Supply chain management in the PV industry

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ABSTRACT

Efficient management of the PV supply chain can save a company money, both directly by reducing material and component cost, and indirectly by improving lead time, inventory optimization and quality throughout the entire value chain. So-called static supply chains compare poorly to their dynamic counterparts that see cost reduction and quality as well as material availability improvements. What follows is a proposal of improving the supply chain using methods like integration, data exchange and collaboration that can also help to improve entire E2E flows through re-structuring and outsourcing from one level to another.

Motivation

As succinctly put by Linda Cantwell, an IBM executive in the ISC organization, "It's very exciting to see how the challenges of today's global marketplace are bringing increasingly sharp focus to how supply chain business processes – operated as an integrated whole – bring strategic competitive advantage to the enterprise. The more complex the business model becomes, the faster supply chain excellence is recognized as a critical competitive tool and solution. Whether trying to determine how best to accelerate delivery of value to one's clients or where in the world is the optimal location in which to operate, supply chain emerges as a critical discipline which can bring direct and truly sustainable business performance improvement."

Supply chain or value chain?

Each industry has its own supply chain structure and set of issues, but many principles are common to all (see schematic in Figure 1). The typical scenario for most supply chains is that the complexity goes from the client down into the supply chain, moving from tier 1 down to tier x. Efficient and flexible management of such a complex chain of events and participants is not a trivial matter.

The value chain consists of the value-added processes that enable a company to bring its products from conception to market, usually comprising the E2E chain from raw material to finished product for the end customer. The supply chain is a subset of the value chain.

Figure 2 clearly demonstrates that any problem encountered at the beginning of the value chain (raw material supply) can cause major problems at the end of the value chain. If the raw material, the sheep and its wool, is not stress reliable, for instance, the end customer will have problems with his/her pullover seeing faster degradation while wearing, washing, etc. This issue will be discussed in more detail in relation to the bullwhip effect (see Figure 9).

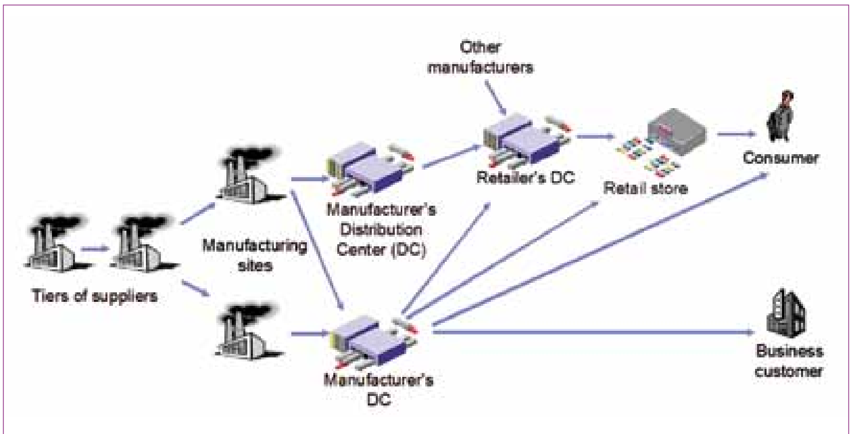

Figure 1. Typical supply chain structure.

Figure 2. Value chain example from sheep farming to clothing (end product).

In the case of the PV industry, the value chain (E2E) covers from raw silicon (or even as far back as sand) up to the final installed module at the customer's site, including after-sales activities such as maintenance, upgrades, grid management, etc. The supply chains in the PV industry go from raw silicon to wafer (wafer manufacturing); silicon wafer to solar cell (cell manufacturing) and solar cell to module (module manufacturing). Beyond this, the distribution net (grid) starts. The supply of materials such as raw silicon wafers is pretty much based on the static approach, using normal purchasing and long-term contracts, to secure materials availability. Other industries not only order materials in their supply chain, but also transfer technical as well as quality responsibility into the supply chain in order to achieve better improvement potentials in terms of technology, quality, yield and cost.

Supply chain requirements

Various elements must be available to achieve an efficient supply chain that works in a competitive manner and brings about cost savings. The following sections put forth a list of essential elements that must be in place in order to make the graduation from a static to a highly dynamic working supply chain approach. The key items discussed are supply chain integration, process integration, data exchange in the supply chain and supplier auditing and development. When setting about improving an existing supply chain, the working level should be at least at the static supply chain level, from which point the improvement can be performed step-by-step as outlined in the following sections. Improvement steps can be introduced simultaneously if the required capabilities and support mechanisms are in place. It should be mentioned at this

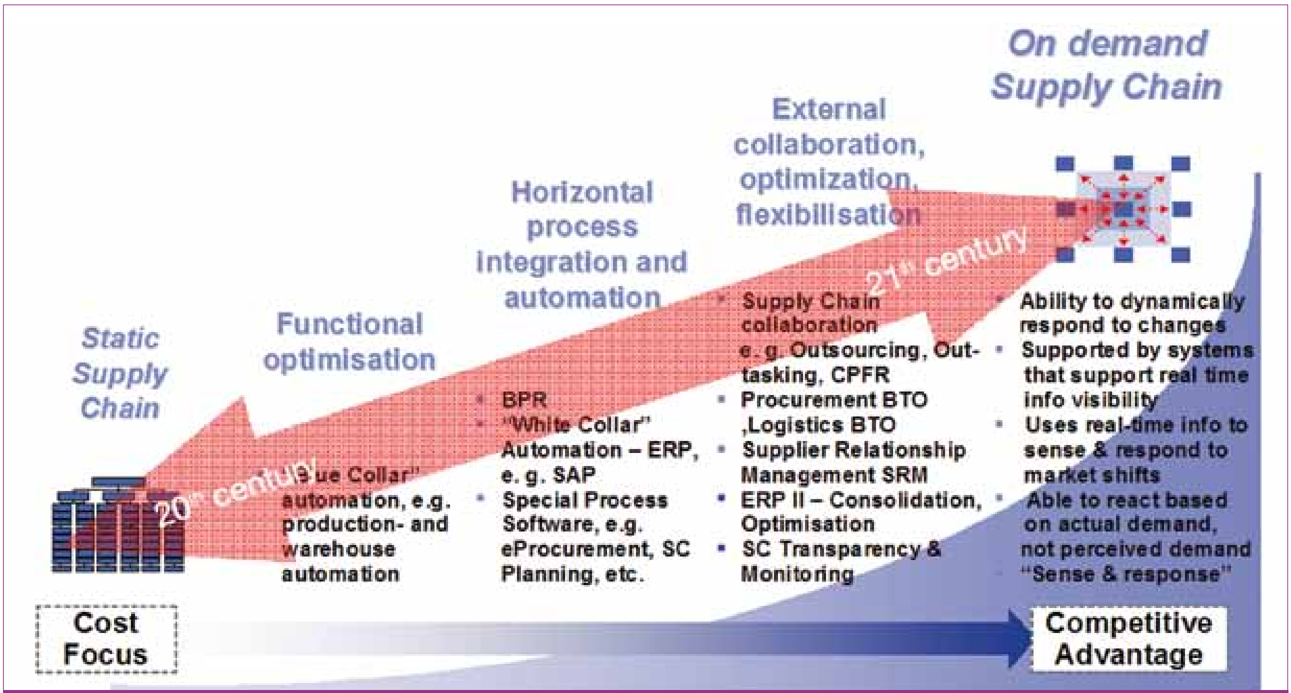

Figure 3. 'Point-of-View on the Progression of Supply Chain Management to a Smarter Future.'

point that the realization of the following sections would, in every case, require a certain IT structure. The elements of this structure can be implemented while applying the individual improvement steps.

Supply chain integration

The process from a static supply chain to an on-demand supply chain takes various steps, as shown in Figure 3. This process also has an integration effect in the supply chain. While the static approach brings only a cost focus, the on-demand approach generates not only cost but also competitive advantages.

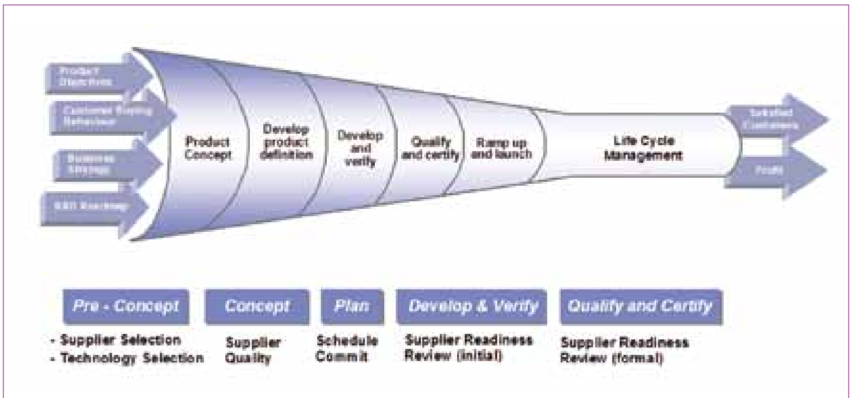

Figure 4. Supplier involvement during product life cycle.

> "The smart supply chain is interconnected, allowing the development of strategies, policies and providing the infrastructure to connect to the thousands of partners involved in a system."

IBM's 'Point-of-View on the Progression of Supply Chain Management to a Smarter Future' begins with the overall competencies of the organization as it moves from static and isolated departmental performance to functional, focused operational excellence, and from functional optimization to horizontal process integration (or internal collaboration) within the company, and then to external collaboration and integration with partners.

The smart supply chain is flexible in responding to the volatilities and complexities of today's marketplace. At its core, it is instrumented and manages the complexity through integrated transactions (integrating ERPS to ERPS of manufacturers to suppliers and then to customers), and uses sensors and actuators to automate transactions.

The smart supply chain is interconnected, allowing the development of strategies, policies and providing the infrastructure to connect to the thousands of partners involved in a system that balances risk, increases performance and enables shared decision-making.

The smart supply chain is also intelligent and enables the optimization of the '4 Flows': product flow, information flow, people/process or work flow and the one so often forgotten, the cash or financial flow. Implementation of networked planning and smart execution practices across the entire supply chain network with decision support will result in flexibility and stability in the race to achieve profitable growth.

The automotive, electronic and semiconductor industries, for example, have reached the on-demand level, and beyond, while the PV industry mainly works in the static supply chain mode in order to control supplied material cost and secure the material supply with mid- to long-term contracts.

Integration within the supply chain has improvement potential for the PV industry in that it provides:

- Tighter cost control throughout supply chain
- Cost improvements
- Quality improvements
- Utilization improvement
- Inventory improvement
- Efficient collaboration, faster development and NPI (time-to-market)
- A joined technology roadmap.

Process integration

Product life cycles are constantly shrinking, creating a need for a much more flexible and adaptive supply chain. Life cycles are shrinking from years to quarters, resulting in:

- a high ramp-up risk

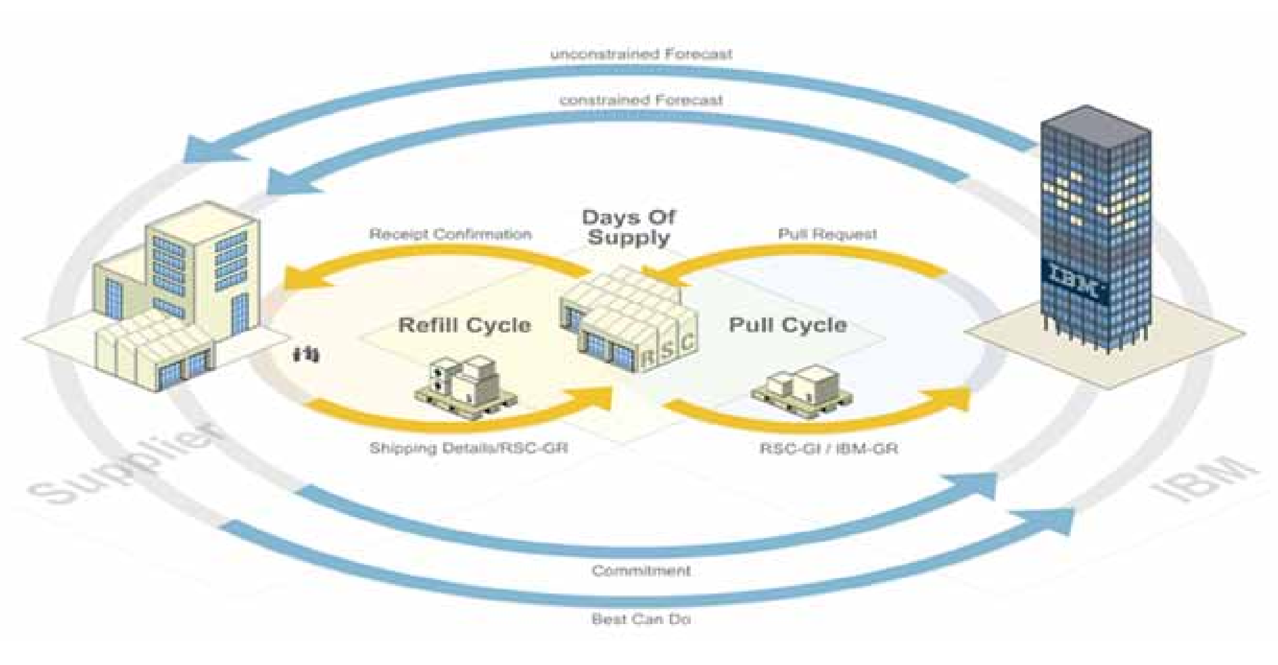

Figure 5. Data exchange model used in the replenishment process.

- short volume production
- the need to plan and execute phase-out very professionally.

The life-cycle reduction carries the risk of missing the time-to-market window as well as the appropriate management of the end-of-life timing of the product, elements that can be managed much more effectively by having a well-integrated process in place. Product development is executed by cross-functional teams following a stringent process with clearly defined rules, objectives and milestones. Figure 4 shows an example of a flow from product concept to end of life cycle. Suppliers are integrated in the product development process to leverage their expertise at key stages.

It is very important to have an E2E management process that is capable of understanding the entire chain and of reacting in a preventive way to any incidence taking place throughout the entire chain. The design principles determine the degree of supplier involvement: in this example, the process flows from white, to grey and to a black box design, as outlined below.

In the case of the white box design, the knowledge is entirely on the OEM side and also provided through the OEM into the supply chain. The grey box approach represents shared activity between the OEM and the supplier which means that the OEM still has to carry pretty much all of the knowledge of the design. The black box approach is set up so that the entire design knowledge is covered through the supplier. Such a set-up certainly requires much higher visibility on the part of the OEM into the supplier development as well as manufacturing so as not to lose track of the OEM's own technology. This is achieved by being involved not only in providing specifications, but also detailed requirements and definitions, with the necessary securing of appropriate interfacing with the OEM follow-on product and processes.

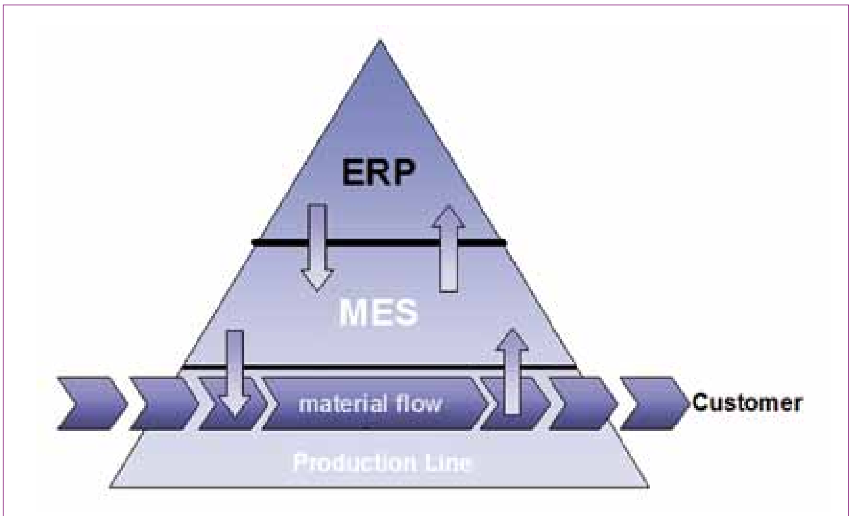

Figure 6. Typical IT structure in a semiconductor or electronic manufacturing environment.

The marketplace we are operating in is a dynamic one of ever-changing ups and downs and, regardless of the state of the market, it will always have high demands. Customers want the best price on a product with delivery as soon as possible, with the supplier holding buffer inventory up to the point of use.

How can we be responsive enough, effective enough, and keep supply chain cost low enough to meet these demands?

Effective collaboration and planning are possible using:

- Resource management
- Demand management
- Availability management
- Manufacturing alignment.

Possible benefits for the PV industry in applying process integration would be:

- The ability to outsource technology into the supply chain
  - Higher quality on supplied material
  - Better controls through supplier responsibility
  - Shared technology roadmaps and collaborative efforts
  - E.Q. technology transfer into the supply chain, such as texturing, doping, characterization (receiving COC – certificates of compliance), etc.
- Supplier involvement in development enables a joined roadmap
- Efficient equipment management on demand ('pull, not push')
  - E.Q. development speed and requirements will be determined by the solar industry, not the equipment supplier.

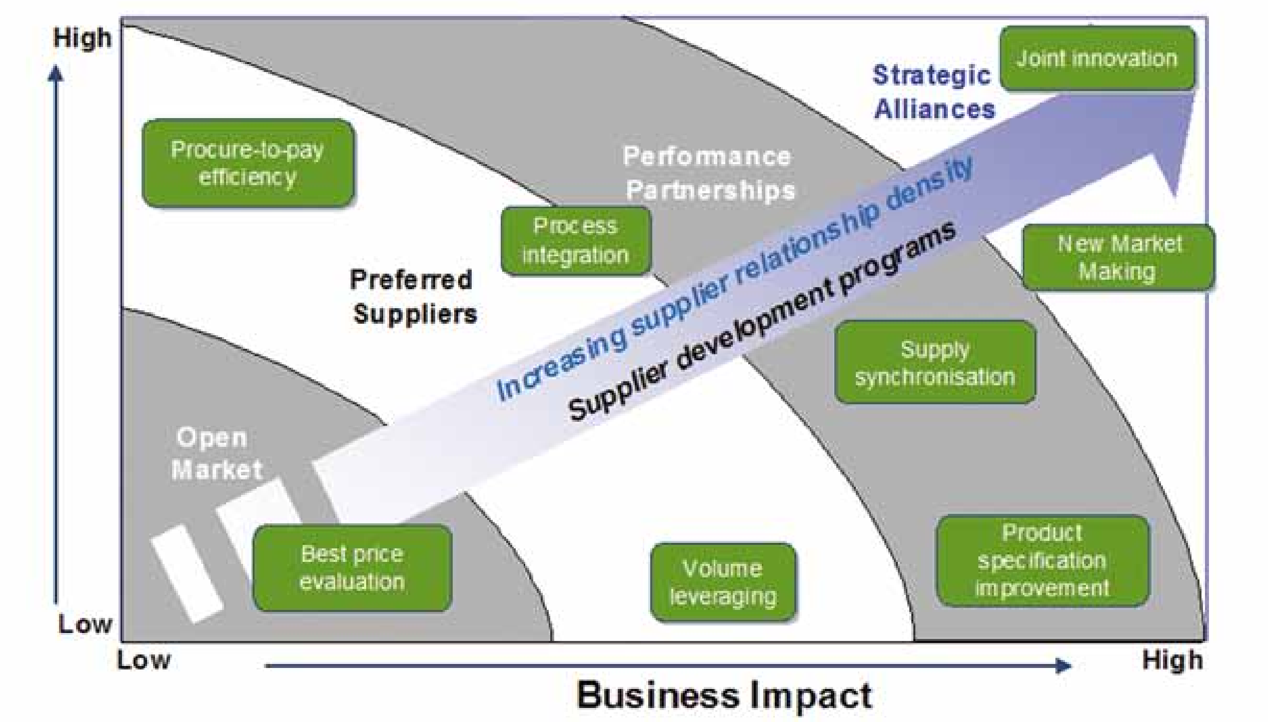

Figure 7. Supplier development framework and relationship chart.

Figure 8. Cost pressure and requirement chart for supply chain management.

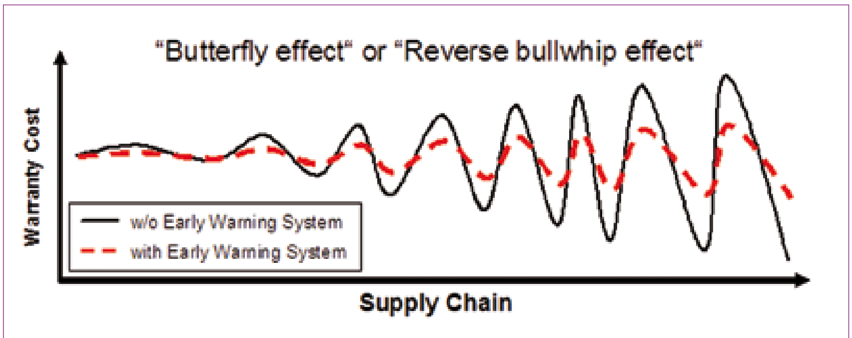

Figure 9. Example of the bullwhip effect reverberating throughout value chain.

Data exchange across the entire supply chain

Real-time data sharing and exchange is a must for visibility into the supply chain and to improve reaction time. Figure 5 gives an example of the data exchange model in the case of supplier collaboration and the replenishment process.

The data exchange in the replenishment process transformed logistics warehousing from 100% owned to 100% vendor-managed. The ability to respond to shifts of hardware demand inside quarterly lead time improved by up to 50%. Using the data exchange within the supply chain effectively necessitates a good IT structure in the manufacturing, as outlined in Figure 6. This IT structure ensures that all data from the incoming supply chain can be used to secure optimized and cost-effective manufacturing; required data is also delivered to the outgoing supply chain. The incoming supply chain, in a best-case scenario, provides all necessary data to secure the optimum quality and material availability. It also can be used to release the material into manufacturing, replacing the COC. The real-time data availability from the supply chain enables the site to work in a preventive working mode rather than a reactive mode, which typically has the disadvantage of reacting after an incidence has already occurred, or 'after the fact.' Preventive mode ensures that there is little or no damage to the production line by, for example, having failed material, or material that has not yet left the site of the supplier.

Possible benefits of applying data exchange in the supply chain for the PV industry are:

- Quality visibility throughout the supply chain
- Traceability throughout the supply chain
- Ability to transfer from reactive into preventive working mode
- Specification management and ongoing improvement
- Improvement management
- BOM management
- Technology roadmap management.

Secure material availability

A part or product may be critical for several reasons, including:

- Supply constraints
  - identified during planning cycle
  - identified during execution
  - identified by surprise
- New technologies
- Single sourced
- Unique part
- Quality problems.

State-of-the-art supply chains are no longer back-office functions – they are developed in a competitive way to generate value. Customer satisfaction as well as growth and profit are directly impacted by superior supply chain management. Use of a tight integration model allows the OEM to plan the entire parts demand in one planning run, thus avoiding sequential planning.

There are several positive factors that may arise from applying secured material availability, which include:

- Reliability for the customer
- Improved forecasting and planning
- Tigther material and inventory management
- Improved backup structure to secure shortages (unplanned)
- Better utilization of manufacturing, especially within global business
- Speedy collaboration across the entire supply chain.

Supplier development and auditing

Managing a supply base will involve the use of different relationship strategies to support the category strategy. Determination of the appropriate type of supplier relationship provides a framework for how suppliers should be developed, managed and integrated. The relationship overview chart is shown in Figure 7.

Cost pressures and quality expectations have significantly intensified over the last few decades, and may resemble the example given in Figure 8.

How can a more complex world be managed with a reduced number of audits?

- Today's companies are faced with much higher quality expectations than they were a few decades ago.
- In parallel, pressure on cost has been a superimposing imperative.
- Due to increasing supply chain complexity and supply challenges (disaggregating and globalisation) as well as cost pressure, the number of audits had to be reduced.

The 'butterfly effect', also known as the 'reverse bullwhip effect' means that a minor incident can cause major problems (see Figure 9).

- A defective 50 cent chip from a Tier 2 electronic supplier can cause tremendous damage for the end customer and result in major warranty claims to the electronics OEM.
- A quality early warning system could have detected the defective part even before delivery from the Tier 1 supplier to the electronic OEM.

Having a better understanding and knowledge of the supply chain helps in the reduction of warranty costs. A baseline for this is to have an appropriate supplier development program in place as well as auditing, which delivers visibility and knowledge into the supply base. Performing audits ensures that the supply base is aligned with the customer requirements concerning volume, quality, timing, cost, etc.

Various audits are performed, such as:

- Technical audits with the purpose of
  - Qualifications
  - Manufacturing readiness review (MRR)
  - Quality assurance gates
  - Quality audits
  - Following-up
- Business audits with the focus on
  - Manufacturing readiness review
  - Supply chain audits.

Each of these can be performed as external or self audits. An external audit is usually performed by external resources, for example the supplier's customer or another third party, and takes the form of an audit questionnaire which is provided to the party undergoing the audit upfront. Self auditing is normally performed in-house with internal resources, and is also based on the client's questionnaire. The client receives the answered questionnaire and can follow up based on the evaluation.

Audits represent a powerful mechanism with which to assess and assure an expected level of performance in the supply chain, and can be applied in the PV industry with the following possible outcomes:

- Secure the highest quality and best cost within the supply chain; because supplier quality determines final quality, no improvements in follow-on processes are possible
- Supplier performance visibility and proactive mode capability
- Effective supplier management (prioritized)
- Secures volume-based demand and required flexibility
- Maximum mobility and accessibility.

Summary

It is of utmost importance that the supply chain is integrated with the supplier's involvement as well as the related processes. The supply chain should be improved in terms of visibility and data availability (real-time) to secure material flow at an appropriate quality level and cost. The positive numbers resulting from supply chain implementation or improvements are very significant and have beneficial effects for the financial, operational as well as the client-facing areas.

Taking the example of IBM's findings, the company saw cost and expense savings of more than 5% of the yearly revenue (calculated year-over-year for at least four consecutive years). Significant cash sums were also generated on a yearly basis in the magnitude of three-digit million dollar amounts, with further financial potential possible by altering average payment terms by one day or more.

Operational success factors include inventory standing at its lowest level in 30 years, cycle times being improved by more than 7% year-over-year, or audit records reaching the 100% level and remaining at this mark.

Client-facing success factors include significantly improved turning of client orders at greater than 30%, coupled with customer satisfaction improvements of over 2% year-over-year and significant improvements in time delivery as well as order-to-delivery cycle time, each of which saw a rise of more than 10%.

It is clear that the financial, operational as well as client-facing figures are showing outstanding improvement year-over-year, which has been enabled solely by improving the supply chain as discussed in this paper.

The PV industry stands to benefit from these supply chain advancements by enabling a much faster route to grid parity, reduction of material and process cost, improved efficiency and quality and a resulting acceleration of technology roadmaps. In conclusion, it would certainly be worthwhile to investigate how the discussed supply chain enhancements could be applied to the PV industry.

About the Authors

Rainer Krause is manager of the ISC (Integrated Supply Chain) technology centre and has worked at IBM for 13 years in positions including engineering manager for automation, test engineering and lithography. Earlier in his career, he spent several years at DEC (Digital Equipment Corporation) within the storage technology and HDD (Hard Disk Drive) development sector. His additional responsibilities in IBM include master inventor, innovation champion and member of the technical expert council and patent review board, and he is also a member of the worldwide solar council within IBM. A qualified electrical engineer, Mr. Krause also has a Ph.D. in physics.

Udo Kleemann is Senior Procurement Manager and Head of System and Technology Groups, EMEA for IBM. He has over 25 years of technical leadership and managerial experience across IBM's Integrated Supply Chain (ISC) from Production Procurement, Cost Engineering, Manufacturing Engineering to Supply Chain Management, Materials Management and Logistics. Currently serving as senior manager within the ISC EMEA Production Procurement team, Mr. Kleemann has developed and patented a supply/demand collaboration tool, RSC@. He has a Master's degree in mechanical engineering.

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