Automotive Product Data Management

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Summary
For an automotive company product data is the heart of the information. It is data needed everywhere, it needs to be common, and you must be able to get advanced and diversified services from it.
Below you will have an overall description of what is meant by vehicle product data and how it should be managed, important examples of how product data can be used all over the company, and what base technology is needed to achieve this.

My name is Lars Wentzel. All my life I have been working in the automotive industry with information handling: Systems, investigation, information analysis and design of algorithms. Areas I have covered are Planning, Capacity Management and Order to Delivery in a context where multiple systems are involved.

For twenty years I have also worked with product vehicle data, both configurations and part contents (BOM). Focused on common company product data and advanced use of it in planning, ordering, order scheduling, pricing, invoicing, cost calculations, dummy order creation and capacity management.

The below description is a try to generalize what I have learnt.

Basics

Most products are usually described by a top part number. From that you have a complete tree of ingoing parts so you can get your BOM – Bill of Material.
Vehicles are different. The variation and frequent changes of the content of vehicles makes it very unpractical to describe each specific vehicle as a part number e.g., in ordering a specific vehicle. Instead, you describe *configurations*.

Configurations
An automotive vehicle - a car or a truck - is much better described as a ***configuration*** of features like engine, gearbox, brakes, seat material, rims, tires etc. Vehicle configurations is the core data of product data for vehicles.

(Possibly there is even a higher level like a product number which might contain a base product, optional features, and packages)

Below the elements of vehicle configurations are described.

Features
Features are grouped into families (variables) like RIM – with several possible values e.g., 18”, 19”, 21” … In some families there might be a value of non-existence like No Air Condition. Examples:

RIM 001	18” steel
RIM 002	19” aluminium
RIM 003	21” black aluminium
ACO 000	No Air Condition
ACO 001	Air Condition
TYP 001	Car XC1
TYP 002	Car Sedan B2
SMA001	Textile

SMA002 Leather
SMA003 Nubuck
SHE000 No heating
SHE001 Seat Heating

Normally, for a configured vehicle, you should get exactly one value in each feature family e.g., RIM002, ACO001, TYP002

The number of feature families should not be too big. The minimum number is the one you need to specify an order. The number or feature families are decided by diversity of the vehicle. Customer choices don't need much more than 100 families. But for different reasons is practical to have some more to get more information at this level. I would not recommend adding a lot for families for parts only. I would recommend about 200 families for a vehicle.

Feature combinations
Feature combinations are of course restricted e.g., 18" steel is not allowed on XC1, Sedan B2 must have Air Condition, or Seat Heating must have Leather

Base vehicles
For many reasons it is very practical to introduce the concept of base vehicle. This represents a standard configured vehicle. A good idea is to call some feature families *main families* like type, engine, and market area. Then a base vehicle is a unique combination of these features.

A base vehicle has a standard list of features from all families. These can then be exchanged with the available optional features.

Example of base vehicles using three feature families:

TYP	**Type**	**ENG**	**Engine**	**MKT**	**Market area**
SE1	Sedan I	D01	Four cylinder diesel	EUR	Europe
SE1	Sedan I	D02	Six cylinder diesel	EUR	Europe
SE1	Sedan I	P01	Four cylinder petrol	EUR	Europe
SE1	Sedan I	P02	Six cylinder petrol	EUR	Europe
SE1	Sedan I	E01	Electric	EUR	Europe
SE1	Sedan I	P01	Four cylinder petrol	USA	USA
SE1	Sedan I	P03	Eight cylinder petrol	USA	USA

The base vehicle concept is very handy in several cases e.g., when making volume plans on a high level or when creating homologation information. And when you specify an order, you only need to give the base vehicle and the optional features.

When it comes to rule handling, the bigger part of the combination rules is in the definition of base vehicles. Thus, the other feature rules can then be minimized.

Example of base vehicles

	TYP	SE1	SE1	SE1	SE1	SE1	SE1	SE1
	ENG	D01	D02	P01	P02	E01	P01	P03
	MKT	EUR	EUR	EUR	EUR	EUR	USA	USA
BRK	**Break size**							
001	**18"**	S	S	S	S	S	-	-
002	**20"**	-	-	-	-	-	S	S
RIM	Rim							
001	18" steel	-	-	-	S	-	-	-
002	19" aluminium	S	S	S	O	S	-	-
003	21" black aluminium	O	O	O	-	-	S	S
ACO	Air Conditioner							
000	No Air Condition	-	-	S	S	-	-	-
001	Air Condition	S	S	O	O	S	S	S
SMA	Seat matrial							
001	Textile	-	-	S	S	-	-	-
002	Leather	O	O	O	O	S	S	S
003	Nubuck	S	S	O	O	O	O	O
GBX	Gearbox							
001	Six step manual	S	S	O	O	-	-	-
002	Six step automatic	O	O	S	S	-	S	S
003	Electic aut	-	-	-	-	S	-	-
-	Not possible							
S	Standard							
O	Optional							
Example of rules								
	RIM003 may not have BRK001							
	RIM002 may not have BRK001							

Packages

A package or a sales package is just a collection of features. For different base vehicles, the list may not be exactly the same e.g., if a base vehicle already contains a feature as standard. There may exist alternative features of certain families i.e., upgrades.

Factories

If you have several production sites you need to handle what vehicles can be produced where and when.

Parts

How to get the BOM. Well, you do this by setting up rules where you attach a part number to one feature or a combination of features.
FeatX and FeatY -> Part 123456. E.g., TYP001 and ACO001 -> 72935401 (Compressor).
The part numbers for a specific vehicle may also be different in different manufacturing sites.

Changes

Changes in products will occur all the time. Introduction of a new feature, decommission of an engine, part replacements, and so on will happen almost each week.
All features, combinations and part rules are of course time dependent. E.g., the compressor part is exchanged with another compressor at a certain date (week).
The base vehicles can come and go, and the features of a base vehicle can change from standard to option or vice versa. Features can be added and removed. Change point is when a change occurs and can be a date or I would recommend using week.

Connected data

There will be a lot of other data needed to describe the vehicle.
Examples:
BOM (mentioned above)
Accessories
Spare parts
Technical data (Weight, Dimensions, Drag, Rolling resistance, Performance, Emissions)
Pictures
Descriptions
Prices
Cost

These do not come second in importance. But they should all be connected to the configurations like parts. E.g., top-speed 230 = Engine D02 *and* Gearbox Man.

The alternative is of course to let it be an attribute of a part number e.g., weight, cost, software.

How to manage configurations

You want to set up and maintain your configurations. It should be simple and straight forward to do. Immediate verification of configurations should be done as you type. For this the Array Technology described below is essential. These are the most important functions when setting up configurations.

1. Define your features
2. Define change points i.e., when configurations change e.g., a week or a date
3. Set up your base vehicles
4. Create necessary combination rules
5. Define the content of the base vehicles, the configuration grid
6. Define your packages.

I will not go through all functions. Instead, I will show a bit of the most important one, (5) the configuration grid. This is a matrix update with base vehicles as columns and features as rows. Of course, the change points are needed but they are omitted in my example.

	TYP	SE1	SE1	SE1	SE1	SE1	SE1	SE1
	ENG	D01	D02	P01	P02	E01	P01	P03
	MKT	EUR	EUR	EUR	EUR	EUR	USA	USA
BRK	**Break size**							
001	**18"**	S	S	S	S	S	-	-
002	**20"**	-	-	-	-	-	S	S
RIM	Rim							
001	18" steel	-	-	-	S	-	-	-
002	19" aluminium	S	S	S	O	S	-	-
003	21" black aluminium	O	O	O	-	-	S	S
ACO	Air Conditioner							
000	No Air Condition	-	-	S	S	-	-	-
001	Air Condition	S	S	O	O	S	S	S
SMA	Seat matrial							
001	Textile	-	-	S	S	-	-	-
002	Leather	O	O	O	O	S	S	S
003	Nubuck	S	S	O	O	O	O	O
SHE	Seat heating							
000	No heating	S	S	S	S	S	S	S
001	Seat Heating	O	O	O	O	O	O	O
GBX	Gearbox							
001	Six step manual	S	S	O	O	-	-	-
002	Six step automatic	O	O	S	S	-	S	S
003	Electic aut	-	-	-	-	S	-	-

There will be some advanced functionality in this. The dependency rules are used as you type. This means that you will get immediate feed-back when inconsistencies are detected.
As an example, seat heating is only available when you have seat material=Leather
So, if you remove leather from the first car then it cannot have Seat heating as an option
You will immediately see the inconsistency.

SMA	Seat matrial							
001	Textile	-	-	S	S	-	-	-
002	Leather	-	O	O	O	S	S	S
003	Nubuck	S	S	O	O	O	O	O
SHE	Seat heating							
000	No heating	S	S	S	S	S	S	S
001	Seat Heating	O	O	O	O	O	O	O
			Must have leather					

To correct this, you can remove the optional Seat heating, or you can make Leather available.

Another important functionality is to be able to update on a base vehicle aggregated level. This means that you can update features that are independent of some of the main features e.g., engine, and will speed up the work.

	TYP	SE1	SE1
	ENG	*	*
	MKT	EUR	USA
BRK	**Break size**		
001	**18"**	S	-
002	**20"**	-	S
RIM	Rim		
001	18” steel	-/S	-
002	19” aluminium	S/O	-
003	21” black aluminium	-/O	S
ACO	Air Conditioner		
000	No Air Condition	-/S	-
001	Air Condition	S/O	S
SMA	Seat matrial		
001	Textile	-/S	-
002	Leather	S/O	S
003	Nubuck	S/O	O
SHE	Seat heating		
000	No heating	S	S
001	Seat Heating	O	O
GBX	Gearbox		
001	Six step manual	S/O	-
002	Six step automatic	S/O	S
003	Electic aut	-/S	-

	TYP	SE1	SE1
	ENG	*	*
	MKT	EUR	USA
BRK	**Break size**		
001	**18"**	S	-
002	**20"**	-	S
RIM	Rim		
001	18” steel	-/S	-
002	19” aluminium	S/O	-
003	21” black aluminium	-/O	S
ACO	Air Conditioner		
000	No Air Condition	-/S	-
001	Air Condition	S/O	S
SMA	Seat matrial		
001	Textile	S	-
002	Leather	S/O	S
003	Nubuck	S/O	O
SHE	Seat heating		
000	No heating	S	S
001	Seat Heating	O	O
GBX	Gearbox		
001	Six step manual	S/O	-
002	Six step automatic	S/O	S
003	Electic aut	-/S	-

To the right you see how you can override a mixed value and make textile standard on all European vehicles. But then you will be notified that you must change the Leather and Nubuck features as well.

How to use

There are some basic principles for use of vehicle product data.

Product data must be regarded as a **common** asset of the automotive company. For a successful company this should be a corner stone. What you can homologate, plan for, and order is also what you can build.

Data must be available in a very **flexible** way. Different operations will need to see data from different angles and use it for different purposes.

Data shall not be distributed but made available through **services** i.e., you send in a request with input data, and you get a reply. These can either be on-line services where you get an immediate answer, or it can be a batch service where you get the result some minute or more later.

Using services is of course an architectural choice. It is not required, but it will guarantee that you have a consistent interpretation of the data.

I will give you an example list of services needed.
The basic ones:

- Check one or several orders
- Break down one order (or dummy order) or several e.g., one year's production, to features and/or to BOM.

Then all the rest:

- Respond to a configuration click – selection of a feature – and the effects
- Create dummy orders for one years planned production
- Get all base vehicles and their time authorization for two years
- Can n orders be moved to a different week
- Get the available optional features per base vehicle
- Find the configuration with the highest weight
- Calculate the CO2 emission for each dummy order of one year production
- Calculate the cost of each optional features per base vehicle.
- Find the availability of two features in combination in all vehicles for two years
- Get a big list. Fore each base vehicle and single optional feature get the complete feature list.
  TYPSE1 ENGP02 MKTEUR with RIM002 (19" alu):
  TYPSE1,ENGP02,MKTEUR,BRK001,RIM002,ACO000,SMA001,SHE000,GBX002
- Find all vehicles where a part is used.
  … and much more

It is very important that new services can be implemented quickly when a new or existing systems require new services i.e., be flexible.

As you might see from the list above you will need advance handling. For this you will need the Array Technology below.

Array Technology

Array Based Logic is an invention of the Danish persons, Gert Moeller and Claus-Erik Jensen. The basic thinking is that you have a big but limited configuration space. By using tables connecting variables you can represent configurations of a very large problem space. Example:
You have rims 18",19",21". Then you have brakes 18" and 20". Dependencies can be represented by rules: Rim 18 must have brakes 18 etc. This can also be represented in a table:

RIM	BRK	
18"	18"	Yes
19"	18"	Yes
21"	18"	Yes
18"	20"	No
19"	20"	No
21"	20"	Yes

Or only the net allowed combinations

RIM	BRK	
18"	18"	Yes
19"	18"	Yes
21"	18"	Yes
21"	20"	Yes

This ruleset can be used to verify the consistency of the base vehicles.

Here comes another example with seats (material and heated seats). Heated seat must have Leather:

SMA		SHE		
001	Textile	000	No heating	Yes
001	Textile	001	Seat Heating	No
002	Leather	000	No heating	Yes
002	Leather	001	Seat Heating	Yes
003	Nubuck	000	No heating	Yes
003	Nubuck	001	Seat Heating	No

Or only the net allowed combinations

SMA		SHE		
001	Textile	000	No heating	Yes
002	Leather	000	No heating	Yes
002	Leather	001	Seat Heating	Yes
003	Nubuck	000	No heating	Yes

If you have 200 variables this will become a table that is not manageable. But by finding only the limited dependencies you can represent all configurations in a lot of small, connected tables. These are representing the complete space of possible configurations. And the tables contain only allowed combinations.

By using this technology, you can do several things that are not otherwise possible i.e., verifications to see consistency, finding combinations of variable values, and analyzing data from any angle. These abilities are attractive especially when you want to use data in a manyfold way.