PHENIX

WHITE PAPER

PRODUCTION SCHEDULING – THE GOOD, THE BAD, AND THE UGLY

Lessons from the field on the importance of having a best-in-class scheduling strategy supported by the right software – and best practices to get there.

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INTRODUCTION

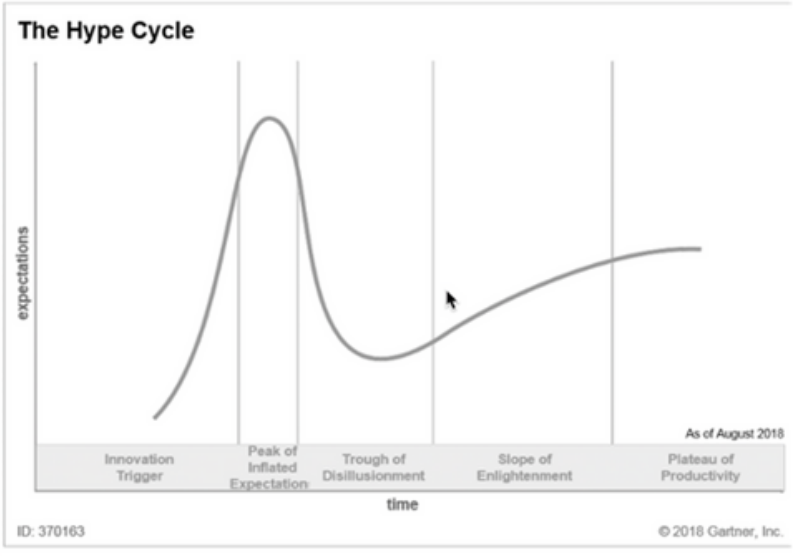
Production planning and scheduling is an extremely important activity that often doesn't get the attention or resources needed for manufacturing and corporate success. Indeed, it can be considered mission critical; if done well it can be a strong competitive advantage, but if done poorly it can prevent corporate goals from being achieved. With 90 years of combined experience in this field, we have seen all sides of this multidimensional activity. We have witnessed and recorded the strategies and methods of those who have done it well, and have observed, analyzed, and sometimes rescued those who have not.

THE PROBLEMS

Production scheduling is essential to a company's ability to achieve their supply chain goals, yet often not given the attention it truly deserves. The hidden costs of ineffective scheduling are often overlooked. An excess of some SKUs can be produced, while an inadequate amount of others might be made. This results in high working capital and poor customer performance at the same time. As an example, the finished product inventory for weatherproofing house wrap once had 80 days of finished product inventory, yet the customer fill rate was only in the low 80 percent range. Poorly designed scheduling systems generally lack the degree of agility and robustness to deal with the frequent schedule disruptions that most manufacturing plants experience.

Some companies know their scheduling should be improved but they delay addressing it because they're in the midst of a big ERP transition or upgrade. The reality is that improving scheduling first will pave the way for a successful ERP implementation and result in achieving benefits faster.

We have seen cases where there is initial enthusiasm for developing and implementing an improved scheduling strategy or system. Planners realize that the business benefits are quite substantial, but the reality is that they can be hard to sustain without the right strategy, business processes, and culture. The Gartner Group's Hype Cycle, and its "Trough of Disillusionment" comes to mind. For any innovation to succeed, there must be commitment from leadership and the will to stay the course when you hit speedbumps.



Source: Gartner (August 2018)

We've worked with many companies that rely on Excel for production scheduling. Some believe that it is effective, while others realize that it is cumbersome and ineffective but don't know where to turn. Compared to specialized scheduling software, Excel is inefficient for both the planner's time and the company's production resources. The barriers to replacing Excel with a system designed specifically for scheduling are often in attitudes like:

Excel seems to be working just fine for us. Planning managers who believe this have generally not sat beside a scheduler for a day and experienced the difficulty of creating an effective schedule in Excel, or the chaos that any schedule disruption can cause. Nor have they been on the plant floor to see the inefficiencies caused by unexpected schedule changes.

Excel is simple and everyone knows how to use it. Many companies fall into the trap of thinking that Excel will allow planners to create an ideal customized solution for their business. However, the typical scheduling spreadsheet is complex, with multiple sheets and macros. No one except the person who wrote it can completely understand it. The reality is that many schedulers struggle when left with a complex planning workbook created by someone who may no longer be in the division or the company. A new scheduler must either write their own spreadsheet or continue to use one that they don't fully understand. And writing your own Excel spreadsheet to accommodate all of the different situations and variabilities of your operation is not easy. Even for the person who wrote it, it's hard to understand the complex and sometimes unintended relationships in an Excel spreadsheet, so errors can happen and go undetected.

Most home-grown Excel-based scheduling tools we have seen are not well documented, either in how the functions, equations, and macros are structured, or in how to use the workbook. That makes it difficult to train a substitute scheduler for vacation or absence coverage, creating stress on schedulers for fear of letting the organization down when they take time off. It's not easy for the replacement either; one of us once had to cover the medical leave of the company's planner for diaper packaging, using the model that they designed. He did his best, but probably cost the company a couple hundred thousand dollars in packaging obsolescence.

It's too expensive and too much work to change our process. This is often a "pay me now or pay me later" situation. Making the commitment now can reduce or eliminate the on-going economic penalties of an ineffective scheduling process. Does it cause a bit of disruption? Yes, change inevitably will. Does it take time and money? Yes, but will save a lot more in the long run.

Per Lora Cecere, noted supply chain strategist: "over 90% of companies depend on Excel spreadsheets. This is problematic in many ways. Excel spreadsheets are woefully inadequate to model a complex, non-linear system. The output, isolated, disconnected and out of sync with the business, spins endlessly. The lack of adequate supply chain planning systems drives maverick behavior in the organization".

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LORA CECERE

BEST PRACTICES

Overcoming these difficulties requires two things: the right scheduling strategy, one that balances the use of production capacity with customer performance goals and working capital targets, coupled with the right scheduling system, that enables that strategy to be implemented easily on a week-by-week basis and adjusted in real time as conditions change.

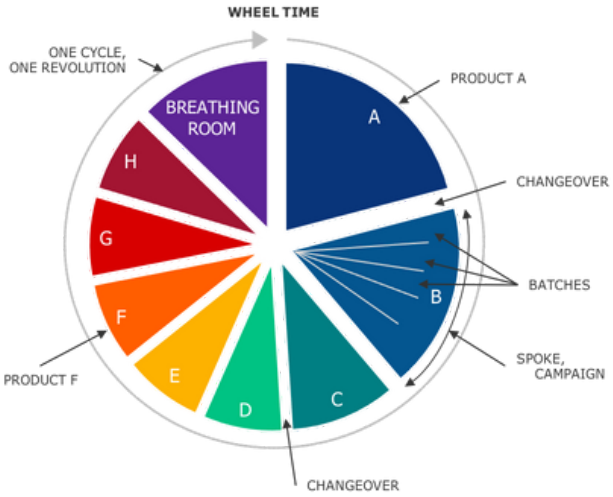
Before delving into scheduling strategies, it's important to define what scheduling is, and note the difference between planning and scheduling. In planning, we decide which products to run, and in what quantities, during each time period. In scheduling, we choose the best sequence in which to make the products for each time period, in a way that setup costs are minimized, without running out of stock or missing customer due dates. Scheduling calculates the start and end times and dates of production or process orders and passes the output to manufacturing operations for execution.

Proper capacity planning is a pre-requisite for successful scheduling. It's impossible to create a good production schedule from an overloaded production plan; no matter what the scheduler does, some orders won't fit. However, capacity planning is a subject for another paper, and the remainder of this discussion will focus on scheduling.

In addition to leading to strong financial results, a quality schedule ensures smooth and stable use of manufacturing resources and supports customer service goals. To do that, schedules must balance priorities, accurately represent the reality on the shop floor, and provide a zone of stability for material procurement and production execution.

Product Wheel Scheduling is a proven strategy for success. Variations on the concept are known as Rhythm Wheels, FSVV (Fixed Sequence, Variable Volume) and Repetitive Flexible Supply (RfS).These have been shown to improve manufacturing efficiency by 5-30%, and can be implemented in a few weeks, with rapid payback. Nature's Bounty, a global nutraceutical manufacturer, implemented Product Wheels at a major bottling facility, and saw a 12 point (33%) improvement in OEE (Overall Equipment Effectiveness), and a 34% increase in throughput. As a result, they were able to operate at the same capacity on 20% fewer lines and reduce annual operating costs by $1.5 million; these improvements were seen without any capital investment, simply by changing the scheduling strategy.

A Product Wheel is a regularly repeating cycle of all the products made on a production line or major asset. The fundamental cycle time is fixed and is based on the optimum balance of economic factors, such as the cost of various kinds of changeovers and the cost of carrying inventory, consistent with shelf life, minimum batch size and available inventory space constraints. The sequence is fixed to give the lowest cost path through all the changeovers required. Low volume products are not made every cycle, only frequently enough to justify the cost of the changeover. Make to Order products can co-exist with Make to Stock products on any appropriate cycle.



We have worked with companies that already employed some elements of a structured scheduling strategy before we started, but saw enhanced benefits through the rigorous adoption of the complete product wheel methodology, following a comprehensive implementation roadmap.

Any effective scheduling strategy, whether it be product wheels or some variation on the concept, must be supported by a scheduling system and an inventory strategy. The system must make it easy and convenient for a scheduler to execute the strategy. It should provide the scheduler with visibility of what is currently scheduled, new orders that must be scheduled, and how they fit into the established scheduling pattern. It should make it easy to adjust the schedule as the normal day-to-day disruptions occur. It should show the scheduler any problems, such as missed shipments, created by schedule upsets, and provide alternative solutions.

The inventory strategy must ensure reliable completion of the schedule. The scheduling system should alert the scheduler to inventory requirements of the resulting schedule, so that any space limitations can be resolved.

One common objection to Product Wheels is that using them will lead to inventory increases. In practice, we've seen the opposite. Often, properly calculated inventories with properly designed Product Wheels require less inventory than the business has been carrying. Unstructured production and inventories usually result in confusion, rush orders, accidental orders for unneeded products, and more inventory than if a structured approach had been used.

CHARACTERISTICS AND BENEFITS OF A GOOD SCHEDULING STRATEGY

A good scheduling strategy establishes a zone of stability that minimizes the negative effects of short-term changes to production orders. While short-term changes may seem necessary to deliver urgent customer requirements, they often generate significant additional costs and ripple effects on the following days, creating more service problems than they were supposed to solve. They may create several additional long and expensive changeovers – which leads to capacity loss and total production volume reduction, which in turn creates more disruption, more schedule changes, and more money and efficiency lost. At Procter & Gamble we used to call this the death spiral. We've seen many organizations where the culture of saving every missed case creates chaos in planning and manufacturing. A better strategy weighs the immediate benefits of a schedule change against the longer-term consequences.

We've seen a dozen ways that a structured, regularly repeating pattern like product wheels offered users substantial value:

1. **Enhanced predictability**, by establishing regular repeating production patterns. Everyone gets on the same page and adopts the rhythm that the wheels set, and this rhythm creates a drumbeat for the entire supply chain by creating regular, predictable patterns of raw material needs. Procurement can therefore give suppliers more accurate forecasts.

2. **Simplified changeovers**, by grouping similar products into families and dedicating each family to a specific production line (known in the trade as Group Technology). In-family changes are much easier to manage than family-to-family changes.

3. **Fewer, more efficient changeovers**, by making each product in a quantity that justifies a changeover.

4. **An optimum sequence** that minimizes the number of process functions that need to be changed on a changeover. The lines startup better with fewer minor stops.

5. **Leveled production**, to eliminate peaks and valleys, which waste resources in the valleys and require extra resources during the peaks (aka Heijunka).

6. **Clarity of which products should be Make to Stock and Make to Order**. An MTO strategy for the appropriate products will reduce inventory. MTS for the appropriate products will enhance stability and predictability.

7. **Optimized inventory** based on predictable production patterns and frequencies. With regular production cycles, the amount of cycle stock needed for any SKU is easily calculable. Because the elapsed time between production opportunities for each SKU is known, the time-at-risk factor in the safety stock calculations is also known.

8. **Increased customer delivery performance** by right sizing inventories based on production frequencies and forecast accuracy.

9. **Enhanced stability** by establishing production schedules that have a reasonable tolerance for variation and inventory levels matched to the variability.

10. **A stable base** from which any necessary day-to-day adjustments are easier. Wheels clarify the best courses of action and illustrate the ramifications of any changes.

11. **A simplified process for schedulers** by setting routine patterns for most scheduling decisions.

12. **More time available for schedulers to deal with disruption**. Because routine scheduling decisions have been made as part of the Product Wheel design, schedulers will have more time to analyze unforeseen events and make better decisions.

SCHEDULING STRATEGY CRITICAL SUCCESS FACTORS

For any scheduling strategy, such as Product Wheels, to be sustained, there are four crucial business processes and capabilities that must be in place:

1. Finished product and raw material inventories must be properly calculated and built to allow the business to reliably complete the planned sequence, considering the normal variability of demand, supplier delivery performance, and production reliability. Unless the Product Wheel sequence can be reliably completed most of the time, it's not really a Product Wheel.

2. Despite the best efforts to properly design inventories, there will be unplanned exceptions. The business must learn to react in a systemic way, evaluating whether a deviation from the designed pattern is the right thing to do. When a deviation is approved, they must place the emergency or high priority orders where they will have the least impact, and then return to the wheel structure to complete the remainder of the sequence. Without deliberate reaction, emergencies can cascade making it difficult to get the schedule back on track. Contingency Planning, a process to anticipate each possible schedule disruptor, determine the appropriate response, and get consensus from all stakeholders, is the critical task.

3. There must be a process to assess when business conditions have changed, and a commitment to redesign the Product Wheel patterns when needed. Often, everyone knows that conditions have changed, but the effort for redesign seems too high, and the business decides by default to muddle through, resulting in lost efficiency and unmet business objectives.

4. And finally, and perhaps most importantly, the strategy must have strong support from operating leadership, up to senior levels. Leadership must clearly understand the benefits the strategy provides, embrace it, provide the required resources to execute it, and show value for the appropriate KPIs. Leadership must display support for the strategy when schedule disruptions occur, and insure that the appropriate contingency plans are being followed.

CHARACTERISTICS AND BENEFITS OF A GOOD SCHEDULING SYSTEM

A good production scheduling system balances all relevant priorities. First, it must respect production order due dates as defined by the planning system. Second, it must respect raw material constraints, making sure that the manufacturing process is not interrupted by missing raw materials. Third, it must respect various manufacturing constraints, like availability of special equipment, which is needed to produce some of the products, or of specialized operators required to run specific production lines. Beyond meeting these base priorities, it must support an optimal sequence of production to minimize changeover time and material losses, optimize available capacity utilization, and minimize production costs.

Has sufficient capability, functionality, and algorithms to manage the complexity, and supports the scheduling strategy. We've described the limitations of Excel and similar tools for anything beyond the simplest scheduling requirements. More powerful software is generally required to manage the challenges that most manufacturing plants experience. The software should enable following the designed schedule patterns.

Well established stability: A good schedule has a zone of stability which allows for delivery of raw materials and predictability for the operations. How can material planners, purchasing, and suppliers effectively supply materials on time if the schedule keeps changing? Their only choice is to buffer the uncertainty with inventory of everything, but this leads to risks of obsolescence and shelf-life expiration. Our advice is to consider the lead times of your incoming materials and set a zone of stability that allows most of them to be procured within the stable period. Only a few critical materials will need to be buffered, and the overall inventory of finished products plus materials will be less.

Measures and analyzes performance: Schedule attainment metrics can provide an overview of scheduling effectiveness. If the schedule is not being achieved, further diagnostics are required to determine the causes and corrective actions. The simple question is: "did we make what was scheduled within the zone of stability, and if not, why not?". The root cause analysis should address:

- Are the production run rates correct? (If not, the cycle will either finish too early or too late.)
- Does the scheduling system represent reality on the shop floor, or is it producing schedules that are impossible to follow?
- Are operations being blocked or starved by lack of coordination with upstream and downstream processes?
- Are the downtime and uptime calendars correct?
- Did the schedule use the correct production lines and resources?
- Are the changeover times and the assumptions behind them correct?
- Is raw material availability a chronic limitation?
- Do equipment outages exceed the factors on which the schedule design was based?

Companies that have improved their scheduling processes have generally taken these five steps:

- They found a scheduling system that helped them balance priorities and accurately represent reality on the manufacturing floor.
- They made sure the data in the scheduling system was accurate. They reconciled various data bases so that there was a single source of truth for any parameter. They insured that units (pounds, gallons, cases, etc.) were clearly defined.
- They created a zone of stability to allow for effective and low-cost material procurement and production staging.

- They measured their schedule achievement within the zone of stability. It is almost always true that things that get measured show better performance than things that don't.
- They recorded deviations from the designed patterns, the specific circumstances and reasons, to determine the root causes and take corrective action.

The primary benefits of the right scheduling system are substantial:

1. It enables the business strategy to be executed in a straightforward, effective manner.

2. It assists the scheduler in managing disruptions by providing alternative choices and illustrating the consequences and impact on inventory, customer service, and manufacturing efficiency.

3. It provides a path to get back on the designed patterns.

In short, all the benefits we've described with a best-in-class strategy are very difficult to achieve without the right supporting system.

SCHEDULING SYSTEM CRITICAL SUCCESS FACTORS

When evaluating a scheduling strategy, look closely at its ability to execute these activities:

1. As families of products are being assigned to production lines, there must be visibility to the available capacity and current loading of each line, so that no line becomes over utilized.

2. The system should provide a straightforward, convenient way to place new orders into their best position in the sequence while meeting their due date.

3. An effective strategy will cause high volume or high value products to be produced more frequently than low volume or low value products; therefore, the system must provide a way to visualize and track multi-cycle wheels, where low volume products are not made on every cycle.

4. All product attributes influencing changeover cost or difficulty must be visible during the scheduling process and when designing Product Wheels. In our experience, many well-known scheduling systems fail to provide adequate visibility of a product's characteristics and their implications to changeovers and sequencing. Batch chemical processes typically have three or more relevant attributes, food packaging lines can have eight or more, and nutraceutical lines can have more than a dozen. Lacking proper visibility to attributes, planners must memorize them; this makes backfill difficult, and the sequence is often suboptimized.

5. Changeover costs and time, based on product attributes and production sequence, should be visible and recalculated whenever the schedule is changed.

6. Inventory calculations should consider customer service goals, lot sizing, planning lead time, goods receipt time, quality hold requirements, demand variability, and production reliability.

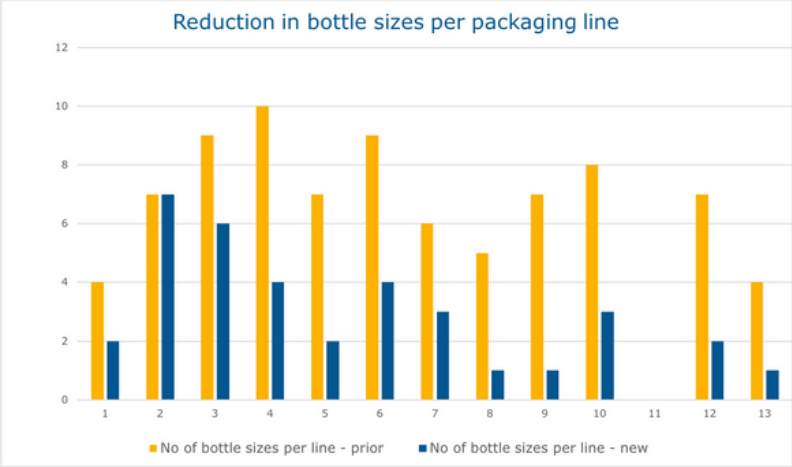
7. Consistent master data should be used for wheel design, scheduling, and execution. There should be a single source of truth for any required data, and the path to obtain it should be clearly understood and documented.

8. A straightforward way to transfer or activate a completed wheel design to production scheduling must be provided.

EXAMPLES

Of the many production scheduling strategies out there, our team has seen food, pharmaceutical, batch chemicals, consumer goods, and nutraceutical manufacturers experience the most significant benefits with Product Wheel scheduling, including more efficient line changeovers, less overtime, increased Overall Equipment Effectiveness (OEE), higher manufacturing throughput, improved customer service levels, and significant annual savings.

The Nature's Bounty product wheel success and financial benefits were mentioned earlier. The first part of their implementation was to group products into families with similar packaging requirements. We found fourteen characteristics that might be changed on a changeover, including allergens (like fish oils), cap type (child proof, flip, gear shaped, plastic or metal), tablet color (especially for dusty tablets) etc. The most extensive and time-consuming change was bottle size, because everything up and down the line had to be adjusted or replaced. Knowing this, the scheduler had tried to limit the number of bottle sizes run on any line, but lacking a comprehensive design process was not able to make it work for any sustained period of time. Applying our product wheel roadmap, we were able to group products into families based primarily on bottle size, with dramatic results.



The number of sizes run on each line was reduced, with some lines going from 8 sizes to 2, and others from 7 sizes to one. Size grouping alone increased OEE by 4 points, resulting in a 10% throughput increase.

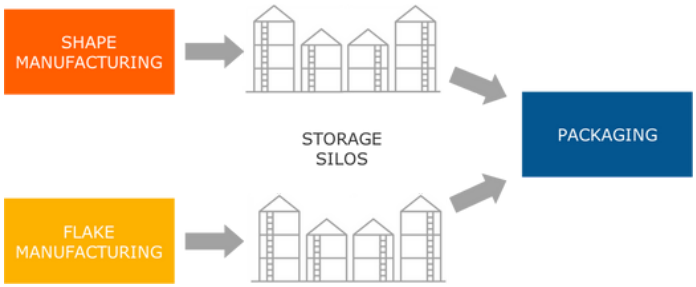
A successful new product introduction left Procter & Gamble short of capacity to produce Luvs Diapers. Rather than investing in new equipment, they decided to employ a product wheel strategy, adopting the philosophy of producing every item every week in a repeating sequence that maximized efficiency and minimized inventory. Changeovers were improved by working with production crews and enlisting the help of the Tide stock car racing team (P&G was among the sponsors) to apply the processes they used to improve pit stops. By the end of the project, operating efficiencies increased from around 70% to around 90%. Inventory turns were up three times. Component suppliers were able to follow a regular and stable pattern of requirements. Production volume doubled while the total value of finished product and component inventory was reduced.

At a large pet food manufacturing site, planners were spending most of their day to create a daily schedule in Excel. Pet food making is a two-stage operation: a large processing unit makes kibble and puts it in bins, then packing lines pull the kibble from the bins and pack it into different sizes and language variations. It's a tricky flow balancing problem. The schedules created in Excel frequently overfilled the bins causing the upstream processing unit to shut down, or starved the bins forcing the packaging lines to shut down.

Implementation of specialized scheduling software reduced the time to create the schedule to one hour, and it was released to the floor early each morning. Two planners could now do the work that previously required three people! The schedule could be run as issued without bin locking or starvation. This in turn had a significant impact on production efficiency.

The pet food manufacturing site isn't an isolated example. Powdered detergent is similar to pet food in its scheduling characteristics. A large detergent plant in the Middle East implemented the kind of advanced scheduling software we've described and experienced the same benefits in planner productivity and reduction of unplanned stops, increasing production efficiency by approximately 5%.

A similar situation occurred in a cereal plant that manufactured two families of cereal, one formed into thick shapes like stars and circles, and one formed into relatively flat flakes of various shapes. The plant can be divided into three major areas: shape manufacturing, flake manufacturing, and packaging, which includes bagging, boxing, cartoning, and palletizing.



While packaging had a utilization of only 75 percent, in real life the intermediate storage silos between manufacturing and packaging often became full and forced the production lines to go down. Analysis revealed that although the packaging area appeared to have excess capacity, it was being scheduled with no coordination or synchronization with either production area, so it became a constraint. Applying product wheel scheduling coordinated the two process areas and relieved the capacity constraint.

CONCLUSIONS

Companies that do an effective job of production planning and scheduling have these things in common:

- They recognize that production scheduling is a mission critical activity, that profitability of the manufacturing operation depends on effective, achievable schedules. They also understand the influence of scheduling on working capital tied up in inventory and on customer service performance. They therefore give it an appropriate level of leadership attention, funding, and attention to Key Performance Indicators.
- Their scheduling systems and processes are built on a strategy which achieves the best balance of inventory, customer service, and capacity utilization, consistent with business objectives.
- The scheduling processes are supported by computer systems that are easy to use, quick to react to schedule disruptors, and balance competing objectives when making changes.

SUGGESTED READING

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Mac Jacob, Head of Product, Phenix Software Inc., was a key contributor to building Procter & Gamble's supply chain, ranked as one of the four best in the world by the Gartner Group. He had assignments in project management, production planning, warehousing, and shipping, including as planning manager for Luvs Diapers North America. Mac led what became P&G's global SAP/MRP II implementation. At one time or another, he was the business leader, developed the work processes, and wrote the original training materials for most of P&G's supply chain planning systems.

Oleksandr (Sasha) Velykoivanenko, Principal Mathematician – Phenix Software Inc., is an expert in Supply Planning and Supply Chain Management and Optimization. Sasha played a leading role in multiple planning system designs, development, and implementation during his 23 years at Procter & Gamble. He made critical contributions to Supply Chain Optimization and improvement work, bringing significant cash and cost reductions to the business.

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