Review Article

Engineer to Order Approaches in SAP

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Abstract - *This paper discusses the possible approaches for designing Engineer to Order (ETO) supply chain scenarios in SAP. SAP is one of the key global ERP vendors and has embedded manufacturing strategies in its product. Some of the most common supply chain strategies included in SAP are Make-to-Order, Make-to-Stock, Assembled-to-order, and Configure-to-order. Heavy engineering/design-based Industries follow the Engineer Order manufacturing strategy to meet customer requirements, usually unique and heavy design-oriented. The ETO scenario is very complicated compared to other manufacturing scenarios as this involves the Design phase, which involves customization, it includes NPDI -New Product development and Introduction, it needs to support advance procurement of long-lead components while the design is under progress, it needs features for forecasting the cost even before the firm sales order is placed by the customer. This paper analyzes key requirements for an ETO scenario and available SAP solutions and then recommends the appropriate ETO approach.*

Keywords *- Engineer-to-Order, ETO, Supply chain, SCM, SAP, ERP, Make-to-Order, Manufacturing strategies.*

1. Introduction

1.1. *Characteristics of Engineer-to-Order*

Despite several scholarly articles on Engineer-to-order, the ambiguity still exists, and the ETO strategy hasn't received full attention [4].

Some of the supply chain structures which are well defined in industry are BTO(Buy-to-order), MTO(Make-to-order), (ATO)Assemble-to-order, MTS(Make-to-stock) [13]-[17].Engineer-to-order [4] is also known by many other terminologies in the industry like Project [2], craft [1], one-of-a-kind [3], and Design-to-order [4].

The unique characteristics of the ETO supply chain are well explained by Jonathan Gosling, and Mohamed M. Naim, in their engineer-to-order supply chain management: A literature review and research agenda [5].
"1) Production flow in ETO supply chains is all driven by actual customer order 2) The decoupling point is located in the design stage 3) ETO companies may modify existing designs or develop completely new designs."

Based on the above scholarly articles, if an organization is producing products that are mostly unique to each customer, if the product development is fairly complex and involves design engineering if you need to plan long lead items before the final BOM(Bill of material is ready), if the estimated cost quoted to the customer is based on a template consisting of version based Bill of material and roughly built routing to manufacture the same, if the final product design might take several days to months based on design discussion between the customer, manufacturer design team

and external vendor who supplies /manufactures some assembly based on a design shared by the design engineer, if the change requests are very frequent compared to Make-to - Stock or make-to-order strategies and if the final cost usually varies quite significantly from the initial estimate due to change requests, then we could say that organization has ETO manufacturing strategy in its landscape.

SAP uses the variant configuration and advanced variant configuration product to satisfy the customization needs of the ETO scenario [10]. Product complexity differs from one customer to another, which is documented well by Forza [11]. This complexity could be handled in SAP using variant configuration. This would give a competitive advantage to customers [12].

1.2. *The difference between Configure to order (CTO) and engineer to order (ETO)*

"Supply chain structure literature is largely conceptual" [5]. Hence there is no uniformity in naming ETO strategies. However, for driving a difference between completely new customized design ETO vs. modifying existing ETO design [6]-[9][18]-[20], some industries differentiate the ETO to Pure ETO (Entirely new customization) and partial customization as CTO (Configure-to-order). The approach for these strategies would differ in SAP. This difference would also decide how much customization should be automated in SAP.

Table 1. ETO Vs. CTO (Initial status)

Type	*Engineering/Design	*BOM Routing readiness	*Accuracy of cost estimation	Bare minimum product design when a Sales order is received
ETO	90-100%	<30%	<30%	Doesn't exist
CTO	<10%	>90%	>90%	Exists

*Rough estimation based on author's SAP ETO implementation experience with SAP. Due to the missing uniform approach by industry, when SAP is used as manufacturing software, an approach is necessary based on the type of ETO used along with other constraints explained in the other sections of this review paper.

1.3 Challenges and Pain points in Identifying right the ETO approach in SAP

1.3.1. SAP landscape

In brownfield implementation, the existing landscape plays an important role in deciding which modules in SAP need to be chosen to build an optimal ETO approach. The customer's budget would decide which modules could be proposed for an optimal /full-fledged ETO approach in greenfield implementation.

1.3.2. SAP business processes

Although SAP has features to configure all the business processes required for ETO, it is up to the business to decide which ETO processes should be inside SAP. This challenges the consultant on integration and automation as some key data would be outside SAP.

1.3.3. Automating design knowledge

Many companies don't want to automate their design knowledge. Where the competition is intense, companies want to automate their design knowledge during the quote stage itself to respond to customer requirements quickly without having to iterate with design engineering for every design input. In SAP, automating design input is achieved through the Variant configuration module. Designing a Variant configuration module for easy input by the customer/CRM team and achieving automated BOM and routing creation is a challenge in SAP.

1.3.4 Capturing design processes before manufacturing

There are many out-of-the-box options in SAP to capture the design process SAP. Choosing the right option based on business requirements is a challenge by itself, E.g., how to plan to capture engineering Capacity management and Engineering cost before even the actual sales order is received. Where to store the design documents, integrate the design documents with external suppliers/vendors, etc.

1.3.5. ETO Cost considerations

SAP has many options to calculate planned costs, COGS (Cost of goods sold), COGM (Cost of goods manufactured), and track actual Vs. Planned Vs. target costs. Depending on the nature of the ETO business, we may have to plan the correct cost planning model, like whether sales order costing or actual costing should be used. Based on how the business wants to track the changes to planned Vs. Actual cost: We may have to decide how cost version planning is designed.

1.3.6. Manufacturing process

SAP has a manufacturing module (PP) and shopfloor modules like MII & PEO. Depending on how complex the current manufacturing architecture and requirements are, challenges arise to model an optimal manufacturing integration scenario for ETO.

1.3.7. ETO procurement process

The ETO process is time-consuming, so advance procurement of long-lead items is very much part of the ETO process. Challenge is to ensure that when the final BOM is designed and handed over to manufacturing by engineers, we need to ensure no double demand generated from MRP.

2. Methodology

To arrive at various ETO approaches for SAP, business requirements for ETO were compared with the SAP product options. This approach considers As-Is study of the legacy system architecture to be the company's architecture where this would be implemented. Since the ETO scenario requires Sales, Engineering, manufacturing, project management, procurement, and finance scenarios, the following systems are needed to implement an optimized ETO solution.

Table 2. ETO Methodology

Functionality	Product Options	Pros	Cons
Initial ETO Cost estimates	SAP Product life cycle costing [21]	The highly flexible cost forecasting tool	Separate System and may cost additional license cost.
	Use SAP WBS/network (Project) templates for each product variant	Comes out of box solution, but we may have to use the SAP Project system	This is master data which is time-consuming. If the product variations are too many, this may not be a right solution
Manage quotation/sales	SAP SD Quotation/ sales orders	Out of the box functionality from SAP	NA
Mange Design/BOM/Material/Change master/Document	SAP PLM,	Out of the Box PLM	
	PTC-Windchill /Team center/	Popular PLM systems	The interface needed to integrate with SAP
Product Modelling/Configuration	SAP VC-variant configuration	Out of box functionalities to manage variable characteristics of the product	
Capacity management and scheduling	SAP PS/PP	Embedded sap functionality	
Project Monitoring	SAP PS	Out of the box functionality from SAP	
Portfolio Monitoring	SAP PPM(Optional)	SAP product for Project portfolio management	May cost additional license cost
Production	SAP PP	Out of the box functionality from SAP	NA
Procurement	SAP MM	Out of Box from SAP	NA
Finance	SAP FI	Out of Box from SAP	NA
There are many other interfaces possible. However, the most used basic modules of SAP are listed here.			

3. Results

SAP software doesn't bind you by one single approach to ETO. It gives enough flexibility to mix and match many of its features to design an ETO Solution.

3.1. Approach1 - Basic

Table 3. Basic Approach

Main ETO process	Features	SAP Modules	Remarks
Customer interaction -Quote process	-Multiple Interactions with customers for design finalization, timeline, and price	Handled outside SAP	The final outcome of Design features, price, and timeline was transferred to SAP
Planning-Price	Planned price calculation	Stored as condition type in sap sales order	The price is determined outside SAP and stored in SAP for variation analysis.
Planning Long lead items	Since Final design takes time, common Long lead items are planned	SAP MM	Purchase orders are planned ahead of time
Capacity planning for engineers	Availability check and booking of Engineers	Outside of SAP	The cost is temporarily collected at a cost center and then transferred to the ETO material cost.
Planning BOM and routing	Design Engineers finalize BOM iteratively and release	Customer-specific (Sales order specific) BOMs	Every BOM for the material would be

	them stage-wise for manufacturing.	and routings are created	different
Raw Material Procurement	Raw material procurement proposal generation from MRP	SAP PP MRP	MRP is capable of generating the right make/buy proposals
Subassembly production	Subassembly production	SAP PP production orders	
Final Assembly production	Subassembly production	SAP PP production orders	
Change management	Changes to design due to customer requirements or reengineering or due to defects.	SAP basic OCM- Order change management	The basic change order management can handle changes to BOM and routings before the start of production.
Quality management	Quality inspection at various stages	SAP basic QM-Quality management	Standard SAP feature
Timesheet Confirmation	Confirmation of labor and engineering hours	Basic sap confirmation	Production order confirmations
Delivery/Shipment	Delivery of finished goods/ship loose items	SAP delivery and shipment	Standard sap feature
Milestone billing	Phase wise billing	Standard billing feature	Standard SAP feature
Warranty	Warranty services	Outside SAP	

3.2. Approach 2 - Optimal approach

Table 4. Optimal Approach

Main ETO process	Features	SAP Modules	Remarks
Customer interaction -Quote process	-Multiple Interactions with customers for design finalization, timeline, and price	Inside SAP with SAP quotation, Variant configured BOM	Final Quotation in SAP with Rough cut BOM and Routing
Planning-Price	Planned price calculation	SAP quotation with approval and then conversion to SAP sales order	The sap Sales order will now have price and Variant configured order
Planning Long lead items	Since Final design takes time, common Long lead items are planned	Long lead items are planned through SAP project systems	SAP Project system has features for advance procurement which prevents double procurement when final BOM is used in MRP
Capacity planning for engineers	Availability check and booking of Engineers	Inside SAP Project system	SAP Project system has features for doing workforce planning.
Planning BOM and routing	Design Engineers finalize BOM iteratively and release them stage-wise for manufacturing. These BOMs can iteratively be transferred to the SAP project system and trigger MRP requirements.	Customer-specific (Sales order specific) BOMs and routings are created and transferred to MRP via the SAP Project System.	Every BOM and routing for the material would be different for different customers.

Raw Material Procurement	Raw material procurement proposal generation from MRP	SAP PP MRP	MRP is capable of generating the right make/buy proposals
Subassembly production	Subassembly production	SAP PP production orders	Using SAP PS, you can control the schedule of sub-assembly production.
Final Assembly production	Subassembly production	SAP PP production orders through MRP	Final assembly could also be done through SAP PS
Change management	Changes to design due to customer requirements or reengineering or due to defects.	SAP advanced OCM- Order change management	The advanced change order management can be handled changes to BOM and routings before and after the start of production.
Quality management	Quality inspection at various stages	SAP basic QM-Quality management	Standard SAP feature
Timesheet Confirmation	Confirmation of labor and engineering hours	Advanced timesheet management in SAP PS for sap confirmation of engineering hours	Production order confirmations could be integrated with the shopfloor MES system.
Delivery/Shipment	Delivery of finished goods/ship loose items	SAP delivery and shipment	Standard sap feature. We can use the SAP PS solution for partial delivery too.
Milestone billing	Phase wise billing	Standard billing feature	Standard SAP feature
Warranty	Warranty services	SAP warranty module could be used to track vendor/customer warranty	
Cost calculations	SAP FICO	By using SAP PS, you have the feature to monitor ETO profitability on an actual cost basis.	

4. Conclusion and Recommendation

4.1. Basic Approach
- Pros
  - Quick to build
  - Minimal build cost
- Cons
  - The engineering process before manufacturing is outside SAP
  - Initial costing is outside SAP, hence may not be reusable for any similar quote next time.
  - Cannot monitor the ETO project as a project.

4.2. Optimal approach
- Pros
  - Highly integrated solution
  - Maximum visibility from quote to Warranty processes inside SAP
  - Reusable quotes (Due to sap quotation and variant configuration process)
  - Reusable designs (Due to Variant configuration)
  - Would be able to adopt actual planned cost
  - Flexible for changes due to advance changed order functionality
- Cons
  - Build time is high.
  - Build cost is high

5. Recommendations

5.1. Basic approach
- This is recommended for enterprises with the very low competition due to unique products.
- This is recommended for enterprises where design knowledge data can't be automated.
- Recommended for enterprises where ETO process revenues are significantly less.

5.2. Optimal approach
- This is recommended for enterprises where competition is very high and quote/requote response must be accurate and fast.

- This is recommended for enterprises where design knowledge can be automated.

Recommended for enterprises where ETO process revenues are significantly high.

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