route. Now, if we were to expand the number of operations steps to the 300 to 400 operations that are found within a typical wafer fabrication plant, and add all the possible alternative routes that a product may take, then the model size becomes unmanageable and solve times will increase exponentially.

So our competition cannot model the reality of the manufacturing environment and must streamline its models. As soon as this approach is taken we cannot leverage our existing investment in MES systems and aggregate WIP, routings, capacity and materials so that the model could solve in a reasonable amount of time. This produces a result that cannot be executed, making the planning system no better than an Excel spreadsheet at 1000 times the cost. We have concentrated on Wafer Fabrication so far but where the front-end predominately builds a relatively small number of products over a large number of operation steps the back end assembly test processes build a large number of products over a small number of manufacturing steps. .

We have only a few number of operations but due to the way products are built using different package types or the fact that products can bin out to multiple electrical or speeds we end up having to plan a huge number of end products.

This is where the scalability of the Adexa data model really comes into its own. For instance, if you cannot model the true routing then you will also struggle to be able to model the real bin splits and will not be able to perform down binning of components to meet the needs of your customers.

The following table illustrates some of our semiconductor customer's model statistics and the show how the model reality concept is applied. The table also highlights how complex these models can become but also how fast they can solve:

	Hitachi	AMD SCP	PHILLIPS ABQ SCP	LUCENT PP	CENTILLIUM SCP	Power Chip SCP	Power Chip PP	Power Chip PP	TSMC PP
Horizon	1 Year	62 Weeks	18 months	30 days	12 Months	14 Months	9 Months	1 + 1 Year	6 Months
Operations	1112000	4266	9886	29,487	399	49	37782	43	57124
Com@locs	90000	123	2987	10,103	410	692	31	10	2397
Resources	1000	658	434	4282	114	129	998	21	1798
BoMs	138000	135	2987	7166	312	450	6	5	432
WiP Lots	20000	8079	364	3149	109	437	4000	517	1094
Supply Lots	0	0		3149	169	1846	1244	13793	510
Data import time	1hour	1.5 mins	17 min	26 mins	15 sec	11 sec	5 mins	15 sec	20 mins
Balance Time	20min	40 mins	< 2 min	~ 7 mins	2 mins	430 sec	20 mins	45 sec	1min
Schedule Time	20min	37 mins	< 2 min	~ 6 mins	2.5 mins	381 sec	50 mins	40 sec	2mins
Total # of Lots	1300000	47934	200000	78,000	14000	58000	27000	14,000	133000
Model Size after Bal & Sched	7G	133MB	8.8 MB	49.9 MB	20MB	140MB	380 MB	7.6MB	365 MB

Semiconductor Specific Functionality

In order to create usable solutions that can be executed against in the semiconductor environment, the solution design must comprehend diverse cultural and process realities. In addition, achieving accurate planning runs with short solve times is critical in handling constant WiP movement and demand changes between planning periods.

In this section we will introduce the solving strategy within Adexa's optimization tools; organized into three sections:

1. Adexa Solving Algorithm
2. Solver Flexibility
3. Detailed Semiconductor Functionality

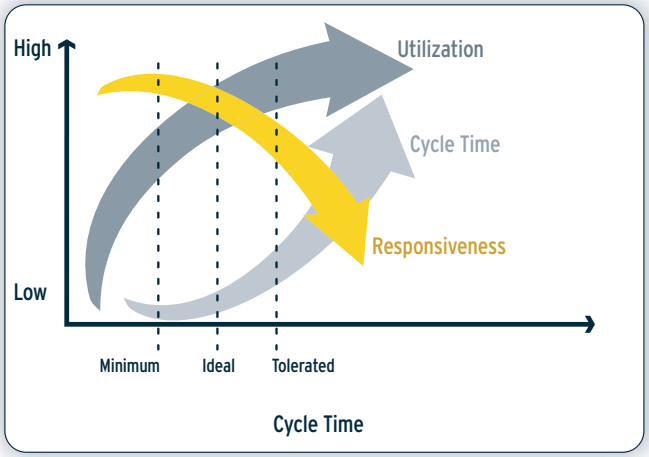
1. Adexa Solving Algorithm

Considering what is available today regarding solving algorithms in production planning and scheduling tools, our competitors appear to have a somewhat rudimentary scheduling algorithm based upon one objective. Which cycle time do you want to schedule against? The algorithm adds up all operation process times and schedules based upon a fixed production lead-time. When comparing this method with Adexa's Continuous Flow Index approach or lot release strategy, prospects and customers realize the superiority of Adexa's technology and engine.

The basis for Adexa's lot release and scheduling approach is determined by the following three competing objectives:

1. Resource utilization
2. Cycle time
3. Responsiveness to order changes

How are these competing objectives? Consider a resource utilization target that has been set by a plant manager, who needs to justify the purchase of a new tool. To increase the utilization of this new tool, we must minimize the amount of time the tool is left idle. Additional product starts are introduced into the line to ensure the new tool always has materials in the queue to load and process. By doing this, and introducing more product onto the shop floor, increased product cycle times result. This is demonstrated using the graph on the next page of this document. If we follow the utilization curve toward a high level of utilization, notice that an increase in product cycle time results.



In addition, the level of responsiveness or ability to change these work orders is decreased. This is a result of product introduced to the shop floor earlier than required to meet the customer order. The product is being introduced early due to the high utilization objective for the new tool.

How does this phenomena relate to Adexa's solving algorithm? The management objectives just described above determine how a company wants to execute at the manufacturing and company level. Is our main concern on the shop floor resource utilization, product cycle time, or delivery performance? Is the company's objective a balance of all three? By defining where the company wants to be with regards to one of these criteria, the other two criteria are inherently defined.

Adexa captures these management objectives in terms of the cycle time curve for each product and lot scheduled. The cycle time is defined with a minimum, ideal, and tolerated cycle time value, which the system uses to determine the appropriate lot release and speed at which the lot should flow through production. For example, consider the rate at which a product flows through manufacturing for a production order. Now consider the rate at which the product flows for a high-priority hot lot. The ability to define minimum and maximum thresholds at which product moves through the line allows the system to determine the rate in which the order is satisfied, relative to all other orders in the system. Performing this iteration while considering capacity and material constraints, lot priorities and due dates, allows for accurate and usable planning results.

To what values do we set these minimum and maximum thresholds? The maximum threshold determines how early the system is allowed to release orders to the floor, based on the due date of that order. The larger the value of the maximum threshold, the earlier product will be introduced to the shop floor relative to the order due date. As the maximum threshold value increases, the level of WiP on the shop floor increases and responsiveness begins to decrease. The minimum threshold determines how quickly, relative to theoretical cycle time, manufacturing is able to manufacture a product. The minimum may be based on known rush or hot lot cycle times. The system recognizes this minimum cycle time as a hard constraint, meaning the system must release the lot no later than the minimum threshold offset the order due date. Otherwise the lot will be late.
This ability to capture minimum and maximum thresholds at which product is released and moved through the line allows users to toggle and create the appropriate balance of manageable WiP levels, resource utilization and targeted deliver performance based on responsiveness to order changes.

2. Solver Flexibility

Adexa understands that each company may perform planning and scheduling functions differently, perhaps following unique management objectives at each facility in the supply chain. A planning system must comprehend unique business rules and be flexible enough to allow quick re-configuration. The ability to incorporate new rules into the planning tool, as well as exceptions to those rules, is an area Adexa has clearly shown dominance in the APS industry for semiconductor manufacturing.

Plug-In Business Rules

Through the use of plug-in business rules, users are able to insert customized instructions at major decision points in the algorithm. Adexa has a host of standard plug-ins such as Demand Sort Plug-In, which enables users to manipulate in what order demands in the system are met (i.e. customer orders, safety stock, forecasts). Another pre-defined rule is the Resource Choice Plug-In, which allows the user to dictate which resource within a resource group, must be selected for a specific lot. The ability to manipulate behavior at the lot level while maintaining short solve times gives our customers clear advantages in running what-ifs and re-planning due to WiP changes and demand fluctuations between planning periods. Custom plug-in rules may be designed and configured by the customer. Often times we see this in engineering and development environments where non-standard process flows and complex testing and sampling scenarios take place.

Other Detailed Semiconductor Functionality

At the lowest level of the route structure are operations (or recipes), which allow for yield at each step, along with overrides (or exceptions) at each step of the process flow. These overrides at the operation level can be defined for specific products, for specific resources, or for a specific time period. These time-phased overrides are often used for time-phased yield and processing time improvements. No other vendor is able to reach this level of detail to enable exceptions and other MES attributes allowing for more accurate results.

Binning areas through backend operations is another key differentiator of Adexa in the industry. Multiple test operations with various binning rules are handled through our Bill of Grades object which recognizes bin percentages at the product level and more recently, at the lot level; a feature that we have yet to see any other vendor replicate with true customer data.

Ease of Implementation

Adexa's unified data model architecture means that integration between your ERP and MES systems need only be conducted once, regardless of how many modules are used. Adexa recognizes the significant investment made in other manufacturing support systems. Wherever possible, Adexa has developed standard integration bridges into leading ERP and MES systems.

Customer Case Studies

Adexa has some of the shortest documented implementation times in the industry. In this document we have discussed some of the major contributing factors to our implementation successes for the semiconductor industry. Our average implementation per manufacturing site is at 4 months and our supply chain average is roughly 6 months.

The following information highlights some of our successes as TSMC, Toshiba and Philips.

Philips Semiconductor
Introduction of Adexa applications at Philips Semiconductor has produced a number of unprecedented benefits and results. Through better visibility, Adexa applications are enforcing the required disciplines and institutionalizing the ongoing process of data correction and adherence to practices defined by management. Examples of the latter are ongoing cycle time reduction and continuous improvement to delivery performance.

Adexa applications have helped to optimize a number of key parameters including cycle times, work-in-process inventory volume and delivery performance. After a few months of Adexa applications operation, delivery performance, measured by percentage of on-time delivery, was improved by high double-digit percentages. Cycle times and improvement to WIP levels also improved by comparable amounts.

Even more important than reducing the manufacturing cycle time is the reduction of planning cycle time. Reducing planning and scheduling cycle times are critical for being more responsive to the customer.

Adexa applications have helped to reduce the time from receipt of forecast to commitment from weeks to hours. Furthermore, the time needed for promising a delivery for each work order can now be performed while the customer is waiting on the telephone. Other intangible benefits include real-time status checking of orders, what-if analysis based upon changing business volumes, material and capacity availability.

Adexa applications provide the functionality to perform all planning functions from forecasting and commitment to release of lots and machine sequencing all in one unified environment.

Such an integrated environment has helped Philips to avoid the use of individual spreadsheets, hard-to-maintain simulation systems and many other homemade systems, which have constituted the traditional planning functions in semiconductor and other industries.

Toshiba Semiconductor -Iwate Facility
In February 1998 the Toshiba Semiconductor plants in Iwate was experiencing all kinds of difficultly with there i2 Factory Planner implementation. They had been working on it for nearly 18 months and the results were not as they had hoped. The planning model in Japan was taking over 20 hours to solve and the result was unusable.

Adexa was contacted and was asked to build a prototype model of the Iwate facility. This plant comprises multiple fabrication and assembly/test plants. The prototype project was extremely successfully and we progressed to full implementation of our applications for these facilities. The full implementation took a total of five months to complete, over 3-times faster than i2, and ours was successful.

The results that the plant experienced using the Adexa planning tools were equally as impressive as the time it took to implement. The following results were published independent of Adexa in a Japanese trade publication. The Iwate facility decreased their planning & scheduling cycle time by 87%, decreased inventory by 30% and increased throughput by 20%.

Taiwan Semiconductor Manufacturing Company (TSMC)
TSMC is the world's largest pure play foundry company, based in Hsin-Chu Taiwan. They build roughly 45% of the worlds wafers that are produced from foundries.

In April 2000 TSMC started their selection processes for an Advanced Planning & Scheduling solution. The two vendors selected were Adexa and i2. The selection process went on for five months and involved each vendor having to build complete factory planning solutions for two different MES data sets. The two MES systems that TSMC used for this prototype activity were Promis and Poseidon.

Each vendor was given the exact same data from these two systems and had to create two working planning models. TSMC was going to pick the vendor that demonstrated a solution that was fast, accurate and produced a planning result that they could execute to.
Adexa won this bake off and in October 2000 was selected to proceed to implementation on the first six manufacturing plants. As of April 2002, only 18 months later, Adexa had successfully implemented the following modules:

1. Plant Planner (PP) for one mask making facility.
2. Plant Planner (PP) for ten wafer fabrication facilities.
3. Supply Chain Planner (SCP) for six probe sites.
4. Supply Chain Planner (SCP) for their outsourced assembly/test manufacturing.
5. Supply Chain Planner (SCP) for master production scheduling for all wafer fabrication plants.

One of the great achievements has been that in just 18 months we implemented 14 different modules successfully for TSMC.