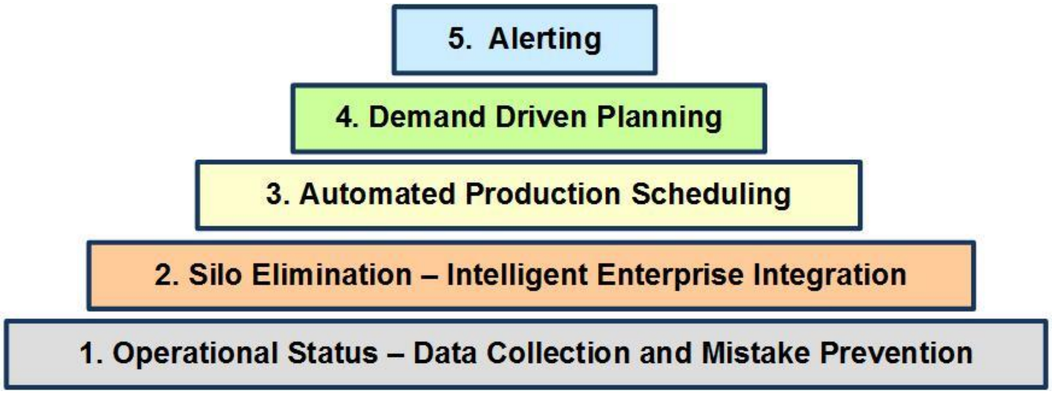
The 5 Levels of Intelligent Manufacturing Operations Management



Introduction

In this paper we explore how technology, and especially knowledge-based systems based on Artificial Intelligence (AI) technology, can empower operations managers to increase the sales and decrease the operating costs of their manufacturing plant.

Please note that this paper was originally released in 2016 and has been updated and re-released in 2020 as it is still as relevant today as it was back in 2016.

The Five Levels of Intelligent Operations Management

1. **Real-Time Operational Status and Mistake Prevention** - this is the foundation layer where technology provides the means to know what is going on in real-time with customer orders, materials, people, and equipment, as well as inbound and out bound supply chains. It also provides the means to automatically warn people when they are about to make a mistake, such as using the wrong material for a job.

2. **Silo Elimination** - this is where technology automatically exchanges information between the systems used by different departments (silos) within a manufacturing organization so that information flows seamlessly to the people who need it.

3. **Automated Production Scheduling** - in our frenetic, demand driven, on-line ordering, next-day delivery world, where things can still go wrong in the blink of an eye, it is rapidly becoming impossible for people to handle the demands of scheduling hundreds of orders, through dozens of operations and still get them out on time.

4. **Demand Driven Planning** - this is where technology automatically orders and plans the purchase and/or making of materials in response to changes in demand as well as to changes in ground truth, incoming data from other silos, such as sales, and changes in schedule due to machines going down or people getting sick.

5. **Automated Alerting** - this is where the system monitors the lower four layers for changes in operational status, schedules and plans, and automatically alerts people when they need to take action, typically on their mobile device. Instead of managers "walking

the floor", or sitting "glued" to their computer screens, trying to determine when something is about to go wrong, AI rules and algorithms examine vast amounts of data in real-time to determine when human intervention is needed.

The Reality

Is this a nice theoretical model and nothing more? Absolutely not. Over the past decade we have been successfully implementing systems, based on this model, for organizations ranging from small metal fabrication and food processing companies, with under $10 Million in sales, to large biotechnology, defense, and construction engineering companies.

Did we start with the model and build the technology to fit? No we started with the experience we had gained building real-time Artificial Intelligence (AI) based systems for the US Air Force to advise pilots in combat situations. We then used this technology to solve real-time operations management problems for our manufacturing and engineering clients, which, on many days in a manufacturing plant, is not a big stretch from a combat situation ☺. As we built more and more systems, the model emerged.

For a long time, we "hid" the fact that our systems were based on Artificial Intelligence (AI) as AI was out of favor. Then IBM, Jeopardy, Apple and Google made it "cool" to talk about AI. And so we could talk about our systems as real-time AI, or knowledge-based, advisory systems, which they really are.

Data Collection Technology - Knowing Operational Status

At the bottom layer of most of these systems is good old-fashioned barcode scanning, which is increasingly being done by personal mobile devices with built-in barcode scanning and wireless mobile communications. But, even here, we use a significant amount of AI to simplify the data collection, prevent data collection mistakes, and most important, to warn users when they are about to make a mistake.

In a knowledge-based operations management system like BellHawk, the user interface is web-browser based, which means that it can be used anywhere, anytime there is an internet connection to the server, which is performing all the knowledge-based data analysis behind the scenes.

The knowledge-based data collection is patterned after ordering something on Amazon or another website. But, after each item of data is entered on the form, a message is sent to the server and that data is checked for data collection and operational errors using situation specific rules and algorithms. Also the form on the user's screen is modified so they only have to enter the minimum data that is needed based on the system's current knowledge of what they are doing.

Here, a large knowledge-base of rules, which can take a significant time to set up, is being used to make the data collection task, on the shop-floor or in the warehouse, as simple and as quick as possible, and to prevent mistakes by providing real-time point-of-action warnings to users on their mobile devices.

Contrast this to an ERP system where office workers have to know which of dozens of possible boxes on each screen they have to fill out in order to get the right data to be stored in the right place in their ERP system. It is for this reason that ERP systems have largely failed to transition to the factory floor. Instead we see data collection being done using paper forms on the shop floor, which are then typed into an ERP System (or Excel spreadsheet) by someone in the office on the following day.

This use of paper forms and subsequent manual keyboard data entry eliminates the ability to have a real-time operational status about what is going on in the manufacturing plant. This real-time status is the foundation of the other four layers operations management, as well as preventing the ability to provide point-of-action warnings to prevent expensive mistakes.

We are increasingly embedding data collection using RFID and other IIOT (Industrial Internet of Things) sensors in these systems. But none of this data collection is of any use until all the large volumes of data can be interpreted by a knowledge-based system, such as BellHawk, and presented in meaningful operational terms that managers and other personnel can easily view and digest on their PCs, tablets, mobile phones, or other mobile devices.

Intelligent Data Exchange - Eliminating the Silos

Despite some notable attempts, most of which were failures, to socially reengineer manufacturing plants by eliminating management silos, rapid response, demand driven manufacturing requires separate departments for accounting, sales, engineering, manufacturing operations, warehouse management, and human resources for efficient operation.

Each silo typically uses one or more computer systems that were selected as being the best of breed for the needs of that department. The problem is how to make sure that information known to one silo flows smoothly to other silos.

There are two possible solutions to this problem:

1. Use one system that performs all the functions needed by all the departments so that they all have access to the same massive volume of data. This is the model promulgated by the ERP systems. Unfortunately, the cost of developing and maintaining such a body of software is very expensive, such that the system is:

    a. Very expensive to purchase and implement within each manufacturing plant

    b. Sold to tens of thousands of companies.

    c. One size fits all or customized at great expense

    d. Updated annually whenever tax changes occur

    e. Bloatware - thousands of features because it tries to meet the needs of all silos

    f. Very difficult to use - especially for lower level operations people.

2. Use simpler, lower cost, best-of-breed systems for each department. Here the problem is that information is not easily shared between departments and/or requires duplicate data entry. This problem is solved by technology such as Milramco's MilramX software that automatically exchanges information between the different systems in use.

It is noteworthy that even MilramX turns out to be highly knowledge-based. Most departments do not need access to all the information stored in systems used by other departments. Warehouse managers do not need to know about all the details of the tax treatment of different classes of materials in their warehouse. Operations managers do not need to follow all the struggles of the sales guy recorded in the CRM system in order to win a new customer.

Instead, MilramX is used to:

1. Intelligently extract just the information needed for operations management from the other systems in the manufacturing plant's IT ecosystem.
2. Intelligently transfer the operations management information needed by other silos or departments to the systems used by these departments.

Note that this is not a blind synchronization of data between systems but rather requires intelligently interpreting data in one or more systems and injecting just the needed information into a target system.

Eliminating the Scheduling Headache

To paraphrase an operations manager who is a friend of mine "It's not when things go right that I have a problem, it's when things go wrong".

Currently many organizations still do their scheduling by holding a weekly or daily planning meeting and then use a planning board to decide what to run on which machine and when. But typically, 30 minutes after the end of the planning meeting:

1. A machine breaks down
2. A critical employee calls in sick
3. A truck, delivering critical materials on a just in time basis, runs into a ditch
4. A task that was expected to take 10 minutes on a batch of products is already 20 minutes overdue.
5. A rush order is received from an important customer for delivery tomorrow.

Even worse, some companies try to use the MRP (Materials Requirements Planning) component of their ERP (Enterprise Resource Planning) systems to do their scheduling and planning. These systems were great for long-run manufacturing when a manufacturer was able to fill their warehouse with raw materials and then plan their production for the next 3 months based on a sales forecast.

Now orders arrive over the Internet for delivery of semi-custom products in 48 hours or less, which makes the long-range planning and scheduling algorithms in the ERP systems totally inapplicable in this environment.

In many of our clients, we see dozens or hundreds of jobs, involving hundreds or thousands of custom parts, being scheduled through dozens of operations. Even when things go right, this is a difficult scheduling problem. When things go wrong, it is impossible for people to respond in a timely manner.

In BellHawk, we use a dynamic real-time rules-based scheduling algorithm that advises shop-floor workers in each work cell as to what they should be working on next, as they finish their previous task. This dynamically optimizes the assignment of resources to ensure, as far as is possible, that orders still get out on time, even when problems arise.

But it should be noted that this is an advisory system, because we want to make use of the general knowledge of the workers as well as the special knowledge built in to the system. So the rules prioritize what the person should be working on but allows the user to make alternate choices if they have knowledge of some event, such as a burst-pipe near a recommended machine, that the AI based system does not know about or have any rules for.

Managers are also given "levers", such as setting the importance of jobs or customers or changing delivery dates, whereby they can influence the scheduling algorithms and rules, based on their general knowledge.

In this way we make use of the computer to rapidly handle all the details of dynamically rescheduling production using its special knowledge whenever an event happens on the floor (good and bad) but also to give the flexibility for managers and production workers to use their general knowledge to guide or override the recommended scheduling choices.

Incremental Demand Driven Planning

As described in the prior section, manual and MRP/ERP based production scheduling methods fail to keep up with the needs of today's demand-driven, quick-turn manufacturing plant. By implication, the decision about what products to make and what materials to buy, and when, is also driven by the same factors.

It is no longer enough to know what inventory you have in stock, it is also essential to know in real-time what you have on order, work orders scheduled to be make and to consume materials, and orders to pick, pack and ship products. Then based on this, the system can advise managers what work orders need to be issued to make intermediate or finished products and what materials need to be purchased and when.

This incremental replanning is typically done when new customer orders arrive but can also be performed when other events occur, such as a batch of materials needing to be scrapped, or a change is made from make to buy on some intermediate parts. Typically this incremental planning is done on an advisory basis, with the system using its built-in rules and algorithms to advise managers what to make or buy and when but allowing managers to use their general knowledge to override or improve on the decisions recommended by the system.

Note that this is very different from the materials planning typically done by an ERP or MRP system, in the following ways:

1. The knowledge-based materials planning, in a system like BellHawk, is done on an incrementally, in real-time, based on incoming customer orders and the current operational status about what inventory is currently available, and materials will be available or consumed at different times in the future.

2. MRP algorithms typically start "from scratch" and replan materials purchases and production schedules based on demand forecasts for weeks or months ahead, without regard to current production status.
3. MRP/ERP algorithms typically run autonomously and then people have to "fix up" the resultant productions schedules to account for factors not integrated into the MRP algorithm. BellHawk, by contrast, runs as an advisory system, allowing managers to make use of their general knowledge as well as the specific advice built into the system to incrementally make decisions as planning progresses.
4. The set of rules in BellHawk, by which a system advises people, can be adjusted by clients and new rules added to tailor the system to the demand planning needs of each specific organization.
5. BellHawk can use Alerts (see next section) to warn people when they need to do incremental replanning because they do not have enough materials on hand to meet incremental customer demand.

Advisory Alerts - A Paradigm Shift

For a long time manufacturing managers have "walked the floor" to try to spot problems before they happen and to head them off. When managers were running long-run manufacturing operations, this was a good way to go. Now there can be hundreds of jobs with thousands of custom parts flowing through dozens of work centers and it is almost impossible to spot when a problem is going to occur.

Information Technologists have tried to solve this problem by providing managers with masses of reports and Excel spreadsheets, supplemented by on-screen dashboards and detailed screen displays. All we have succeeded in doing is drowning the poor managers in a "firehose" of data. As a result each manager sits "glued" to his or her screen looking for problems instead of walking the floor.

As one manager said to me "What I want to know is the 6 things that I need to pay attention to today and not have to wade through this mass of reports just to try to discover what is going on in my operation".

This is all being changed by systems like BellHawk that use real-time AI based rules and algorithms to monitor operational ground truth, as well as information from other systems, combined with the state of the current customer delivery mission, in terms of plans and schedules, to alert people when problems arise or pending problems need attention.

These alerts can be as simple as a KanBan bin needs replenishing on the factory floor or more materials need ordering. They can be as complex as an operation taking too long or the planned shipment today of a customer order is in jeopardy because the units are still awaiting final test.

With this paradigm shift, managers no longer need to walk-the-floor or be glued to their computer screens to try to spot problems before they occur. The knowledge based rules and algorithms in BellHawk examine the flood of data being captured by the data collections, enterprise integration, planning and scheduling algorithms, to detect when problems have occurred or are predicted to occur in the near future. The BellHawk system then sends messages, in the form of Emails or Text Messages, to the appropriate managers, and/or their people, altering them to a situation to which they need to pay attention.

This makes managing manufacturing operations much less stressful and makes much more effective use of everyone's time.

The BellHawk Knowledge Base

A key piece of the BellHawk technology is its knowledge base, without which the system cannot function. For the pilot advisory system we developed a real-time expert-systems rules based compiler called the Decision Support Language. But we found that this was too complex for manufacturing organizations to use to express their rules.

Instead, we made use of the fact that many rules can be expressed as tables. As a result, our clients are able to setup the knowledge base rules in the form of Excel spreadsheets and then to import these into BellHawk. This has proved to be a great success and many of our clients are unaware that they are setting up AI rules. To them, they are just setting up the operational data that BellHawk needs to function.

Of course, there are some places where the knowledge is more complex than can be expressed by tabular rules. In these cases, we need to implement algorithms in code, typically using VB.Net. But, even here, we are able to provide parameters that enable managers to use these "levers" to adjust the how the algorithm functions.

Commentary

Implementing a knowledge based operations management system like BellHawk typically proceeds through the five levels, shown at the beginning of this paper, with managers and their people gaining additional capabilities as each level is added.

These systems take time to implement, often taking several years before all the levels are achieved. Also some smaller manufacturers stop after they have achieved level one or two as they find that this is sufficient for their operations at this time.

What we have found is that, with the addition of each level:

1. Labor and other costs are reduced
2. Order delivery times are reduced
3. Customer satisfaction and sales increase
4. The size of the management team is reduced
5. The stress on managers is significantly reduced

Typically the incremental costs of implementing the technology to achieve each of the levels of intelligent operations management pays for itself in 6 months or less.

Are these systems expensive? Yes. A typical client will spend $10,000 to $50,000 in software, equipment, and services to get to Level 1 and $50,000 to $150,000 to get to Level 5. But when you consider that the loaded cost of expediters and other support staff that are longer be needed, now exceeds $100,000 per year per person, this is bargain.

Also our clients have found that they can stop paying expensive maintenance fees for their ERP systems and replace them with a much less expensive accounting system or simply keep using the accounting functions of their old ERP system.

For more details about the real-time AI methods used, please see the companion white paper "The Artificial Intelligence Revolution in Manufacturing Operations Management" on www.BellHawk.com.

Author

Dr Peter Green received his BSEE and Ph.D. degree in Computer Science from Leeds University in England. He was a senior member of the reseach staff at MIT, where he performed reseach into real-time intelligent systems under a DARPA funded contract.

He was subsequently a full Professor of Computer Engineering at WPI, where he performed reasearch into software methods for implementing real-time intelligent-agent based systems for the US Air Force and NASA. He then founded BellHawk Systems to continue this development using SBIR grants to enable comercialization of this technology.

Dr Green currently serves as Technical Director for Milramco and KnarrTek.

Over the past decade, Dr Green and his team have applied these real-time AI methods to the development of real-time operations tracking, scheduling, planning, and mistake prevention systems for manaufacturers. Clients have ranged from small metal fabrication companies and food processors to large biotechnology, building, and defense contractors.

For more information, please contact Peter.Green@BellHawk.com. Also, please see www.BellHawk.com for more details on BellHawk System’s software technology.

