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Improving the Efficiency of Large Manufacturing Assembly Plants

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Abstract

Large manufacturing assembly plants with sub assembly lines, sequenced material deliveries, and batch driven primary manufacturing operations often struggle with coordinating their sequenced part manufacturing and kitting operations with the dynamic constraints of the main final assembly line. This paper will outline the high level data model, workflow and use-case scenarios of how the Factboard system integrates into the factory's engineering and transactional data sources as well as how users have been able to use this more accurate, detailed and timely information to make better decisions.

Keywords: Andon, eKanban, eKitting, MES, Factory Dashboard, Assembly Plant, Factory Efficiency

1. Introduction

Large manufacturing assembly plants with sub assembly lines, sequenced material deliveries, and batch driven primary manufacturing operations often struggle with coordinating their sequenced part manufacturing and kitting operations with the dynamic constraints of the main final assembly line. Additional challenges arise from the many disconnected information streams available to each group which provide delayed information with not enough part and location specific details.

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Iowa State University (ISU), Proplanner and Factory Right partnered with a major Aircraft manufacturer and also a major Industrial/Ag Equipment maker to address this specific challenge with a product called Factboard. The team is being supported by the United States Army via the Digital Manufacturing and Design Innovation Institute (DMDII). DMDII is a federally-funded research and development organization of UI LABS, with a goal of increasing efficiencies of factories throughout the United States.
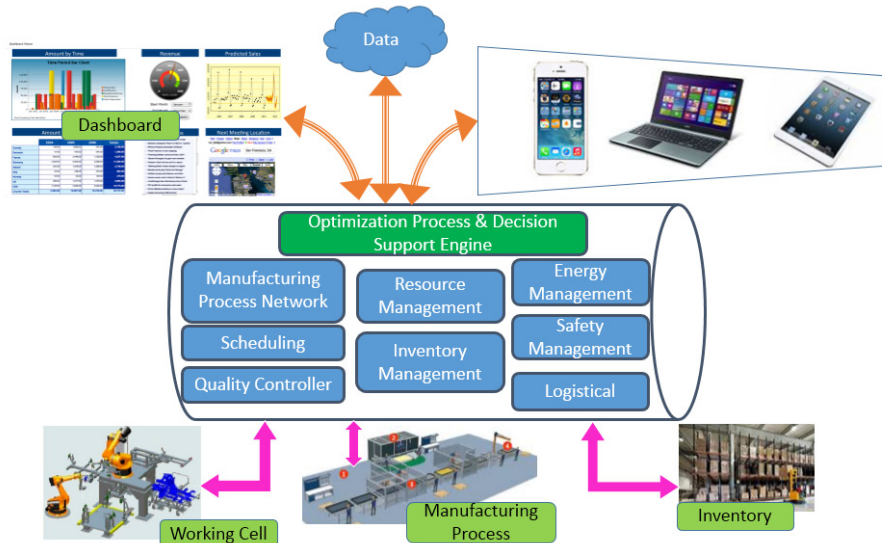

Fig. 1.Factboard Data Flow Model

Making improper decisions with incomplete data reduces a factory's throughput rate, and can result in substantial inventory increases and low overall equipment effectiveness. Pilot studies of Factboard components have demonstrated 98% reductions in line stoppages due to logistics issues, 86% reductions in on-site inventory, and 50% reductions in indirect material handling labor, all while simultaneously increasing productive throughput by nearly 10%. All of this contributes to reducing operational costs and increasing the ability of the factory and its supply chain to respond faster to changes in requirements. The trial-case factory made large 4-wheel drive tractors and large bucket loaders. The reductions were exclusively due to increased line-side inventory availability using e-Kanban and e-Kitting as described in Kouri [1]. In particular, alerts sent to management at the first onset of a materials issue, such as a delayed delivery, or a stock-out at the inventory supermarket (mini-warehouse), allowed time to resolve the problem before a line stoppage occurred. In addition, extensive data on actual inventory replenishment times allowed for safe and substantial reductions with line-side inventory quantities as the workers became trustworthy of the logistics system. These improvements virtually eliminated inventory expediting and allowed for material delivery via fixed route tuggers which greatly reduced fork truck usage, and thus indirect labor, within the plant.

A key innovation of Factboard is its ability to utilize existing transactional data within the enterprise and dynamically respond to increases, or even temporary decreases, in the quantity and quality of these real-time inputs. Because companies are often not in a position to make major upfront investments in shop floor data collection, Factboard can utilize the available information and attempt to fill in the holes to provide a real-time picture of "current events" occurring within the production systems internal to, and supplying, the final assembly line.

This is accomplished by Factboard's ability to map engineering production life-cycle management (PLM) data sets with factory-specific build schedules and real-time transactional production and logistics data to create a series of information-rich and visually effective views designed around the needs of shop floor personas (user-defined dashboard views of production). Factboard's decision support engine then provides specific calculations and probabilistic recommendations about inventory and resource availability at multiple points within the production system.

This paper will outline the high level data model, workflow and use-case scenarios of how the Factboard system integrates into the factory's engineering and transactional data sources as well as how users have been able to use this more accurate, detailed and timely information to make better decisions.

2. Dashboard

The Dashboard is the heart of the Factboard system and represents a sort of web-based Andon environment for the assembly lines and supporting departments within the Factory. Once the dashboard views are set up for each assembly line, the dashboard scans the transaction logs (discussed later) to determine the status of vehicles (units), Stations and Resources (tooling).
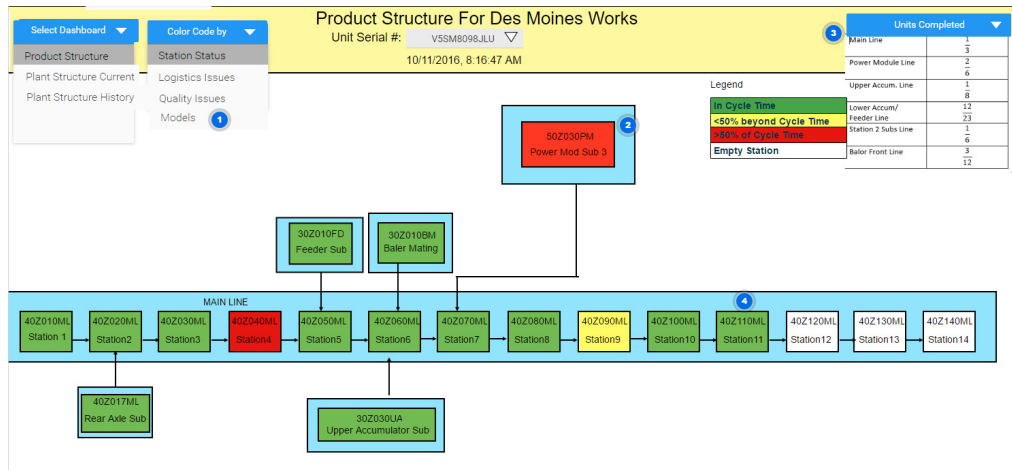

Fig. 2. Dashboard view of a Vehicle

The three primary views of the dashboard are the Product Structure (Fig. 2), Plant Structure Current and Plant Structure History. The Product Structure view shows the history of a selected unit as it progressed through the main and sub assembly stations up to the current location of that unit on the assembly line, if it is still in production. The Plant Structure Current View shows the Unit (vehicle) number in each station and if that Unit's current time is within the planned station cycle time. In the top right corner of the screen a status bar shows the actual versus planned number of units completed for the shift or day so far on that line. As such, each main assembly line is shown in an individual view, however many of the subassembly lines will be shown in multiple views. The Historical Plant View allows the user to select a time range and view a Heat Map of Station Issues.

There are four color coding modes; Status, Model, Quality and Logistics, available in the browser, however the Model view is only valid for the Current Plant Structure view. In the Plant Structure History view, the Logistics and Quality issues are aggregated for all units over the selected time range of interest.

- Status – Current Unit time in station vs Planned. Green in under cycle, yellow shortly over, and Red critically over.
- Model – Model of the Unit. Users can establish a color code for each unique Model (or model group).
- Quality – Quantity of Quality issues logged against the unit at the current station.
- Logistics – Quantity of Logistics issues logged against the unit at the current station.

A user can select a station and view attributes of the events logged within that station. This capability works for both the Product Structure View and the Plant Structure Current View. Likewise a user can enter a Quality or Logistics event, if their IT environment allows those records to also originate from Factboard.

The dashboard is a thin web client application that works in any popular browser. The server application can run on a cloud service such as Azure or on an Intranet-based IIS server. To use Factboard, a worker can simply browse to the applications' hosting site, log in and select the line they wish to view.

3. Issues

Issues related to Part Quality, Assembly Quality and In-Plant Logistics dominated the majority of the problems observed during field studies performed at the beginning of the Factboard project. In addition, plants often had an "Other" category of issues such as problems with tools, SOP work instructions, paperwork, task times, etc. As such, the team decided to include an ability to view, log and report on production issues via Factboard.

While some of the factories in the study had a method to log a quality problem, there was no way to view quality issues in real time as they occurred on the line. In addition, the team found that poor communication about quality issues significantly delayed the time it took to bring the line back to full throughput in that the time to inform relevant people about the quality problem often exceeded the time to resolve the problem.

Fig. 3. Quality Issues Logging Interface

Quality Issues were classified into three categories; assembly, manufactured and purchased. Assembly issues were most often caught by line quality technicians and logged in a clipboard. Some inspectors knew who created the problem and took the time and effort to find them and speak to them. Sometimes these technicians, would fix the problem, or ask the worker who caused the problem to fix it. Other inspectors intended the problem to be resolved by someone at the end of the line who should be reading the logs.

Manufactured quality issues could be identified by the assembly worker or the inspector and often involved issues with weld, paint or machining. Since these issues originate in other departments, it is more difficult for the

people who found the issue to identify and communicate with the people who caused it. Most often shop floor communications was focused on cell phone calls to individuals in order to track down who was working when the problem occurred, who is working there now, and who can resolve the issue. Finally, resolving the quality issue often involved engineers who could design and approve deviations, as well as people in logistics, and upstream department supervisors who can expedite replacements or repairs. Overall, the communications processes that should take minutes, often took hours and nearly always reduced main line assembly output for the day.

Logistics Issues most often traced to not having the necessary parts at the workplace, or responding to Purchased part quality problems related to purchased parts and manufactured assemblies which are produced out of sequence. Some plants logged logistics issues, but most often it would be days or weeks before those logs were evaluated for process improvement. When a logistics engineer was told about a critical issue (usually a cell phone call), they would need to travel to the floor to collect information and then go back to the office to get access to information to resolve the problem. In every plant, the logistics engineers struggled to get access to the production schedule, estimated part demand over time, part availability by location, and the contact information for part sourcing. Finally, the team uncovered a consistent communications problem where purchased part quality issues are not communicated to logistics until far along in the quality evaluation process, where if the logistics people were aware of a possible problem sooner, they could have been working on alternate sourcing options sooner to get the line up several hours faster.

Finally, many of the facilities used part kitting to several stations along the line. This process resolved many of the space and part availability issues when the line was producing to plan. Unfortunately, if problems occurred on the line and the subassembly or main line areas produced products out of the planned sequence then substantial communications problems arose. In particular, supervisors would pull some units forward from their planned production date and sideline other units. This resulted in part kits and sub-assemblies now requested at earlier times than planned. Often these supervisors were not informed quickly and thus upstream production would not be synchronized with downstream demand. Initially, Kit carts and Sub Assembly carts would become scarce, and the main line production would slow.

Factboard is currently addressing these specific problems by first providing an electronic dashboard of all Quality and Logistics issues for everyone in the facility to monitor. Logged issues can be immediately viewed graphically from the Product or Plant views and textually via the Entry/Query forms such as shown in (Fig. 3). Secondly, Factboard is providing a Decision Support Sequencing capability for supervisors to communicate their current build sequence and do so while evaluating the build sequence of all upstream and downstream suppliers and customers. Each user can see the current sequence being produced as well as see quality, resource and logistics problems being encountered by that team at the moment. Logistics engineers can access the Factboard information via mobile tablets and phones and receive and communicate this information directly from the shop floor.

4. Transactions

The dashboard and issues management functions receive their data via a simple event transaction log which any electronic system can post to via text Files, SQL records or Webservices. A transaction is an occurrence of an Event which will involve factory object(s) such as a Unit(product), Part, Station, Resource or Issue. A valid list of Stations, Departments, Resources, Issues and Event Types are defined within Factboard when it is originally configured. The Factboard transaction manager then processes these into individual database Event tables that are ordered by their date/time stamp. Then as the user wishes to view the current status of a line, or aggregate and report on a set of historical events, Factboard references the appropriate transaction logs, processes the data according to the display or report selected, and presents the results.

The easiest and most common transaction format for many organizations will simply be a data file placed into a file directory on a shared server. Each data file represents a single, or group of transactions which occurred on the date and time at which the file is submitted. Additionally, a file may contain a date and time attribute value which may override the date and time stamp of the file itself. Inside the file is an event type, such as "SIGNON" and a set of objects, such as the StationID and UnitID, or attributes, such as Description or Time, for which this SIGNON event was triggered. After the file is processed, it is moved to a different directory where it is eventually deleted.

Transactions are typically generated from the shop floor scanners in use at each workstation and on most fork trucks and tuggers throughout the shop floor. In all cases, the transactions come from existing shop floor systems that are in place to serve specific functions such as logistics, quality or shop floor instructions. In this way, Factboard can make additional use out of this existing infrastructure of information tracking and in some cases even justify additional reporting points.

Each transaction has a unique event ID, and some Event Types, such as SIGNON, also generate a unique Event ID which subsequent events can post to (i.e. SIGNOFF). Events occur within the context of Factory Objects, such as:

- Stations – Locations where Events occur
- Units – Products being tracked
- Resources – Tooling and Equipment used
- Models and/or Options – Globally understood properties of Units.

Some factory objects, such as Stations have an organization object, such as Department which helps with data aggregation, reporting and user interface navigation. Like Events, factory objects have a unique ID so that there is no ambiguity when an event references objects such as a specific station, or a specific vehicle unit.

This non-managed public transactional environment implies that there will often be situations whereby transactions get lost or are never transmitted to begin with. Thus the transaction manager is an important and core capability within Factboard. The transaction manager thus creates "Missing" events as they are discovered in an effort to provide for valid transaction logs for historical reference. For example if a SIGNON event is received for UNIT#7 in Station#3 but it was never signed out of Station#2, then the transaction manager will generate this missing event with the date and time of the SIGNON in the downstream station.

Obviously Factboard cannot create information that is simply not there, but Factboard can interpret common missing data elements via a practical set of heuristics, in order to make the most of the information for which it receives.

The analytical capability of the Factboard system is an interdepartmental unit sequencing tool which allows line supervisors, material handlers, and production schedulers to communicate and collaborate to ensure that the final assembly line has a complete set of components needed to produce a finished product with a minimum of re-sequencing and inventory buffering.
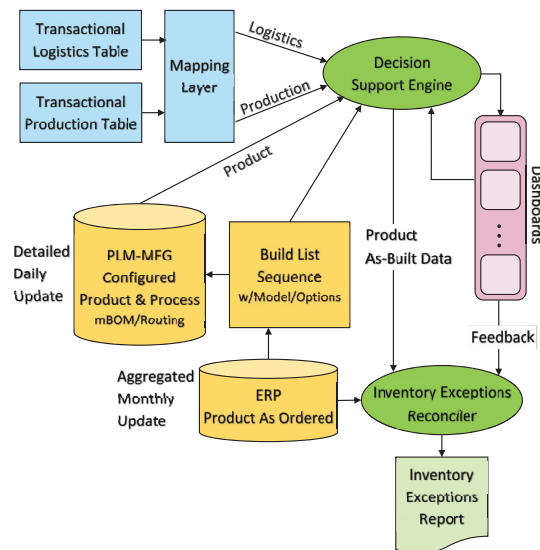

Fig. 4. Decision Support System Data Flow

This system combines the production build list with the Dashboard transaction log, the ERP system part availability and the PLM-Manufacturing knowledge of station based part consumption with task times and resource tool assignments (Fig. 4). While some ERP systems might contain detailed production details, those systems typically don't include station level part consumption, and their Bill of Materials (BOM) is often set several weeks in advance, whereby the PLM-Manufacturing environment maintained by Manufacturing Engineering is typically accurate to the as-built state.

Seq Sub-assemblies Finish Time			
Buckets	Buckets Final Assembly Time	Cabs	Cabs Final Assembly Time
N544458120	11/19 10:00am	N544458120	11/20 12:00pm
N544458121	11/19 08:00am	N544458121	11/20 03:00pm
N544458122	11/20 09:00am	N544458122	11/21 09:00am
N544458128	11/20 10:00am	N544458128	11/21 12:00pm

Fig. 5. Sequencing Interface showing finish times per Sub-Unit in Sequence

With the Sequencing module, each Supervisor of a sub assembly or kitting station can see the unit sequence of their parallel counterparts, as well as the main final assembly line. Most importantly, when a supervisor re-sequences a unit in their area, the delivery time of that unit, and the units after it, are recomputed and shown to the entire factory. In some cases, units are delayed, and in other cases those units are pulled forward from their planned release which requires other supervisors to re-evaluate their production sequence and respond in a coordinated manner.

Another key feature of the sequencing module is the ability of the supervisor to "look-ahead" on their station-based inventory to ensure that they have the parts available to make the units currently in sequence for the next time horizon (hour, shift, day or week). Sequence planner references the part requirements for each station (or group of stations) on the line for each specific unit in the planning build list. It then predicts shortages by unit, and allows the supervisor to re-sequence production to minimize the impact of those shortages within the context of what other supervisors are doing. One challenging aspect of this inventory shortage forecasting is that of adjusting for ERP backflush points along the assembly line being downstream of when the parts are actually consumed. As such, this module needs to deduct inventory from that stated by ERP for those units on the line which have not yet reached their backflush point.

The end result of coordinated sequence planning is that the final line receives parts for each unit in a more complete and sequenced manner as supervisors can make decisions in upstream departments quickly upon discovery of problems occurring in other parallel departments or even the main assembly line.

5. Conclusion

Factboard is a collaborative initiative between Government, Academia and Industry. The initial shop floor discovery phase uncovered many communication and coordination issues which can be resolved by simply improving the communications and coordinating of production, logistics and quality teams throughout the facility. By providing real-time feedback of unit status, inventory availability and short term inventory requirements from the build list to the entire production team in a mobile and easy to use format, the plant can respond to issues quicker and more effectively. Factboard is currently in active development using a waterfall development process to release module updates continuously throughout 2017. In 2018 it will be available to all DMDII members as part of their contract, and to other companies via commercial sale.

References

[1] Kouri I., Salmimaa T., Vilpola I. (2008) The Principles And Planning Process Of An Electronic Kanban System. In: Sobh T., Elleithy K., Mahmood A., Karim M.A. (eds) Novel Algorithms and Techniques In Telecommunications, Automation and Industrial Electronics. Springer, Dordrecht