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DEVELOPMENT OF MODULAR PRODUCT FAMILIES

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1 INTRODUCTION

Due to increasing competition in the global markets and raising demands for customised products, the concept of mass customisation more and more becomes an important strategy for the companies. Basis for this concept, which aims fulfilment of the customer variants whilst maintaining a high number of produced units, is a modular structured product family. This contribution presents a methodical approach for the development of modular structured product families. The method consists of four basic steps. In a first step, the technical-functional product structure, as well as the variants of the product family is analysed. In the next step, the planning of the product family is performed. Aim of this investigation is the determination, which variant characteristics will be implemented. Subsequently, the components are optimised with respect to Design for Variety. This optimisation allows a beneficial mechanical implementation of the variety as a basis for the following modularisation. The modularisation is performed with respect to different phases of the product lifecycle. For the different phases, singular modularisations are developed independently and afterwards merged into one final modularisation.

The following presentation of the method is explained in example of Ultra Low Volume-(ULV)-spraying systems for herbicides in wheel barrow design. A corresponding spraying system is shown in figure 1. Spraying systems of this design are commonly used for application in large areas of in-row cultivation, as well as for pathways and plazas. The ULV-technology allows the use of undiluted fluid. In contradiction to systems which use diluted fluids, this technology saves fluid in process, which improves the environmental impact.

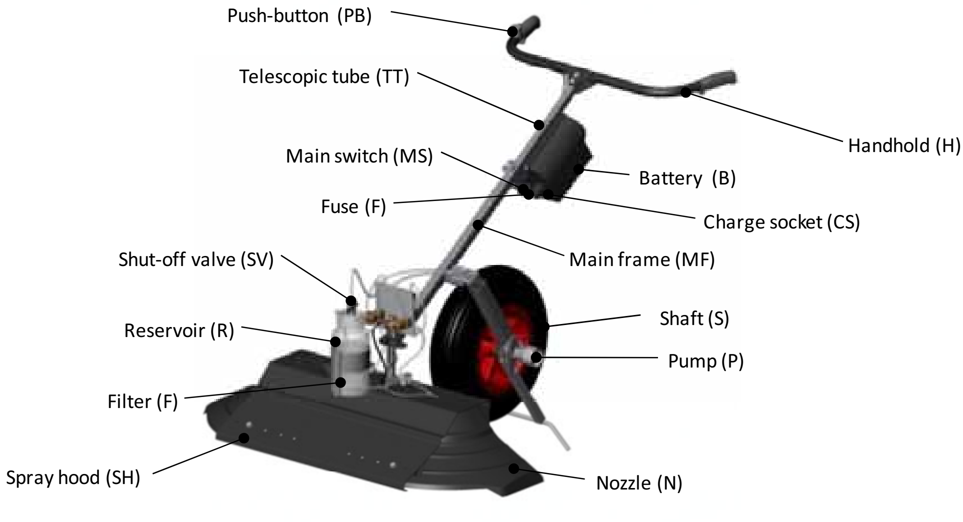

Figure 1. Ultra Low Volume spraying system for herbicides[1]

[1] Source: Mantis ULV-Sprühgeräte GmbH

2 PRODUCT ANALYSIS

In the first step of the method, the technical-functional product structure, as well as the variant characteristics of the product family needs to be investigated. Basis for this analysis is the decomposition of the product into its sub functions and components. The meaningful number of subdivided components needs to be assessed with respect to the individual case. In this context, (Pimmler and Eppinger, 1994) gives a rough value of 30 sub functions/components.

By modularisation, functions are assigned to modules distinctively. The decomposition of the product needs to assure that the sub functions of the product distinctively are represented by components. So the basis for the decomposition of the product is a hierarchical functional structure, in which the sub functions on lower level are assigned to components. If a component is not assigned distinctively, it needs to be decomposed further more.

Following, the technical product structure is visualised in the Module Interface Graph (MIG) (Blees and Krause, 2008). The MIG is a schematic drawing of the components with their structural connections as well as power-, media- and information flows (figure 2). The components are shown with their approximate size, location and shape. This drawing of the structure of the current product gives a rough overview about the component interfaces and allows a visual consideration of geometrical constraints of the product. The MIG is used in further steps of the modularisation process for considering the functional product structure.

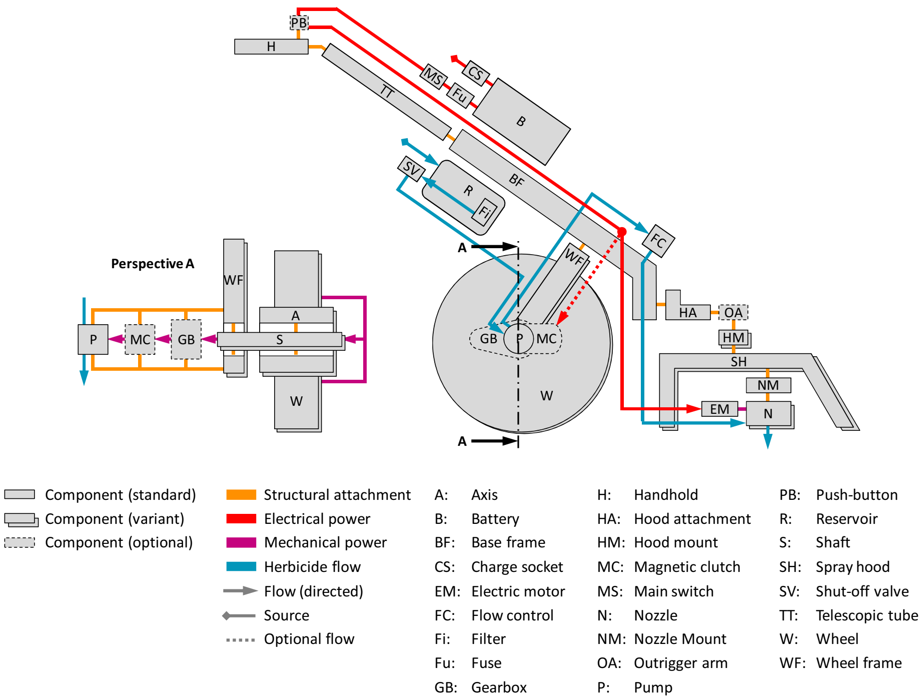

Figure 2. Visualisation of a spraying system by the Module Interface Graph (MIG)

Afterwards, the variant characteristics of the product, which differentiate variants of the product in the customer perspective, are analysed. The variety is analysed in a tree-visualisation. The tree hierarchically represents the variant characteristics.

3 PRODUCT FAMILY PLANNING

In context of product family planning, the comparison between planned variants of the product and needed efforts for implementing a variant is investigated. For visualisation, a portfolio according to figure 3 is used. The assessment of the customer importance of a variant should be performed by members of sales or marketing division. For decision making in this phase, tools such as the kano-model or QFD can be used. The kano-model supports the differentiation between different categories of customer preferences such as threshold-, performance- or excitement attributes.

For assessing of the implementation efforts of a variant, particularly the additional costs for development and manufacturing need to be considered (Robertson and Ulrich, 1998).

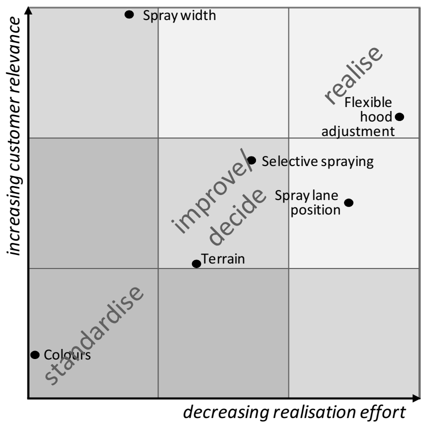

Figure 3. Portfolio customer relevance - realisation efforts

The shown portfolio basically can be subdivided into the three areas *standardise, improve/decide* and *realise*. Variants, which are assigned to the dark grey area, have low customer importance and high implementation efforts. Basic strategy for those variant characteristics is a standardisation in all members of the product family. For instance the idea of providing the spraying device in different colours has been dismissed. In contradiction, variant characteristics with high customer importance and low efforts should be implemented into the product. The following Design for Variety-optimisation (section 4) should particularly be focussed for those variant characteristics, which show high customer importance but also high implementation efforts.

The portfolio of customer importance and implementation efforts gives an easy visualisation for assessing the variant characteristics. The portfolio can be used as a basis for the decision whether characteristics of the product should be varied or standardised. Using the portfolio, a compromise between market view (marketing & sales) and engineering view (development & production) can be performed. Still one needs to consider that the portfolio gives a qualitative overview only. Therefore the plausibility of the derived decisions basically needs to be approved.

4 DESIGN FOR VARIETY- OPTIMISATION OF THE COMPONENTS

Based on the elementary product family planning, the design for variety optimisation is performed. Aim of this optimisation is on one hand a component design, which allows easy variation of a specific characteristic of the product. On the other, this optimisation sets the basis for a successful modularisation later on.

For optimisation, the interdependencies of components and variant characteristics are analysed and visualised by connections in a network diagram. Aim is the reduction of connections by an optimised design of the product. For support, the guidelines of design for variety can be used (Kipp and Krause, 2008). For example, components can be oversized towards using them as carry over parts in the product family.

5 MODULARISATION OF THE PRODUCT FAMILY

Lifecycle modularization of the components takes place on the basis of the design for variety of the components (Blees et al., 2009). This approach addresses a separate development of product structures according to the product’s life phases, namely product development, purchase, production, sales, use and recycling/disposal. The basic advantage of this approach is the adaptability of the modular product structures to the different life phases. This makes it possible to highlight clashes between different perspectives and facilitates the search for solutions.

Starting point of the modularization is the product development phase. From a product development perspective, modules with very little technical-functional interdependencies are required to reduce the complexity of the development task. Therefore a modularization using the three heuristics Dominant Flow, Branching Flows and Conversion-Transmission according to Stone (1997) is performed. The heuristics can be applied to a function structure in early design stages (prior to the approach described in this paper) as well as the Module Interface Graph in subsequent design stages. Alternatively a DSM-approach could be used to develop a technical-functional modularization.

Product-strategic modularisation is achieved through an extension of the module driver concept developed by Erixon (1998). As is shown in figure 4, the module drivers have been assigned to different product life phases. The greatest advantage of the module driver concept is its adaptability to various corporate strategies. A disadvantage, however, is that the module drivers only provide very general guidelines for module deployment. For this reason, the module drivers are further substantiated by product-specific module driver specifications. In the case of the spraying device, the technical specification of the module driver is substantiated, e.g. by the module driver specification *Terrain*.

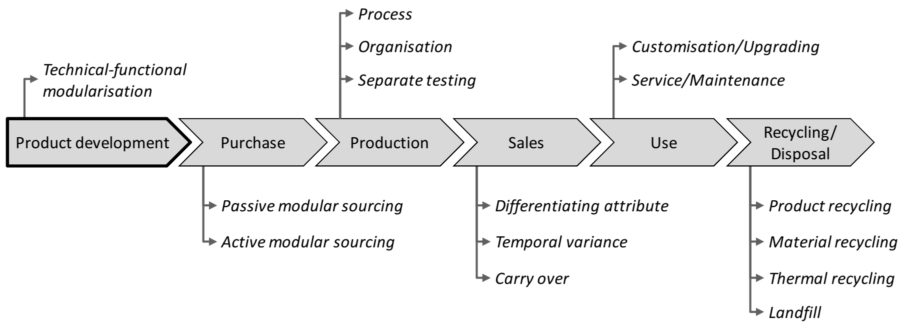

Figure 4. Allocation of the module drivers to the product life phases

The development of modules is based on network diagrams, each of which applies to one particular product life phase. In the network diagrams, the product's components are linked to the module driver specifications of the particular product life phase. The aim of each network plan is to group the components that relate to one of the module driver specifications into one module. For instance, in figure 5, components relating to the driver specification *Terrain* have been grouped into a module. By swapping the variant terrain module a standard (small wheel) and an all-terrain (big wheel, knobby tire) product variant of the spraying device can be created.

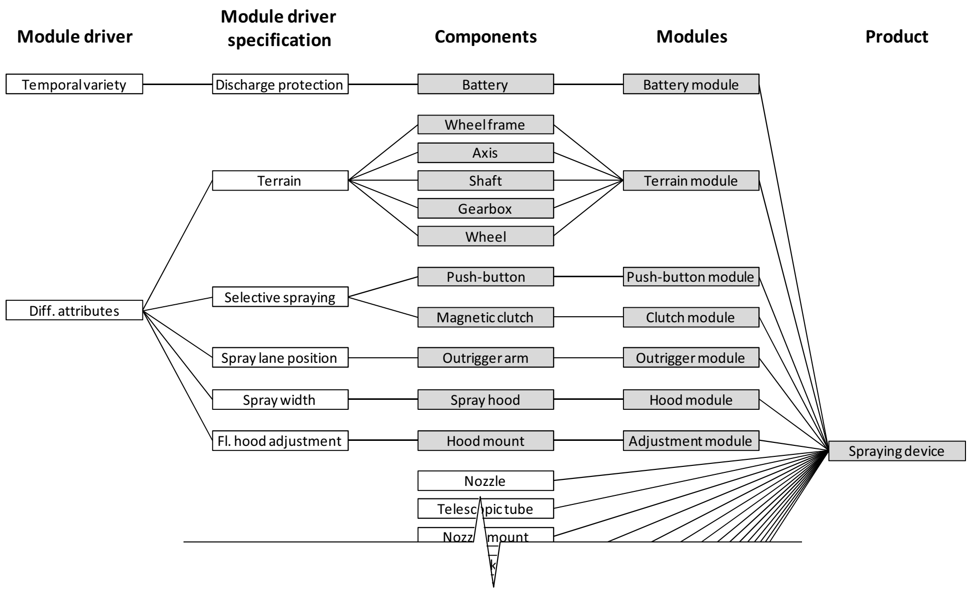

Figure 5. Modularisation network diagram of the sales phase

The particular product structures are then pulled together into a structure representing the entire product life (figure 6). The starting point for the alignment of the different product structures is the product development perspective. Since the technical-functional independency of the modules is beneficial in all phases of product life, target is to maintain the product development's product structure in the subsequent phases. To achieve a modularisation that is consistent throughout the life of the product, the product-strategic modularisations are then aligned. For instance, in the case of the spraying device, the components flow control, spray hood, nozzle mount and the nozzle can be sourced as a module from a supplier, prior to the in-house assembly of the motor. In sales phase, the module can be used to create product variants with different spray widths. During the use phase the electric motor, which shows considerable wear, can be detached for maintenance reasons. Ultimately, the module can be broken down into synthetic waste and electrical waste. Hence production and sales represent the generation of the product; the modules of these phases converge to the end product. Subsequently the end product diverges again into use and recycling modules.

In addition to the alignment of the product structures, an improvement of the concept can be focused. For instance, purchase modules could be combined to reduce the number of suppliers.

Concluding, the detail interface design of the modular product structure can be deployed from figure 6. The starting point is the purchase phase of the model. Purchase modules can first be designed as integral designs. In the subsequent assembly process, non-detachable connection types can be used. Easily detachable connection types, however, have to be employed if the module must remain removable during the use phase. For recycling and disposal, a destructive detachment of modules is an entirely feasible option.

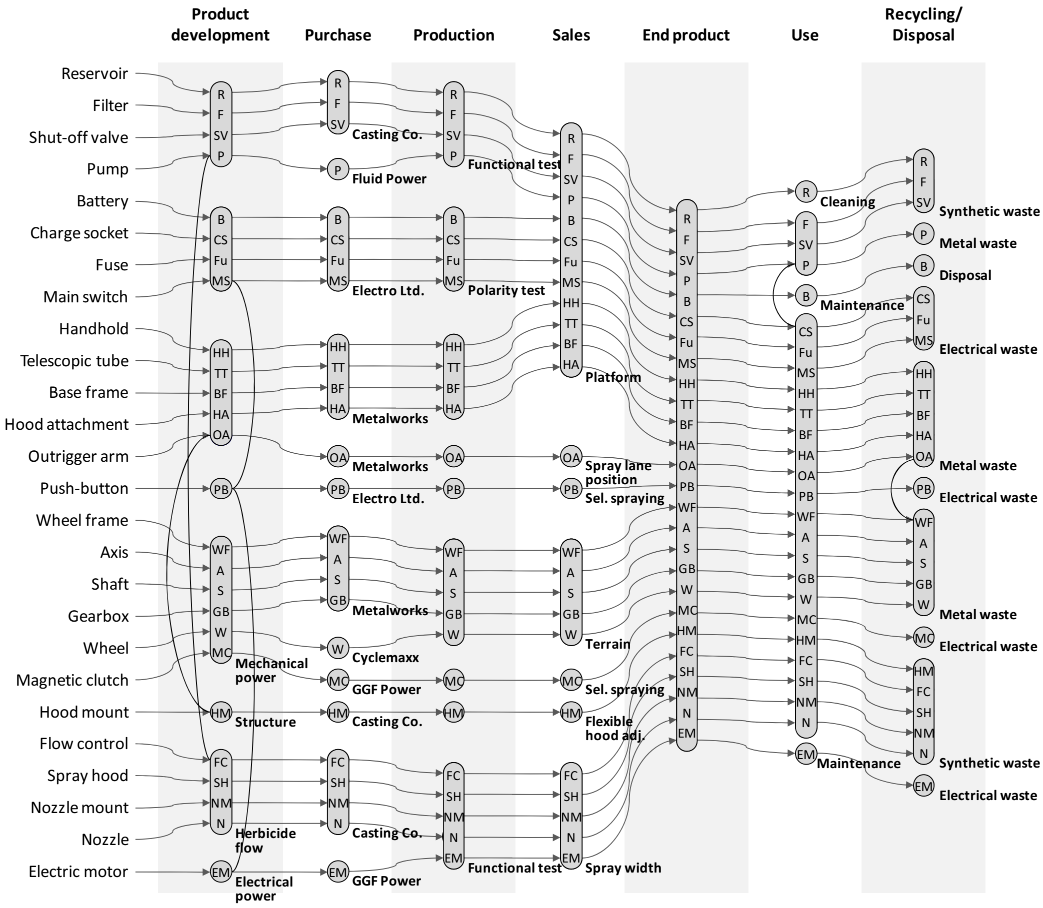

Figure 6. Modularisation of the spraying device over the course of product life

6 CONCLUSION

This contribution presented an approach for the design of modular product families. In contradiction to technical-functional approaches such as e.g. (Pimmler and Eppinger, 1994) or (Lindemann, 2009), which aim the very early development phases, the current method sets its focus rather on the late concept- and early development phases and low- to mid complex products.

The advantages of this method are in particular a consequent support of Design for Variety ending up in modularisation, the consideration of different product lifecycle phases and the open procedure of the method, which allows a consideration of iterative changes in the mechanical design.

Aim of future research is an application of the method in further case-studies for gaining improvements to the practical application and usability. A focus will be set in product family planning.

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Index

- Introduction to the case study
- Analysis of the product family
- Product family planning
- Design for Variety
- Modularisation
- Conclusion

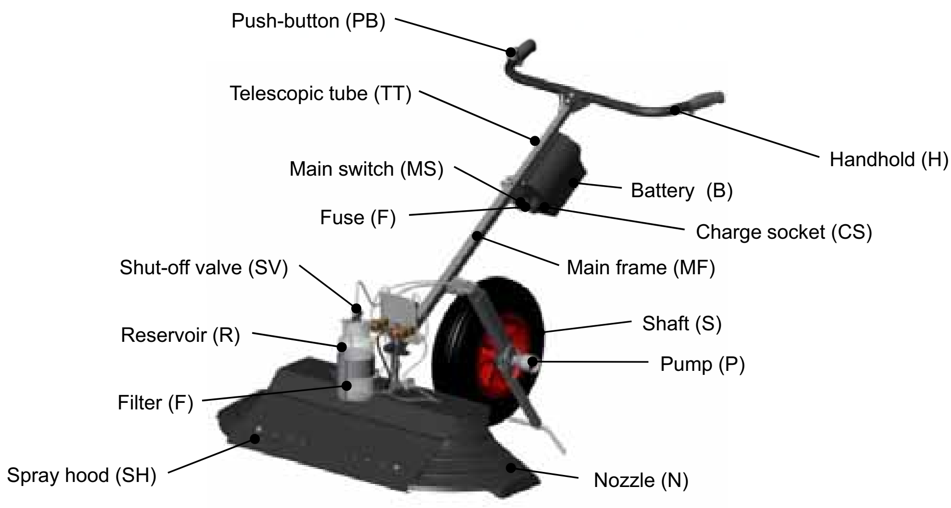
Product family of spraying devices for herbicides

- Grown product family with a multitude of product variants.
- Product variants are not clearly differentiated.
- Product structure is not defined.

Source: www.mantis-ulv.eu

BY MODELLING DEPENDENCIES MANAGING COMPLEXITY
TUHH Technische Universität Hamburg-Harburg
PKT Institut für Produktentwicklung und Konstruktionstechnik

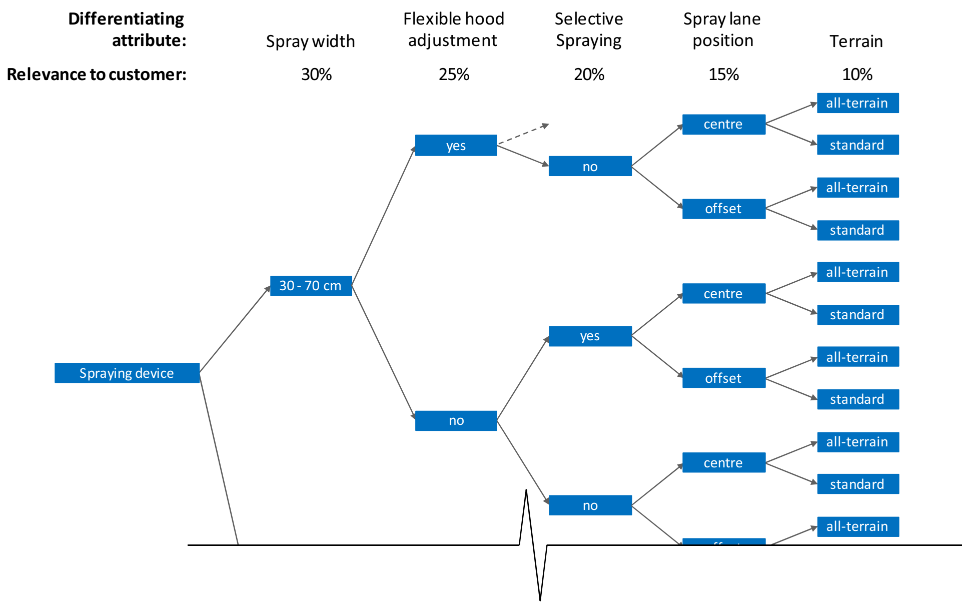
Spraying device for herbicides



- Application in large areas of in-row cultivation, as well as for pathways and plazas.
- Ultra Low Volume (ULV-) technology allows the use of undiluted fluid.

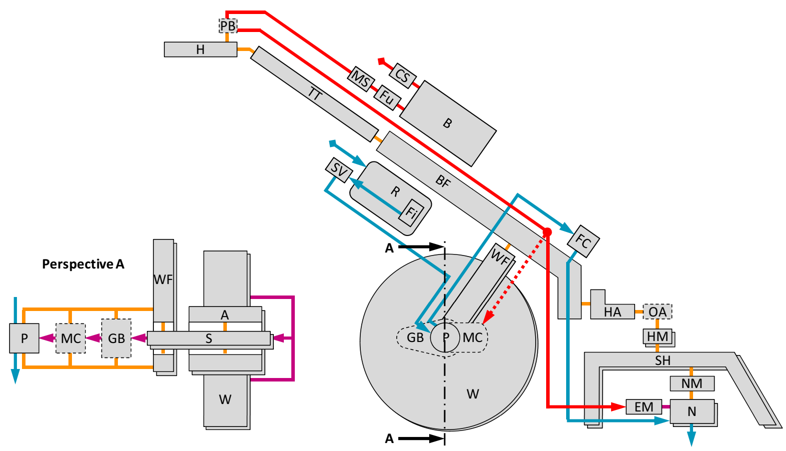
Source: www.mantis-ulv.eu

Variant Tree



- The branches of the tree represent the product variants of the family.
- Variant tree is the basis for the negotiation of the required variety.

Module Interface Graph (MIG)



Component (standard)
Component (variant)
Component (optional)

Structural attachment
Electrical power
Mechanical power
Herbicide flow
Flow (directed)
Source
Optional flow

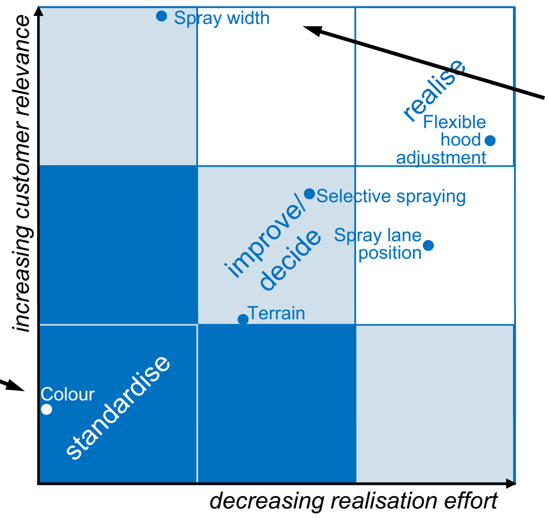
A: Axis
B: Battery
BF: Base frame
CS: Charge socket
EM: Electric motor
FC: Flow control
Fi: Filter
Fu: Fuse
GB: Gearbox

H: Handhold
HA: Hood attachment
HM: Hood mount
MC: Magnetic clutch
MS: Main switch
N: Nozzle
NM: Nozzle Mount
OA: Outrigger arm
P: Pump

PB: Push-button
R: Reservoir
S: Shaft
SH: Spray hood
SV: Shut-off valve
TT: Telescopic tube
W: Wheel
WF: Wheel frame

Product family planning

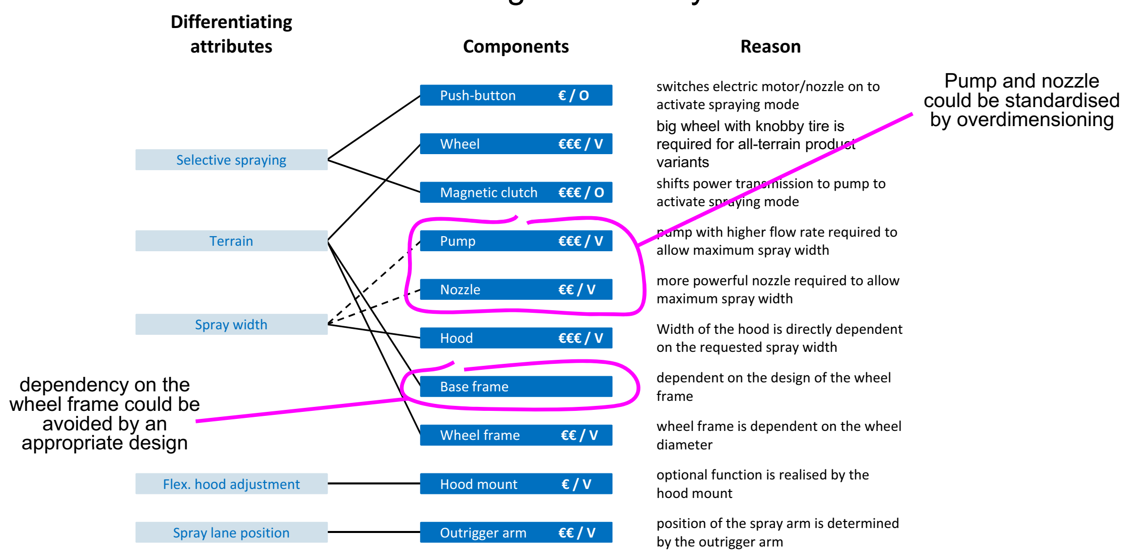
Low customer importance and high implementation efforts. **Standardisation** as strategy



High customer importance and high implementation efforts. **Design for Variety-optimisation** as strategy

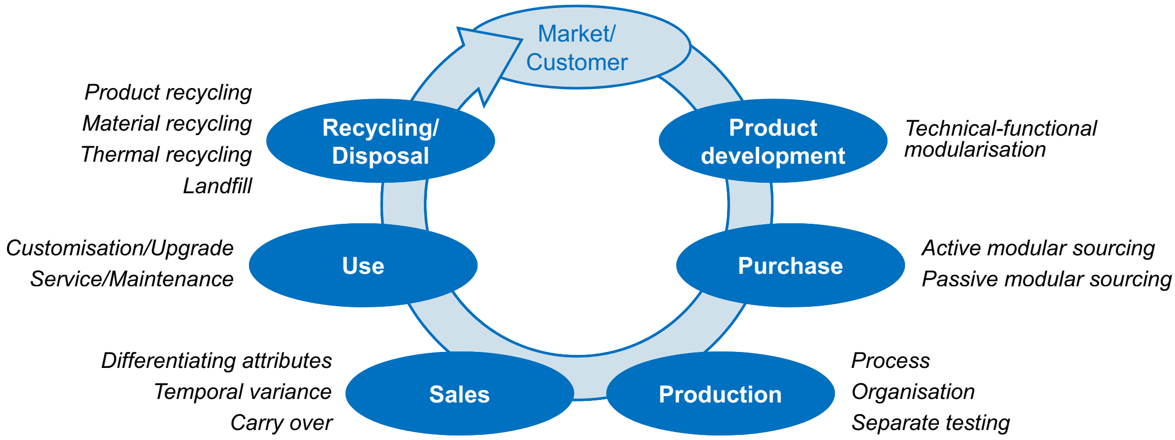
- Analysis of planned variants as pre-processor for modularisation
- Decision making of which variants will be implemented into the product; trade-off between implementation efforts and customer importance

Design for Variety



- Design for Variety of the requirement is a pre-condition for a beneficial modularisation of a product family
- Design for Variety guidelines can be used to improve the design

Life phases considered for modularisation



- For product development a technical-functional modularisation is required to reduce the complexity of the development task.
- For the subsequent life phases the product-strategic module drivers have to be considered

MANAGING COMPLEXITY
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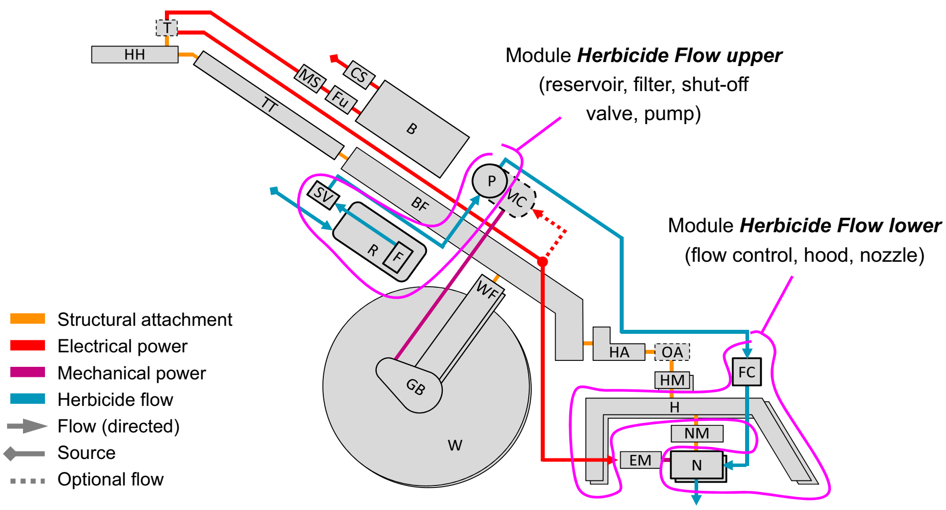
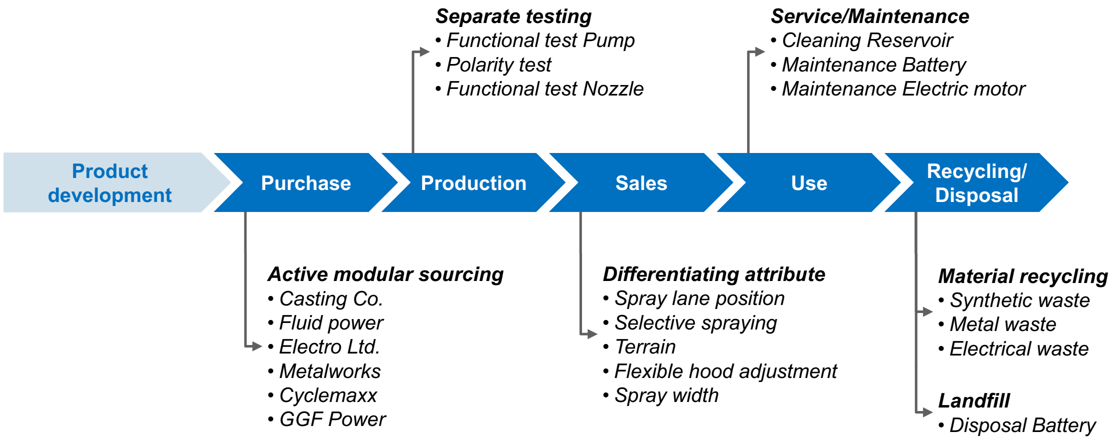
Development of technical-functional modules



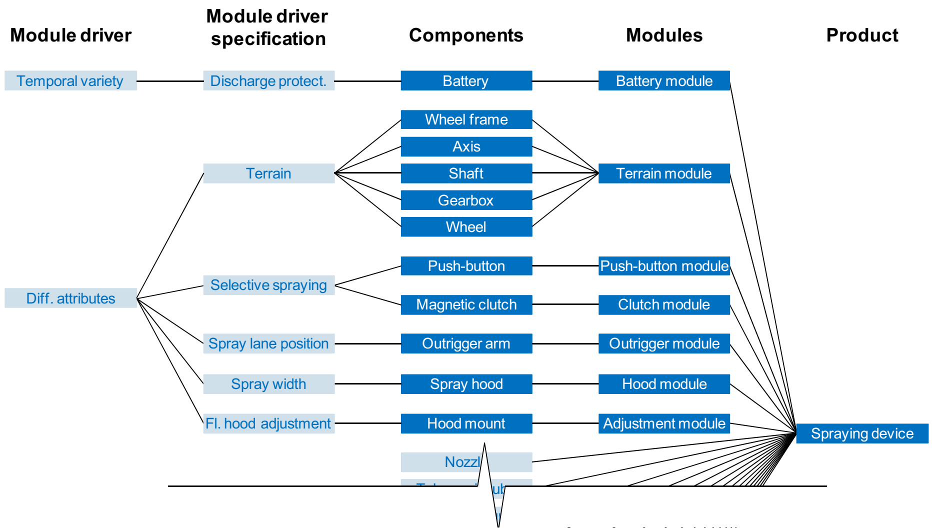
- The heuristics by Stone (dominant flow, branching flows, conversion-transmission) have been used to develop technical-functional modules.
- Alternatively a DSM-approach could be used.

Module driver specification



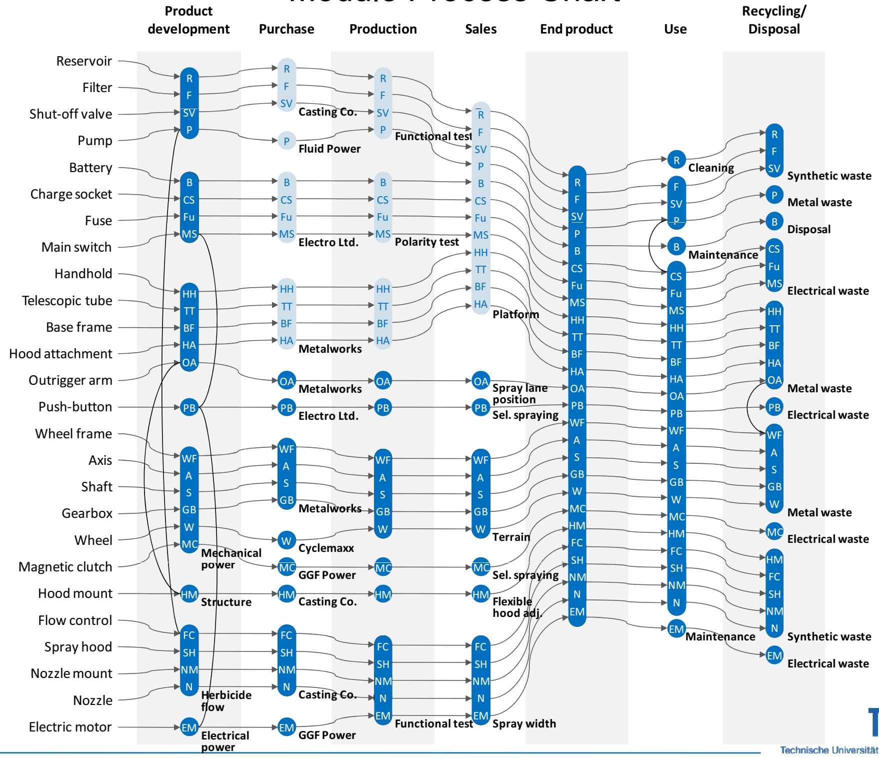
- The module drivers are detailed by the module driver specifications.
- The specifications enable the development of a modular product structure which allows the configuration of product variants.

Development of product-strategic modules



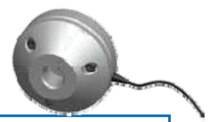
- Components with relation to a module driver specification are combined to modules.
- Modular product structures for the purchase, production, sales, use and recycling/disposal phase are developed.

Module Process Chart



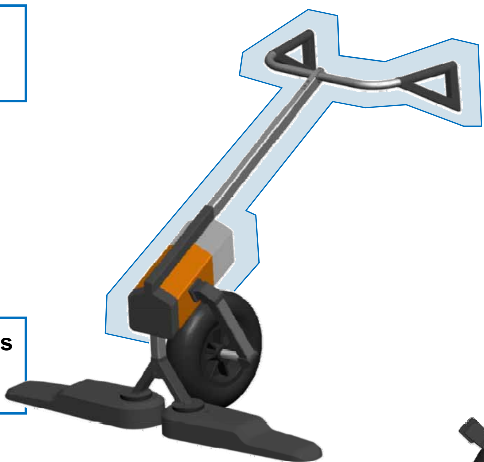
Modularisation from a sales perspective

Exemplary product variant
(platform of the product family is highlighted)



Magnetic clutch & push-button (optional)
Selective spraying option

2 Outrigger arm modules
(centre / offset)



2 Hood mount modules
(rigid / flexible hood adjustment)

2 Terrain modules
(standard / all-terrain)

3 Hood modules
(three sizes)

Conclusion

- An approach for the development of modular product structures has been presented.
- The included modularisation method addresses a development of product structures according to the product’s life phases.
- The shown modularisation approach takes technical-functional as well as product-strategic aspects into account.
- One of the major areas of work will be the elaboration of the product family planning.
- Additional case studies will be performed.