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# Collaborative Process Engineering Framework for Ground Vehicle Systems Manufacturing #193

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**ABSTRACT**

*Currently, each manufacturer is responsible for documenting, maintaining and continuously improving, the manufacturing processes that they use to produce common military vehicle platforms. While some of this information is specific to the manufacturer, facility, location and production volumes associated to a particular site, much of this information is common across manufacturing sites, and even manufacturing vendors for each specific vehicle platform.*

*Automotive manufacturing firms have addressed this problem via the development of Manufacturing Process Management Systems (MPM) that are integrated between their Product Data Management, (PDM) and Enterprise Resource Planning Environments (ERP) systems. Unfortunately, until recently, these systems have been technically, and financially, out of reach to many military vehicle programs.*

*The objective of this article is to provide an overview on how newer commercially available Internet/Intranet-based MPM systems can be, and have been, applied to the unique manufacturing challenges present within the land-based vehicle sector, and subsequently the realized benefits that can be, and in some cases have been, achieved. In particular, this article will present how secure collaborative platforms of manufacturing process information can reduce overall platform program costs, enhance final product quality, ensure multi-vendor vehicle component consistency, allow for scalability to meet demand variability, and most importantly, reduce the time required to get new vehicle designs into the field*.

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## INTRODUCTION

Military Vehicle manufacturers are required to submit a Manufacturing Readiness Assessment on their vehicle to ensure compliancy to a Manufacturing Readiness Level (MRL) according to the guidelines established within the MRL DoD Deskbook [1]. Essentially, the DoD requires the management of an mBOM (Manufactured Bill of Materials), and a BOP (Bill of Process) to define what is made and how it is made, to ensure reliability and repeatability.

Unfortunately, these required documents and procedures are often created off-line, or after-the-fact with regards to the actual vehicle design and manufacturing process, and as such, often fail to achieve their desired benefits in terms of end-product quality.

Finally, this disconnected engineering process often results in the creation of documents that are out of date as soon as they are published. This lack of integration into the functional engineering workflow process causes significant costs, delays and quality problems when vehicle programs are shared among different manufacturers, or when production volumes of particular vehicles ramp up significantly after extended periods of downtime.

A system is needed by vehicle manufacturers which provides MRL compliant documentation on production processes which are synchronized with Product Engineering changes and subsequently create Shop Floor quality documentation, and ERP quality Routings which can effectively be used to drive production.

## MPM AND WORKFLOW

Manufacturing Process Management (MPM) involves the design and management of manufacturing processes which integrate Products, Plants and Resources. MPM technologies originated within the vehicle industry, as it represents the most complicated and dynamically changing process engineering problems found in industry.

MPM systems start with the eBOM (as an initial import) and then these systems import all subsequent ECO's (Engineering Change Orders) which arrive from Product Engineering. These ECO's (sometimes referred to as ECR's until approved by the manufacturing department) provide updated component lists (eBOM's), pursuant to a particular new version of that sub assembly.

Manufacturing Engineering is then responsible for determining how, where and when these components are assembled into a final product configuration. This involves the detailed definition of all supporting systems (tools, facilities, people, raw materials, etc.)

### *eBOM versus mBOM*

While the eBOM is a structured list of components that appear in the final product, the mBOM represents a structured list of components which are consumed in the creation of the product, and structured according to how the product is manufactured. For example, an mBOM will often contain raw materials, solvents/lubricants, packaging and finish details which are not present in the eBOM. In addition, an mBOM will often reference common part occurrences throughout the structure, instead of just listing a quantity of those components at a particular level of indentation. This "explosion" of common parts is required when those parts (i.e. such as fasteners) are assembled within different workstations, or which appear in different process descriptions.

This difference between the eBOM and mBOM is what causes most direct integrations of Product Data Management (PDM) systems and Manufacturing/Enterprise Resource Planning (MRP/ERP) systems to fail to meet expectations. The simple fact is that many engineering functions are required to be performed in effectively converting eBOM ECO's into mBOM (MCO's) Manufacturing Change Orders, and an automated electronic conversion is just not practical.

### *Manufacturing Workflow*

Upon receiving an ECO or ECR, Manufacturing Engineers are responsible for reviewing these new assemblies and evaluating their impact to the manufacturing process. These tasks involve:

1. Determining (and documenting) the steps, and corresponding time, required to assemble the components.
2. Determining the tooling required, and the location where the components will be assembled.
3. Containerization of the components within the facility.
4. Evaluating quality issues associated to the assembly process (i.e. P-FMEA and Control Plans)
5. Evaluating the ergonomic safety issues associated with performing the required assembly steps (i.e. weight, elevation, torque, frequency of tasks, etc.)
6. Developing effectivity dates for when these engineering changes can be implemented on the shop floor, and for which vehicle programs (i.e. series).

Once this evaluation is concluded, the mBOM and Process Routing need to be authored/updated by the manufacturing engineer and published to the following three systems

1. Shop Floor Work Instructions, or MES - Applications are responsible for delivering printed, or electronic work instruction documents to the workers in the stations for each product, or engineering change, produced.
2. ERP - Applications such as SAP or Oracle are responsible for ordering parts in advance of production, as well as maintaining in-plant inventory levels. These applications need the mBOM from Manufacturing, and a corresponding Routing, which defines how and where tasks are performed, as long as how long that it takes.
3. In-Plant Logistics (PFEP - Plan for Every Part) - Applications are responsible for determining the containerization, and location of every part staged within the plant, as well as the method (device) and manner (inventory request triggering) which causes material to flow.

## ASSEMBLY PROCESS DEFINED

The Routing is at the heart of any assembly process documentation. Routings essentially define the high-level steps of the process, which are required to produce the assemblies to which the routings are mapped. For example, each subassembly in a major vehicle, will have a corresponding Routing which defines the major tasks necessary to produce that sub assembly. The major tasks in a Routing are called Operations, and they represent a list of tasks, called Activities, which define the tasks that an operator will perform at a workstation. As such, the amount of tasks which can be assigned into an Operation is limited to the summation of the Activity times for those tasks being less than or equal to, the available time for the operator to perform the work - also referred to as the assembly line's TAKT time. Essentially, the time for an Operation will equal that operator's Cycle Time.

Activities are the heart of all MPM systems, as they represent the smallest defined amount of work that could be re-assigned to a different individual, and station. Activities have all of the following properties:

1. Consume Parts (i.e. parts are not directly assigned to Operations, they are assigned to Activities which get assigned to Operations to be performed at a station).
2. Tooling required, including tooling attributes such as Torque values.
3. Work Instructions which define how the Activity is to be performed.
4. Quality and Ergonomic Assessments.
5. Time (either observed times, expected times, or calculated times).
6. Precedence to other Activities (i.e. what are the immediate required predecessor Activities)..
7. Steps or Elements are lower level tasks that define the individual work to be performed in completing the activity (i.e. walk to container, pickup part, attach part to bracket, etc.). Note that none of these steps could be separated from the Activity.

Therefore, from the perspective of the Manufacturing Engineer, the Process Routing consists of four distinct levels (Routing, Operation, Activity and Element or Step). This definition is critical to the underlying structure of an MPM process model which is now typically represented wtihin an XML file. It is this Process Model, often referred to as a BOP (Bill of Process) which forms the backbone of information that can drive the creation of the MRL DoD Deskbook, and also be exported to all downstream operational applications (i.e. ERP/MRP, Shop Floor Instructions/MES, and PFEP/InPlant Logistics).

## RELATING PRODUCT & PROCESS TO THE PLANT

Perhaps the most critical aspect to the definition of the BOP in the context of a Process model to be used by the DoD Deskbook is the ability for the BOP to be the basis from which companies can quickly and accurately react to major production volume changes, and/or transfer production from Plant-to-Plant, or Manufacturer-to-Manufacturer. Essentially, the BOP represents the body of knowledge about how the vehicle is manufactured, just as the mBOM is the body of knowledge about the components, that go into that same vehicle. Unfortunately, since the BOP represents a significantly larger, and more complicated data model than the mBOM, it is often, re-created, by hand, and at great expense in terms of time, money and manpower, each time the vehicle is produced in a different plant, by a different vendor, or at a different time. In addition, the lack of a common format, or transfer method, for this information, means that it is difficult to transfer this information between organizations in a usable and meaningful way. While the MRL DoD Deskbook defines the type of information required by vendors, it lacks sufficient definition in how this data was formatted, and relationally structured.

The approach outlined in this paper seeks to clarify these terms and relate them in a manner that it has maximum leverage between the required aforementioned applications.

### *Assembly Line Balancing*

Just as the Activity is the most critical data element in the BOP model, then Assembly Line Balancing represents the most critical application which acts on the BOP Activities.

The goal of a Line Balancing application is to assign Activities to Operators in Workstations, such that: [2], [3]

1. The assignments are valid
   a. Activities respect precedence
   b. Activities are within proper groups
   c. Activities have required tools
   d. Activities are in proper zones
2. The assignments are evenly distributed, such that the sum of Activities assigned to a worker is as close to line TAKT without exceeding it.

Therefore, the result of a line balancing analysis, is not just the assignment of Activities to Operators in Stations, but subsequently, the assignment of the Tools and mBOM Components, as well as, Ergo Studies, Quality Studies and Shop Floor Instructions which are directly associated to those Activities.

In short, an engineer can simply import into a new factory (or even an existing factory re-designed for a larger production volume), a BOP and corresponding mBOM, then complete the line balancing analysis, and automatically transmit it to the downstream processes (MRP/ERP, Shop Floor/MES and PFEP/InPlant Logistics) without human intervention. So what used to take a team of engineers several months to perform and pilot, can now be accomplished by just a few engineers in a few weeks, provided that their mBOM and BOP are in synch with the latest eBOM and ECO's.

In an actual situation, an engineer was able to import a BOP for a military trailer and develop a new process line in a new facility (complete with detailed worker instructions part and tool assignments for each station) in less than 1 hour. Direct quote below:

"This rebalance, that would previously have taken six weeks, was accomplished in a half hour! " Not only were the tasks reassigned properly, but, all the tool locations, part locations, work instructions, and JDE routings were updated."

### *Configured Process Engineering*

A critical aspect of the BOP data model is the fact that Process Routings are configured, just as products are configured "but differently".

In the BOP model, an Activity contains both Global and Local attributes, and is shared within many operations and across several Routings. The Global attributes are the Activity's description, shop floor instructions, process time, ergonomics analysis, safety and quality assessments, whereas Local attributes include the specific parts consumed, tools required and even part finish codes. Essentially, the Local attributes are related to the reference of that activity within a particular Model or Option available within a Routing.

In fact, the entire presence or absence of an Activity within a Routing is determined by the Option code list for a specific Model of vehicle. In this way, one process Routing is authored for an entire vehicle family, and then simply configured according to a Platform Code (i.e. model code with option list) into a specific Routing that would define the process for a specific vehicle serial number produced. In this way, one BOP process routing could define an infinite set of vehicle Processes, and be used to generate their associated shop floor work instructions and part kitting requirements.

Configured Routings are critical, because they allow for the maximum re-use and referencing of the fundamental process knowledge. Using configured Routings, it is justifiable to invest in documenting the detailed information needed to drive so many down-stream applications and workflows.

## MPM AND ERP - WHY THEY ARE DIFFERENT

The trend for many large assembly plant organizations to try and represent the entire BOM and Process Routing within their ERP system (such as SAP or Oracle). In this way, it is assumed that the BOP becomes irrelevant, because everything is in one database structure. Unfortunately, this architecture has not proven successful in:[4]

1. achieving the portability of the necessary BOP information to critical analytical applications (such as line balancing), or across other plants and organizations who will be using different ERP environments.
2. While all MRP-II and ERP systems define Routings and Operations, few systems define the sub-tasks of Activities, Elements and Steps, as these objects create a significant amount of data requirements, user interface needs and analytical functionality. This means that process engineers are continuously aggregating and entering these detailed process objects in Excel without any electronically managed workflow. In short, the information between these applications is often inaccurate and out-of-date.
3. driving configured process generation. As such, the process information in ERP is either very high level, or the detailed task data is very redundant to maintain, and also inaccurate and out-of-date. This problem is greatly amplified when effectivity dates are used to time-in, and out, process objects.
4. providing an MS Excel-like interface that engineers have become dependent on. In short, engineers forced to manage processes within ERP, are doing the majority of their work in Excel and trying to copy-and-paste between those environments, simply because Excel is well suited to the mass-editing of redundant non-relational data, and ERP systems are incapable of establishing the meaningful Activity-based relationships available within MPM.

## CONCLUSION

Military vehicle programs consistently demand shorter lead times, increased competition for price and performance, and higher levels of compliance documentation. The Process Engineering Workflow and BOP data model presented in this document, provide a proven method for engineering a process which can be shared across organizations as effectively as the eBOM/mBOM, and yet provide even greater opportunities in reducing the time to launch new vehicle programs both accurately and cost effectively.

The MPM XML schema required to adopt the BOP, as appropriate for military vehicles, and support of the MRL DoD Deskbook is available from the authors. This open format standard is both robust and market proven, while also maintaining a high degree of extensibility. Currently, nearly a dozen application modules exist for feeding off this BOP to both engineer the process, and manage the expected downstream applications or interfaces.

## REFERENCES

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