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CONCEPT SELECTION IN THE AUTOMOTIVE INDUSTRY WITH EXAMPLES

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1. Introduction

During product development many requirements of various types have to be fulfilled, such as, mechanical, aesthetical, environmental, serviceability and cost. The requirements are not static but change over time due to constant competition on the market. In the automotive industry large amounts of capital and prestige are at stake, projects are international involving billions of euros. Providing the customer with more and more features without significantly increasing cost and size leads to great engineering challenges. This paper will describe the multitude of requirements involved and outline some examples of concept selection in the automotive industry. The aim of this brief paper is to increase the awareness of the complexity involved and the resulting difficulties in concept selection in the automotive industry. This may be viewed as a descriptive industrial paper, a call to increase the interest among the researchers in the engineering design community to develop robust and reliable selection methods suitable for the automotive industry or other complex high volume industry.

2. Background

Concept selection has been a living topic in engineering design for many years, see [King and Sivaloganathan 1999] for some examples. Selecting the right concept is an important decision and has far-reaching consequences with respect to quality, performance and cost. A given concept will often have a performance limit and when the choice is made performance is set within a limit. The complexity, politics and consequences involved in concept selection are not always revealed and understood. Selection methods developed and used on a laboratory scale are often not scalable into the size needed in industrial situations.

Product lifecycle has been reduced in the automotive industry so that more and more models are produced in a shorter time span. However manufacturing equipment often needs to be reused from model to model in order to be amortised over a longer time span. This means that a concept decision is often influenced from earlier concepts and will potentially have a long time impact. Another trend in the automotive industry is the merging of several brands into a group implying that a concept decision will influence and will be influenced by several brands and their specific history and unique requirements.

3. Research method

The author of this paper is working daily within two multi-brand automotive platform product development projects including participation in a multitude of settings from platform management meetings to prototype manufacturing and production launch in a plant. Some of the observations from this work and some reflections from an industrial perspective are briefly described in this paper as observations and comments from a practitioner. The research method could be labelled as participatory design, see [Blomberg et al 1993].

4. The importance of space or handling coupled decisions

It might seem odd to start with something as apparently simple as space. However anyone that has looked under the bonnet of a modern car knows that there is merely no empty space left at all. Even other areas not as visible to the normal customer are filled with equipment. The reason for crowding is that more and more features are provided while the outer size of the vehicle is more or less maintained and at the same time the passenger compartment size is maximized. How is this referred to concept selection? Lack of space means that the design becomes highly coupled or integrated. The change of one component has an impact on a neighbouring component, possibly a component from a totally different area. For example changing the engine means that a bigger silencer is needed which then means that no full size spare wheel can be accommodated without deteriorating the luggage space. As described by [King and Sivaloganathan 1999] many of the well-known concept selection methods such as Pugh's evaluation method or Pahl's and Beitz's utility theory do not consider coupled problems. The DSM method by [Steward 1981, Eppinger et al. 1994] has the ability to show basic couplings but is not a concept selection method in the sense that it is made for enhancing the selection between various concepts. An attempt to include the couplings between concepts is made by [King and Sivaloganathan 1999] with the use of a compatibility matrix. The idea is appealing and it should be interesting to see this used on a system on an industrial scale.

4.1 The packaging department

In the automotive industry the way to handle lack of space is to form an entire department, the packaging department. In the same way as a crash department uses CAD drawings to mesh the geometry and make analyses the packaging department uses CAD files to analyse the static and dynamic distances between both stationary and moving parts in use (e.g. engine and suspension) and also clearances needed for manufacturing purposes. The packaging department's output is precise statements of clearances or interferences. During the concept stage studies are made showing the distances or interferences between components for different concepts. Later on during detail development the packaging departments are almost always involved to check what areas any changes affect. Although a sidetrack with respect of the content of this paper, it is worth mentioning that packaging software and techniques seem not to be taught in any engineering school.

5. Examples of requirements in the automotive industry

The type of requirements and their (in)stability in time have an influence on concept selection. Some of the bread and butter requirements in car development are shown below. There are thousands of requirements depending on the level of detail. Software is used to keep track of fulfilment. Here are just a few basic high level requirements in order to give an idea of the complexity. In an automotive group furthermore each brand ideally has its market segment leading to that the requirements are not the same for each brand. For example a premium brand usually has higher demands on comfort than a sporty brand. To fulfil the different brand requirements with the same platform as a base is a difficult task.

5.1 Performance requirements

- Strength (fatigue and permanent deformation)
- Crash (acceleration, intrusion, compatibility, pedestrian, integrity, non-leakage)
- Weight (overall and single components)
- Engine effect and torque characteristics, handling, convenience, steering, NVH (Noise Vibration and Harshness), interior climate

5.2 Aesthetic and ergonomic requirements

- Exterior appearance

- Interior size and shape, location of buttons, necessary forces to handle levers etc.

5.3 Manufacturing requirements

- Reusing plant layout and equipment
- Stamping feasibility of sheet metal when applicable
- Castability when applicable
- Assembly possibilities (automatic and manual)
- Sealing and anti-corrosion application
- Weldability

5.4 Cost

Cost is one of the most important requirements during development. Market competition is fierce and the customer expects more and more features for less and less money. The total cost of development and manufacturing depends on several factors. As does the cost of ownership for the customer.

- Development cost (In-house (what brand in the group) or at a supplier?)
- Tool cost* (Can tools be reused?)
- Piece price
- Manufacturing costs (labour, investments and commodities)*
- Commonality (Can several brands share the component to decrease piece price?)
- Service costs (Is it easy to maintain the car?)
- Guarantee costs (Are damages easy to repair?)

*Although product lifecycles are becoming shorter and shorter manufacturing techniques still rely heavily on billion euro investments for tools and manufacturing equipment, hence reusing tools and equipment is of great importance and thus will influence decisions made.

6. Examples from multi-brand platform development

The easiest way to explain the particularities and hence needs for concept selection methods is to outline a few examples encountered in the beginning of a project and one example from detail design of another project. The examples have been stripped of details due to confidentiality reasons. Some background is provided in the following two sections to provide information about issues that are not always explicitly stated during the selection process but lurk under the surface and affect the outcome.

6.1 Updates to an existing platform

The first two examples come from a project in which an existing platform (base) is updated in order to fulfil new legal requirements and new expectations from the customers. Three brands (A, B and C) are involved; two situated in Europe (A and C) and one in Asia (B). Huge time, cultural and linguistic barriers complicate communication. Two of the brands (B and C) sell to the North American market which has its own customer requirements and laws to fulfil. Brand C has a premium profile. Brand B is aiming heavily at its home market in Asia in a country where right-hand vehicles are the rule. The automotive group owns 30% of brand B, brand C is fully owned by the group and brand A founded the group. Brand B will manufacture at its home market in Asia and due to transportation costs that need to have local suppliers and their own stamping facilities. Furthermore some raw material prices differ considerably between Europe and Asia, for example, aluminium is less expensive in northern Europe than in Asia. Brands B and C plan to sell cars and to start medium volume manufacturing in a low labour cost country in Asia in the same plant.

6.1.1 Changes and updates of the rear portion of a platform in the concept stage

This concept selection is about what floor(s) to implement and the results need not be one concept but maybe one concept for each brand even if that is not a preferred scenario. Market investigation and information from customers having bought cars made on the base platform shows that better autonomy is required. At the same time higher engine effects are anticipated which means that although the engines will be more efficient the fuel consumption will not be reduced significantly (for these high power engines). Furthermore the legal demands on exhaust noise are becoming very stringent. The premium brand (C) is considering special tyres that allow driving at limited speed on flat tyres hence deleting the spare tyre. However the run flat tyres are heavier and might deteriorate the fatigue properties of the chassis. Brand B is not considering this type of tyres due to their higher cost furthermore they will sell some of the cars on a market where they believe that the spare tyre needs to be of full size and not a compact variant. Brand C has already developed and made tools for a floor compatible with a large silencer of which both are in production. A further requirement is that the luggage compartment should not become smaller. The context mentioned above makes this an example of coupled decision making. A causal chain is described as follows:

1. Better autonomy+higher effect-> bigger fuel tank
2. Higher effect+stringent noise laws-> bigger silencer
3. Brand B needs a full size spare wheel on one market where it also manufactures
4. Brand C does not need a spare wheel if run flat tyres are introduced
5. Brand C has a floor adapted to a big silencer and no spare wheel
6. Same size luggage compartment
7. Run flat tyres are heavier and might deteriorate fatigue properties

Numbers 1, 2 and 3 are in conflict with 6 because the all demand more space of which there is none. Number 4 is an enabler that combined with 5 makes 6 possible but only for brand C and number 7 might present a problem. Brand B and C will be produced in the same factory in Asia so sharing the same stamping tool for the floor would be highly beneficial. As seen this is a very tricky selection and all of the information is not available from the start, e.g., number 7 will need to be investigated. The packaging possibilities play a great part in this occasion and hence the packaging department has produced a matrix showing what is possible to package, see Figure 1.

Tank Volume	Floor	Brand B deep s deep spare wheel well		Brand A small spare wheel well		B & C small spare wheel well		A & C without spare wheel well	
		C muffler	B muffler	C muffler	B muffler	C muffler	B muffler	C muffler	C muffler
big	Wagon (long floor)	not feasible	not feasible	not feasible	not feasible	not feasible	feasible	feasible	feasible
	Hatch (short floor)	not feasible	not feasible	not feasible	not feasible	not feasible	feasible	feasible	feasible
	Notch (med. floor)	not feasible	not feasible	not feasible	not feasible	not feasible	feasible	feasible	feasible
	AWD	not feasible	not feasible	not feasible	not feasible	not feasible	feasible	feasible	feasible
small with current silencer system	Wagon (long floor)	feasible	feasible	feasible	feasible	feasible	feasible	feasible	feasible
	Hatch (short floor)	feasible	feasible	feasible	feasible	feasible	feasible	feasible	feasible
	Notch (med. floor)	feasible	feasible	feasible	feasible	feasible	feasible	feasible	feasible
	AWD	not feasible	not feasible	not in program	not in program	not feasible	feasible	feasible	feasible

Figure 1. Package matrix floor (reduced size)

As seen from the description and the matrix the concept selection is affected by numerous factors and the decision is coupled.

6.1.2 Changes in the front of a platform in the concept stage

To better satisfy customers the cooling performance of the AC system needs to be improved. Hence a new AS system needs to be selected. However most of the surrounding components will be carryovers (same as in older model) and other performances should if possible not be deteriorated. Furthermore the cost of the AC should be reduced by a two digit figure. All three brands have different requirements on the cooling performances and on the ergonomics of the AC system which is bought from a supplier. Cars on the current platform will continue to be produced in parallel on the same production line as the cars on the improved platform. This needs to be done sensibly not to increase complexity and manufacturing costs. The condenser is a sort of air cooler needed to lead the heat away from the AC system needs to get bigger. After long discussions it was seen that the only way to accommodate the AC system regardless of which of the three suppliers that is selected is to move an important electrical box, PJB.

1. Brand C has the highest cooling demand -> bigger condenser and a bigger AC system
2. Brand C requires automatic temperature regulation
3. Brand B needs a footrest on its right-hand driven cars of which they sell many
4. Brand A and C will need to produce cars with the old type of AC system and the new AC on the same production line during a few years.
5. Brand B has the least stringent cooling demands
6. Brand B and C have the highest pedestrian demands (not to injure a pedestrian in low speed crashes)
7. Brand C has a low and sleek bonnet design
8. Brand B needs to source locally and prefers a certain supplier due to strategic reasons
9. All brands needs better engine cooling performance and the intercooler also needs to be improved
10. The PJB is situated very close to the AC system.

Number 1 is in conflict with 7 and 9 because the bigger condenser needs more space and at the same time more space is needed for the engine cooler. Simultaneously these coolers must have a certain distance to the outer fascia so that 6 is not deteriorated. Number 1 is also in conflict with 3 especially for brand B but 5 and 8 are making it slightly easier. The installation of the AC is complicated by 4 and 10. The solution seems to be to move 10. As this is also a packaging problem a matrix has been developed see Figure 2 that also includes issues regarding e.g. the glove box etc. Dark grey box means severe interference and light grey means moderate interference and TBI means To Be Investigated.

	Left hand drive (LHD) clearance to:							
	sheet Metal	Glove Box Brand A	Glove Box Brand C	Carpet	Foot clearance requirement	ALFA AC unit	BETA AC unit	GAMMA AC unit
Current PJB	+ 44 mm	+ 26.5 mm	TBI	+ 12 mm	+ 7 mm	n/a	+ 13.4 mm	n/a
Horisontal PJB	+ 26.6 mm clearance * interference with c/o weld studs	+ 25 mm clearance	TBI	+ 6.2 mm (bracket)	+ 9 mm (bracket)	n/a	+ 17 mm	n/a
Vertical PJB	* Bracket interferes with HTR PLN CHAMBER * interference with c/o weld studs + 16 mm clearance to DASH PNL	- 36 mm	TBI	+ 14 mm	- 16 mm - 6 mm with PJB connector	n/a	+ 23 mm	n/a

Figure 2. Package matrix PJB, only left hand drive shown (reduced size)

Although a lot of work has been done up to this stage, please note that no AC concept has yet been selected out of the three available! However other components, such as, the PJB, the carpet, the glove box and even the condenser far away from the main system need to be moved and/or changed which leads to new challenges and a need for more investigations. This is typical of these highly coupled decisions. It is certain that components close to each other affect other ones spatially but they even affect remote components. As can be seen in these examples cooling packs and silencers are easily affected. This cascading of issues is common and leads to long discussions and the constant need of collecting new information (for all three brands) that was never thought to be needed in the beginning which ends up delaying the selection! Another source of complexity and delay in platform development is that different and sometime contradictory requirements from several brands have to be handled in parallel.

6.2 Changes to two brands in a platform

This example comes from a platform project at a late stage. All three brands (A, C and D) are situated in Europe which to some extent limits the cultural differences and the language barriers. Two brands are premium brands (C and D) meaning that they want to provide higher performances but also can take a slightly higher cost. Two of the brands (A and C) will be produced in the same plant in an emerging market at low labour cost and be sold in Asia

6.2.1 Adding a component at a late stage

Late in the development process testing and FEM analysis proved that an important portion of the car body was too weak. This area is common to all the brands but due to different designs in front of this area the forces leading into this area are different, with brand C having the lowest forces. Furthermore brand D has slightly more free space in this area. It is not necessary to understand the technical solution in detail for any of these examples but the examples are outlined to show the complexity in finding and selecting a solution.

11. Brand A and D have a problem
12. The component and hence the stamping tool is the same for all brands
13. Brand D has more space than brand A at the backside
14. Brand C has no problem and has verified its design in tests
15. A has no space at the backside and very little space available at the front side
16. Brand A is going to make physical prototypes very soon and the lead-time for new components is several weeks

Number 2 and 4 as well as the late stage in which the project is in means that no changes are wanted on this major component. Number 3 means that a solution for brand D is easily found. Number 1 and 5 means that it is most difficult to find a solution for brand A and it is urgent because of 6. Several analyses have been made and finally an outside reinforcement was found to be the solution for brand A. This reinforcement was attached in a very tight area which affects the assembly process for the bigger engine variants leading to increased assembly labour and some additional manufacturing equipment. Furthermore new welding equipment is needed. As previously described, far fetched couplings occurs due to packaging issues. It is also seen that the requirements put on the platform and the brand must be balanced very carefully so that no unforeseen components needs to be added.

6.3 Comments on the way decisions are made in the examples

The concept selection is made in group. In the early stages this group is the platform steering team, including the platform manager and the project manager from each brand and representatives from each area such as car body, engine, chassis, and climate. Packaging, as mentioned in 4.1. are almost always present and show the results from the latest package investigations. Depending on the agenda engineers from the crash analysis department, the NVH (Noise Vibration and Harshness) department or other supporting functions are invited to describe their latest analysis results. The results are generally put in matrix form to try to give an overview of the different concepts. The final decision is made collectively and the platform manager needs to be able to defend the decision all the way up to the top management of the automotive group. In the later stage of a project there are so many decisions to be made so groups on lower level are formed and the decisions are made there and lifted to the platform steering team for approval. As seen in the examples there are a lot of influencing factors and it is very seldom that a decision can be made at once. More information is most often needed; e.g., this can be another packaging investigation, information about a factory line set up at one or several of the brands production sites or more detailed information from one or several suppliers. The cascading character of the selection problems often ends up in that new unexpected decisions need to be made regarding a component far removed from the initial one. In order to make a collective decision everyone needs to understand the problem fully and the implications of the decision. This is becoming even more complicated because of language barriers and time zones. Furthermore the way of working is different in each brand both because of company culture and each country's culture. One brand can have a very flat organisation where decisions are delegated and are made via improvisation low down in the organisation. Another brand can behave in the opposite way, always needing feedback up to top management. One brand lays great importance in oral communication and oral agreements and another only respects written communication and written agreements.

7. Comments on concept selection

Selecting the right concept(s) is important in platform development because the decision not only affects one brand but several over a long period of time, more than a decade even. Furthermore, the platform design affects numerous expensive tools and production lines incurring investments of billions of euros. Ideally an automotive platform should be flexible in order to allow it to be used for different kind of cars, saloon, estate, convertible, SUV, etc.

7.1 A concept selection method does NOT need to be simple…

It seems to be a belief that concept selection methods should be simple and possible to learn in a short workshop but is that so? Is it important that the methods are simple? Of course it is preferable that a method is simple but much more important is the reliability of the result. A method that is very complicated but always give reliable, repeatable and understandable results is not a bad method. For example the Finite Element Method (FEM) is not particularly simple and to really understand it you need several years of engineering studies. However this method is well distributed and used and its results are accepted without everyone really understanding it. The use of the method is left to dedicated experts and the results that they present are respected and used in decision making. In fact *if* it were possible to make a concept selection method that would always give a reliable result it would not be important if it were complicated or not. There would always be enough people wanting to spend time learning it.

7.2 Some difficulties in concept selection

This paper is based on experiences from one automotive group and there might be differences between different groups depending on, e.g., company culture or product profile. However some generalisations should be possible to make that would be valid throughout the automotive industry and also other industries.

7.2.1 New information is encountered and needs to be added throughout the selection process

During development and concept selection almost each decision is coupled to other decisions. This is mostly due to packaging issues. Hence it is almost always necessary to search for new information to make the selection. Most methods presented in ED need everything to be known at the beginning which is rarely the case in industry where development is iterative and not ideally broken down. It is almost impossible to figure out what information is needed before starting to make the decision. A method needs to be flexible enough to adapt to new information.

7.2.2 The size of industrial problems and difficulties in testing the solution

Most industrial problems have a much greater size than laboratory size experiments used to demonstrate methods. If a small example is used to describe a method it is necessary to show how this can be *realistically* scaled to a bigger problem, otherwise a method is of little practical use. It is difficult to test and validate a concept selection method because the size and time frame of industrial problems making this very expensive.

7.2.3 Represent the couplings and strategy

As seen throughout this paper decisions are coupled. These couplings are hard to define and even harder to quantify. Surprisingly many of the established methods do not consider coupled decisions. More or less open brand politics and therefore connected strategy also interacts with the decisions and that is something that is difficult to represent.

7.3. Until the reliable method exists….visualising the selection problem w

Currently with no generally accepted reliable concept selection method clarity and ease of use seems to be the most important issue. If a collective decision is going to be made all the people involved need to understand the selection problem. It is also necessary to create an understanding of what information is missing and that needs to be found. As the problem of taking a decision cascades to other areas these couplings and implications needs to be understood. In fact the scope of the selection needs to be visualised to all involved to be able to support the consensus that needs to be made. Transparency and clarity is also important as many decisions need to be presented and defended in front of top management. For the time being a method, such as, the PPCO by [Vehar et al. 1999] fulfils some of the above.

8. Summary

In this paper some of the typical characteristics of concept selection in the automotive industry have been presented from a clearly industrial standpoint. The importance of the constant lack of space and what it affects leads to the necessity of a packaging department. How space affects concept selection by making the decisions coupled has also been outlined. The author hopes that the three brief examples of development problems linked to concept selection provide an insight into the daily struggle within product development and will spur on the ED community. Finally, methods do not need to be easy if they are reliable! However until reliable, repeatable tried and tested methods exist transparent explicit convenient methods that clarify the selection problem, provide insights in couplings and whenever applicable address the need for complementing information will be the most successful ones.

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