PLM ESSENTIALS

5. ENGINEERING STRUCTURES

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5 ENGINEERING STRUCTURES

At the heart of all complex engineering and associated manufacturing processes is Product Data Management (PDM) - the business function that organises, maintains and reports all product data.

PLM captures and tracks information on the individual parts, components and modules that constitute a finished product throughout its lifecycle, including changes made during development.

This includes part numbers, supplier details, CAD drawings and more, with everything stored in a database easily accessible to the likes of project managers, engineers, salespeople, purchasing and QA teams.

Efficient management of product data helps develop products quicker, get them to market faster, and push costs down.

ENGINEERING STRUCTURES

PUTTING PARTS IN ORDER

While the Bill of Materials (BOM) provides a complete list of everything you will need throughout a product's manufacturing and assembly process, it is also important to know how all of the parts should be put together.

The engineering structure is your guide. This gives everybody involved in production an understanding of the parts and assemblies to be made – and more importantly, it makes tracking changes during development much simpler.

To give you an overview of a good engineering structure, we have put together a detailed case study of one we created for a leading electric vehicle manufacturer.

WHAT ARE ENGINEERING STRUCTURES?

Engineering structure is the name given to the organisation of parts within a BOM. It relates only to the physical structuring of a product's parts and assemblies within the BOM, and not to the organisation of the BOM as a whole.

We typically think of a part or assembly as being made up of 'child' components, so if a child component changes, we must think of the assembly itself as having changed in some way.

That is why we create a digital copy of the structure that mimics the physical organisation of parts. This helps to track and manage any changes to the structure.

WHO USES ENGINEERING STRUCTURES?

Engineers are the primary user, with engineering structures providing clarity, improved traceability and reduced administrative workload.

Several other downstream departments are also affected by engineering structures, as for most (if not all) OEMs, procurement, logistics and manufacture do not occur at an individual component level, but instead at an assembly level.

Product Data Management (PDM) is the first function impacted by choice of engineering structure (whether a distinct role from engineering or not), as management of a BOM can be made more or less difficult through choice of structure. Primarily this impacts configuration management (which again is usually a distinct role, but can be combined into PDM or even engineering functions), as the configuration applied directly filters this structure.

Once the programme develops, it is not essential that an engineering structure remain the same for procurement and manufacturing. However, implementing this can create a significant burden, as every component and change must be restructured into separate purchasing and/or manufacturing BOMs. This then places heavy demands on all three departments – engineering, purchasing, and manufacturing. It is for this reason that engineering structures are often developed with purchasing and manufacturing strategy in mind.

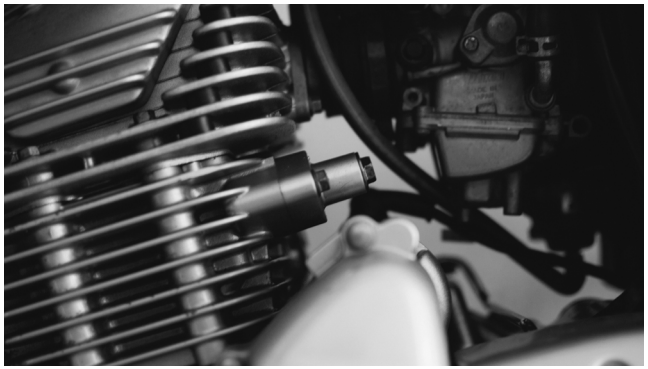
Single structure use is more common across procurement, manufacturing and logistics as the needs are often well aligned or in some cases rigidly bound by legal, regulatory or feasibility requirements.

In simple terms, a unique part number is needed for each physical item that will be purchased and handled, along with the CAD and drawings associated with it. Suppliers also require this and will often charge for having to manage the complexity themselves.

ENGINEERING STRUCTURES AT A LEADING ELECTRIC VEHICLE MANUFACTURER

A recent customer's approach to engineering structures was very ad-hoc. Engineering assemblies – if structured – were completed on an as-needed basis. While there were some loosely defined top-level structures, no guidelines were provided on how components should be structured.

The project complexity was also poorly defined and could dramatically change in future projects. While there may be many configurable commodities, the complexity in each was limited.



INDUSTRY EXAMPLES

COMPONENT-BASED RELEASING (CBR)

The minimum required structuring – and hence administrative burden – within a BOM is to release all components of a given commodity in a 'flat file' format. This 'flat file' is then passed to the supplier, who interprets what is needed and uses the relevant components to create the finished product.

This has the obvious advantage of minimising repetition within the BOM and reducing the admin required to release the change. If a single common part needs a new revision, that part is the only one that needs to be released.

The biggest challenge to this approach is the lack of an actual part number for the finished product. Depending on the region, it may or may not be feasible to use this approach.

For example, in China, items on a shipping manifest must reflect the cargo on a one-to-one basis. That means that one part cannot be shipped as multiple part numbers.

The lack of a single part number also requires clever and robust configuration management to ensure that cost and weight can be accurately reported. This leaves an open question around how an Enterprise Resource Planning (ERP) system should handle procurement and logistics.

Finally, offloading the complexity management to suppliers can incur additional costs. It can also introduce the risk that a supplier will not be able to interpret or produce the desired product or part correctly.

HIGH-LEVEL ASSEMBLY (HLA)

The High-Level Assembly (HLA) approach is the opposite of Component Based Releasing (CBR), in that a part is created for each orderable configuration, complete with the underlying structure. This is fine for non-configurable assemblies, but the admin burden quickly rises as commodities become more configurable.

For example, a wheel that allows for two tyre options, two wheel bolt types, two TPMS frequencies and two wheel styles would need the release of 16 high-level assemblies. If a common part (such as the inner tube) needs an update, the admin burden is increased sixteen times over.

That is not to say this strategy should not be considered. For many commodities on a vehicle, there is no configurability at all, so releasing a HLA is just as easy as CBR, but with less onus on the supplier.

Having a part number for each configuration also allows for much better cost visibility and control (as the cost can be recorded against these part numbers). It is also much easier to manage logistically and within an ERP system.

Variations on this kind of structure and releasing are the most common, as they capture the complete detail of each possible variant.

'MONEY PARTS'

'Money Parts' form something of a halfway house between CBR and HLA structures. The structure is the same as CBR (flat file), but a new part number without structure is released to represent each configuration available and to capture assembly costs.

This gets around the legislative issues with CBR and makes procurement and logistics simpler. It also makes it easier to capture the cost of each variant.

However, if a common component needs a new revision, all the money parts also need revising – meaning there is still a big admin burden, even without the need to structure each and every part.

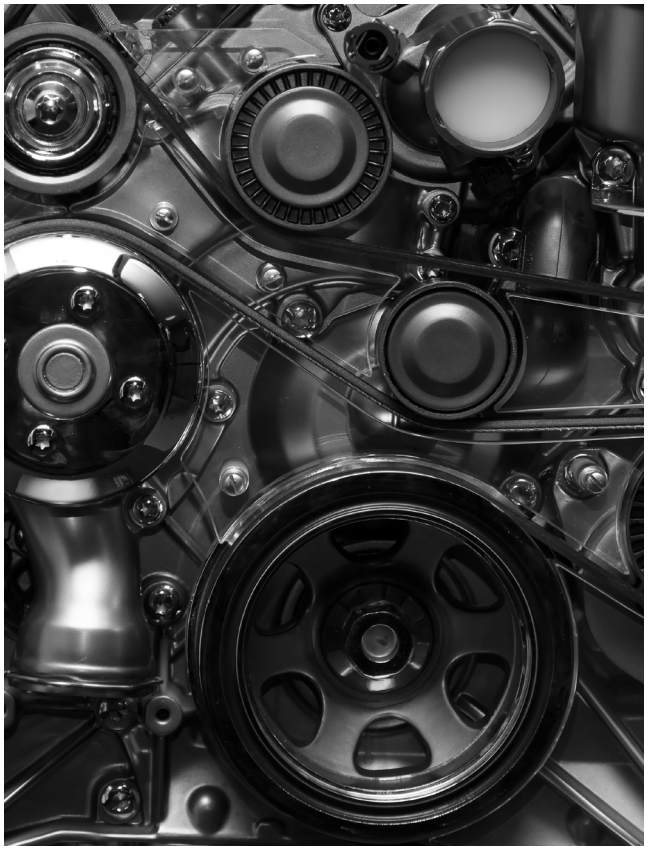
Also, if a configurable component needs a new revision, there is no easy way to tell which money parts would also need a new revision, so there is more chance of errors.

In a typical PLM solution, this presents additional challenges, as there must now be zero costed parts in the BOM (the components) at the assembly level. Without careful configuration management, there may be more errors in cost or weight reporting.

COMMON ASSEMBLY READING

Another attempt at finding something of a middle ground is to release all common components within an assembly, and then structure and release the optional components (i.e. those generating the complexity) as separate items.

This can reduce the number of components that need to be released individually (useful where a large number are common) but still has the challenges of CBR.



DECISION CRITERIA FOR SELECTING AN ENGINEERING STRUCTURE

- **Lean –** Reduce strain on all departments
- **Reportable –** Be able to drive business reports
- **Representable –** Reflect real-world objects and their availability
- **Intuitive –** Easy to use and understood by users in all departments
- **Minimal admin burden –** Improve efficiency and productivity

The ideal engineering system must:

- Support lean processes across all departments
- Support efficient engineering change management
- Not be an obstacle to any function
- Support accurate cost and weight reporting
- Represent the physical assembly of components
- Reflect and support the chosen procurement strategy
- Be intuitive to create, read and understand
- Reduce administrative burden to a minimum

THE ENGINEERING STRUCTURE *WE* DECIDED ON

Given the immaturity of procurement strategy, manufacturing, logistics and product definition within the manufacturer, and the urgent need for standardisation, we recommended the use of High-Level Assemblies and Manufacturing Assemblies as a straightforward approach that would best support the customer's programme.

GENERAL STRUCTURE

Each purchasable item should be released as an assembly with its component content structured beneath it. Figure 1 shows an example of this structure for a heated leather seat. In this example, it is assumed that the item is the complete seat (ASSY SEAT LEATHER HTR PASS), but components below this level may still be 'sub purchased' or free-issued.

The Manufacturing Assembly (MA) here acts as a collector for a finished assembly and any fixings required to mount that assembly to the vehicle. Each MA should only contain a single finished assembly.

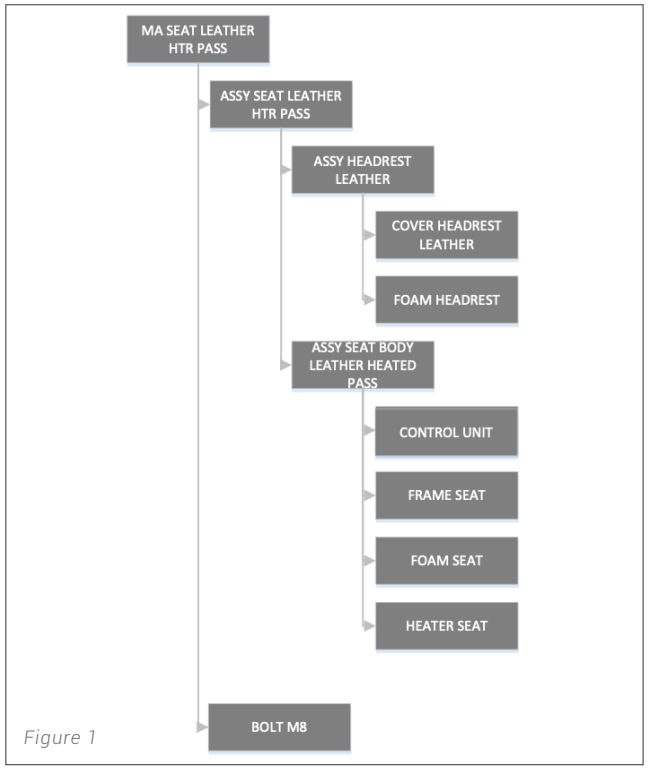


Figure 1

Each MA captures everything needed to mount a single finished assembly to the vehicle. The exception to this is where finished items received by the manufacturer undergo some preassembly before being mounted to the vehicle. In this situation, an In House Assembly (IHA) part is needed.

Similar to an MA, this part captures all the finished assemblies, plus any fixings needed to piece it together in one place. The IHA should then be structured within an MA in the same way as a finished assembly, along with any fixings needed to mount the assembly, as shown in figure 2.

In this example, the seat has now become the IHA, with the seat body and headrest being treated as the finished assemblies (i.e. the final parts purchased).

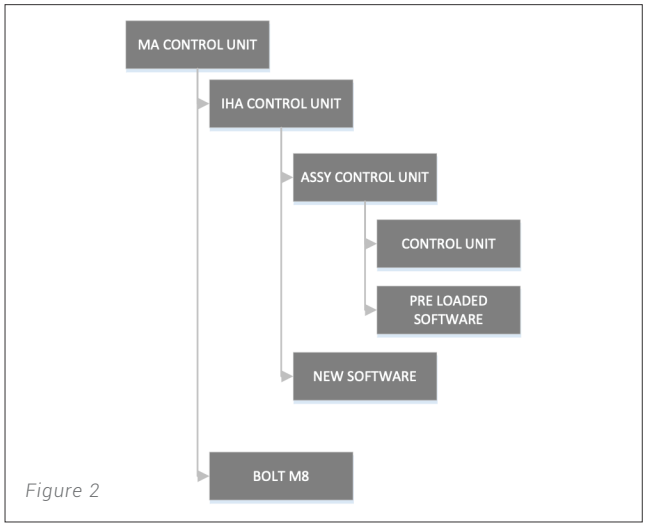


Figure 2

Assembly items can be made, purchased or sub-purchased.

ASSEMBLY TYPE	PROCUREMENT TYPE	DETAIL
MA (MANUFACTURED ASSEMBLY)	ASSEMBLED	ASSEMBLED BY MANUFACTURER
IHA (IN HOUSE ASSEMBLY)	ASSEMBLED	MADE BY MANUFACTURER
ASSEMBLY	PURCHASED OR ASSEMBLED	OUTSOURCED MANUFACTURE/ ASSEMBLY

SOFTWARE STRUCTURE

In most instances, a component is added, and nothing is removed or replaced in the construction of the final product. The structuring of these parts is relatively straightforward.

But some components (typically software) will need to be modified, and some part of it removed before assembly into the final product. In the case of software, it is important to capture the software pre-loaded (as delivered by a supplier), as well as new software, flashed to the component.

In these situations, we recommend structuring the pre-loaded software under the hardware, and both the hardware and the new software under an IHA, as shown in figure 3.

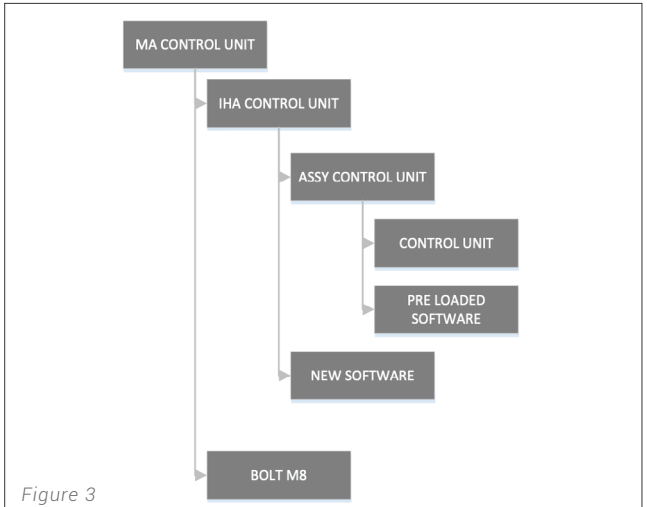
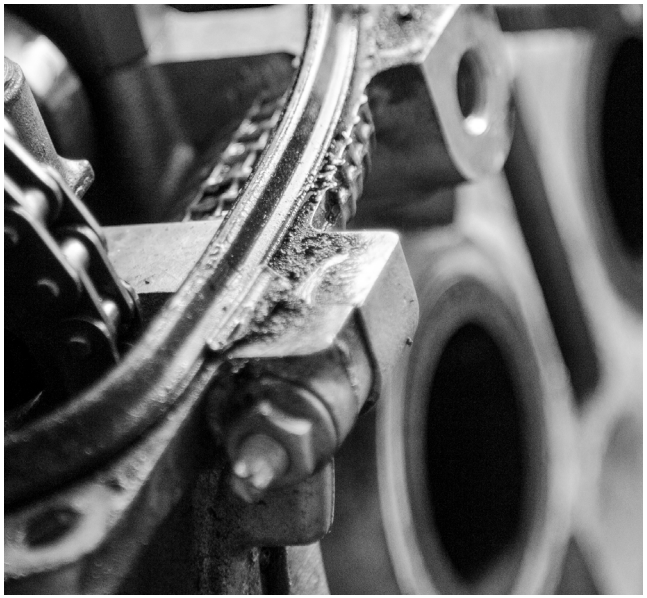
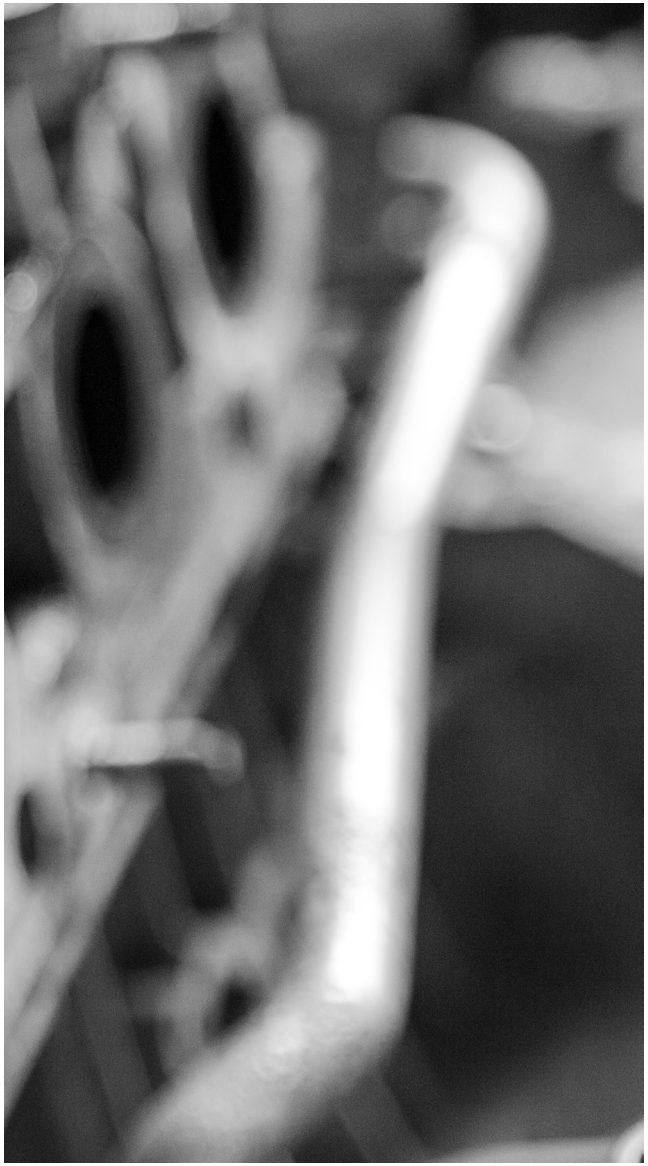


Figure 3

This allows time/weight/cost deltas to be captured against the IHA, as well as capturing the proper structure of the purchased part.





JUSTIFICATION & EVIDENCE FOR THE NEW STRUCTURE

Without the full definition of product complexity or a mature procurement and manufacturing strategy helping to define where complexity will be managed, the customer could not define the best structure to release components.

From the information available, a degree of complexity in the final product was to be expected. However, there should not have been a large degree of variation within any single commodity.

The benefits offered by a CBR strategy did not outweigh the costs and difficulty of implementing such a structure, and indeed without a mature procurement plan, CBR may not have been feasible or even legal.

HLA based structuring and releasing is arguably the easiest to understand and implement and provides the best visibility and support for purchasing, logistics and manufacturing.

Given the apparent complexity described above, the administrative workload placed on engineering to pursue this strategy should be low. HLAs also simplify the task of configuration management, as only a single BOM level must be configured.

Using a fully configurable BOM structure offers the best solution, but we decided against this for the following reasons:

- **A structure was needed soon, and this would have required much more system development and implementation – not an 'off the shelf' PLM package**
- **For this approach, excellent configuration management was needed but this function was still in its infancy**
- **The benefits realised by this solution would be minimal if purchased commodities were complex**

RISKS OF THE NEW STRUCTURE

As noted above, without a concrete understanding of product complexity, it is hard to estimate the pros and cons of each structuring system.

If the complexity of the product increases - and if the complexity needs to be pushed out into the supply chain - the admin burden to manage a HLA based structure will grow exponentially, as hundreds or potentially thousands of variants of the same item must be structured and released. The time, cost and effort associated with making even small changes to common components will also exponentially increase with this increasing complexity.

FUTURE DIRECTION - LEAN STRATEGY

As described previously, HLA releasing simplifies procurement and manufacturing processes but does so at the expense of an increased engineering administrative burden.

There is a further untested solution to consider that may provide the best of both worlds but would need significant system development and robust configuration management to put into place.

The core concept of this approach is that once a configuration is applied to a BOM, the system should then be able to interpret this and automatically produce a full range of HLAs for purchasing and production. This allows engineering to manage a BOM with the minimum size and repetition while giving other functions the full visibility and structure they need.

Within the engineering BOM, everything is treated as a configurable material, so each part has every component that it could comprise of structured as a child component.

For each location on the vehicle where there could physically be an assembly (for example, the left-hand seat), there is only one assembly in the BOM that can be configured to be all possible options. An example using a simplified model of a seat is given in figure 4.

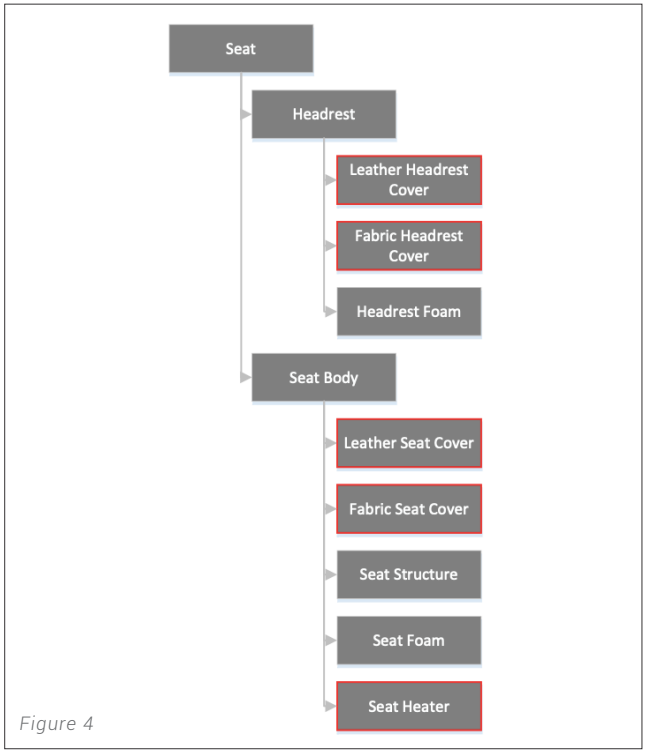


Figure 4

The parts showing in each view of the BOM or in CAD are then determined by the configuration applied. This configuration would need to be robustly managed at multiple BOM levels, in contrast with HLA, where the configuration only needs to be managed at an MA level.

This provides the most condensed and efficient BOM for engineering to work with.

But there are two obstacles with this structure:

1. **Each configurable item now (Seat, Seat Body, Headrest) represents multiple different parts, which requires multiple part numbers**

2. **There's no clear way to assign and roll up costs. As a result, this view of the BOM no longer supports purchasing and manufacturing, and a great deal of admin work is needed to restructure each HLA to enable cost tracking, procurement and vehicle assembly**

We proposed, that given the configuration rules and the identification of a purchasing level within a commodity, that the system should generate the required structures directly into a Manufacturing BOM (MBOM), as illustrated in figure 5.

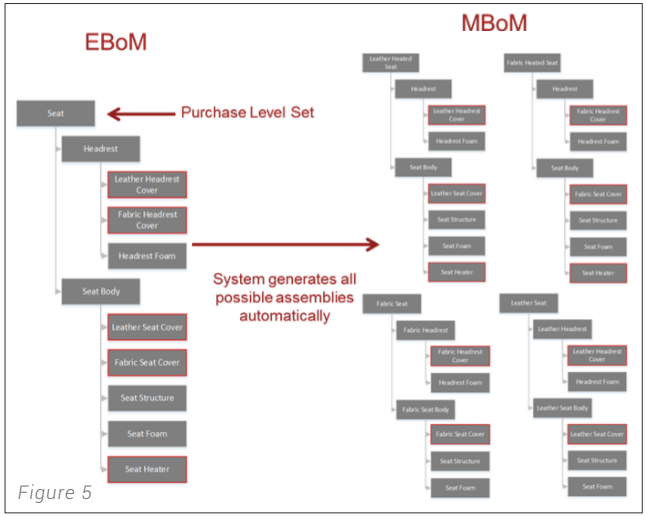


Figure 5

In this case, four HLAs (Leather and Fabric seats, both heated and non-heated) were generated. Note that mixed configurations (half fabric, half leather) were not generated – these rules would need to be captured within the configuration management system.

The system would also need to generate unique part numbers for each variant of each configurable item and have these available pre-release, as a purchase level is identified to accurately capture projected costs.

The main advantages of this process were the single structuring of all common components and the ease with which a transition could be made from one purchasing and manufacturing strategy to another.

If a common component requires revision, engineering need only release a single structure (as opposed to every assembly) and the system will take care of the rest.

And if there is a change in purchasing and manufacturing strategy, all that needs to be done is to release the same structure, but with a different purchase level identified, as shown in figure 6.

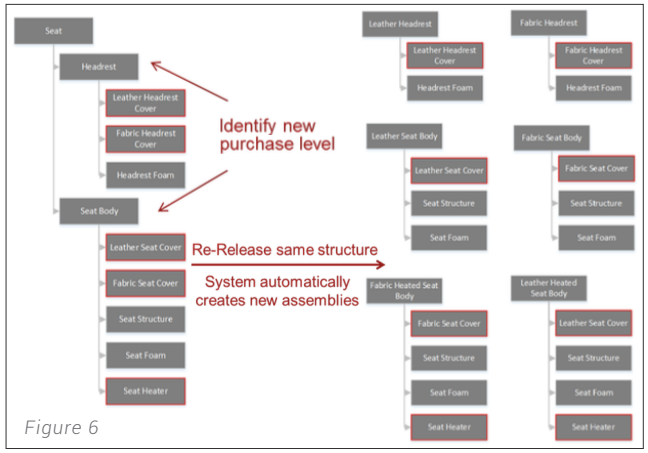


Figure 6

At the time of writing, this method of structuring/complexity management does not appear to be used by any OEMs, so it would be an innovation in product development.

However, it is not without its challenges. It would take a high degree of system development to overcome other obstacles, such as how to configure drawings, run clash checks etc. But if implemented, this has the potential to dramatically reduce the admin burden placed on engineering, and with it, reduce the duration of product development cycles and reduce costs.

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ABOUT QUICK RELEASE_

Quick Release_ is the leading Product Lifecycle Management consultancy. QR_ has 350+ professionals across three continents working alongside some of the largest, most innovative and prestigious vehicle manufacturers, aerospace technologists and Tier 1 suppliers.

Our mission is to enhance competitive advantage by bringing products to market faster and more efficiently. We do this by improving product data quality and flow through every part of a business from concept to manufacture, working with senior management teams to tackle the biggest blockers of productivity; we release engineers to focus on the product, not the data.

Leveraging bespoke tools, methodologies and benchmarking, our professionals offer the full spectrum of PLM services designed to guide start-ups through the unknown unknowns, take businesses looking to scale to the next level, and facilitate transformation in established manufacturing and technology OEMs. Read more: Why does PDM matter?

NEED MORE STRUCTURE?

If you'd like to know more about engineering structures, or any other aspect of PLM, we'd love to hear from you.

QR_ have advised on and implemented engineering structures for EV start-ups, specialist, volume, and commercial vehicle manufacturers.

Our SMEs would love to hear your engineering structure headaches and explore quick, unobtrusive solutions that deliver lasting, whole-business value.

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