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TOWARDS A STRATEGIC DEVELOPMENT OF MODULAR PRODUCT PROGRAMS

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1. Introduction

In product development, balancing individual customer requirements and reducing internal product variety is crucial for the producing company. Common ways of supporting product development for this purpose are Design for Variety [Kipp 2010] and Modularization [Blees 2010]. Supported by these methods, Product Families can offer a high external market variety with relatively low internal variety. Project experience showed us that both methods are only applicable to small product families, since a higher number of different products cannot simultaneously be considered by these methods. This is a barrier towards program-wide conceptualisation of carryover components, which would allow a larger scale for internal variety reduction.

In Addition, a successful product development should point at the future structure of the product program and not only the current situation, since the development project itself takes time and by this time the market requirements might change.

In this paper, a new method for Product Program Development is presented. It consists of two major phases, the first one elaborates scenarios for the future structure of the program and the second one develops strategic carryover-components. The outcomes of the method are dedicated to be used as input for the subsequent design phases of Design for Variety and Life Phase Modularization, Figure 1.

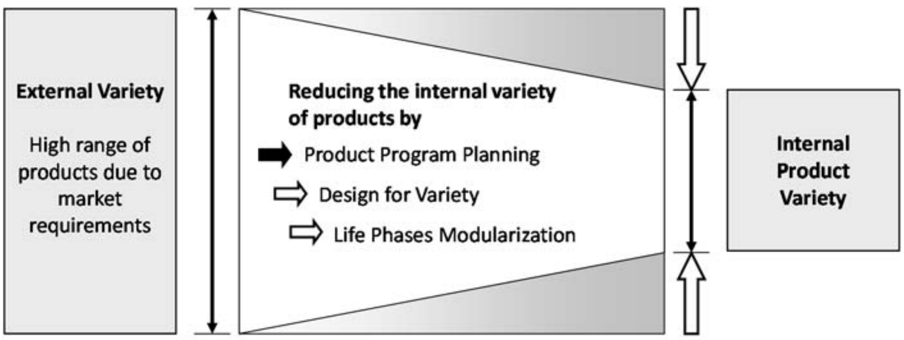

Figure 1. Approach for reducing the internal variety [Krause 2011]

2. State of the art

Figure 2 sketches the main areas that have been investigated for this research project. The aim is to transfer the perspectives of Sales/Marketing and Future Planning into the Product Structuring throughout the element of *Program Planning*. Subsequently in this paper, state of the art methods in these research areas are outlined.

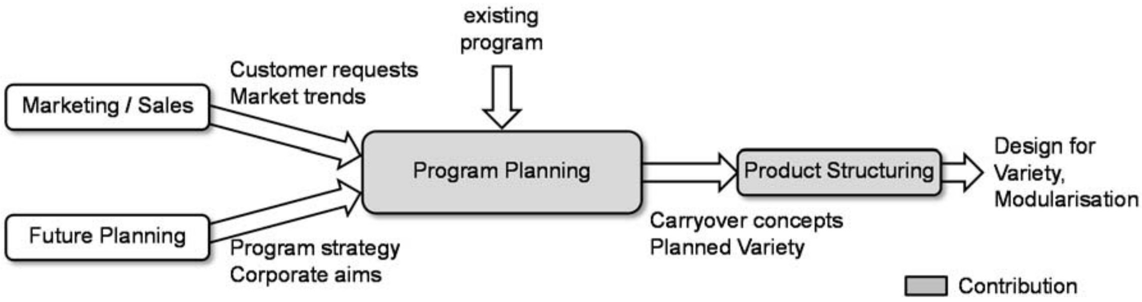

Figure 2. Research areas

In *Future Planning* became widely known the Scenario Technique [Gausemeier 2009]. The technique is a five-step method for projection and prognosis of future development trends. A scenario is the description of a future situation, including the path leading to this situation. The method consists of the steps scenario preparation, environmental analysis, scenario mapping, scenario definition and transfer. An application typically demands high project resources and the perspective leads far into the future. Therefore, the scope is one of more global trends than mid-term adjustment of the product program.

Another tool for Future Planning is Roadmapping. A Roadmap visualises elements, usually products or projects, and their relation to chronological order [Behrens 2003]. Roadmapping involves an analysis of the elements, their future needs/potentials and generation of the future direction. Although a roadmap shows the timeline of the projects, it usually gives no information on the product structure.

The Delphi method for predicting future trends includes structured expert interviews. In a multistaged process, experts are interviewed about technical development trends and their possible timelines; the results are evaluated and fed back to the participants. Due to the iterative nature of the method, the results are supposed to gain quality and converge towards a consensus. Since application of the Delphi method is relatively time-consuming, it is mostly used for long-term planning.

Köster gives product-oriented heuristics for future planning [Schuh 2005], defining the four types as custom engineering, release engineering, variety maintenance and basic-type engineering. An analysis of the influence of the total product program is not focussed.

In *Marketing and Sales*, there is a high number of different analytical tools available [Schawel and Billing 2011]. Two Portfolio analyses after [Gausemeier 2009] and Boston Consulting (BCG) [Kotler and Keller 2010] are shown here in Figure 3.

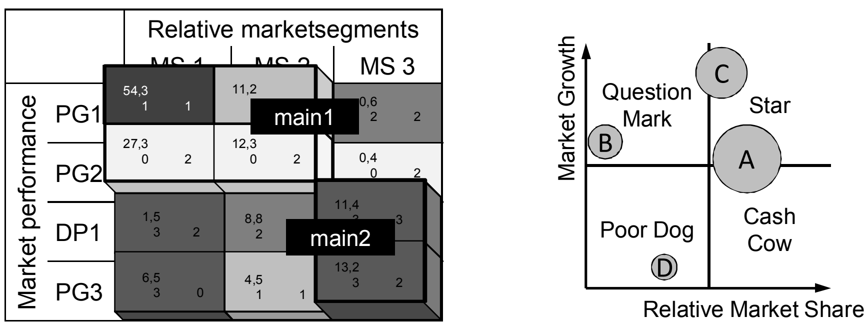

Figure 3. Portfolio analysis after Gausemeier (left) and Boston Consulting (right)

The portfolio analysis after Gausemeier assigns market segments and market performance. The fields of the resulting matrix represent business units; each can be characterised by economic properties such as revenue, growth and profit. In the matrix, superior main business units can be identified using distinct criterions. Segmentation gaps can be identified to derive strategies for improvement. Current and planned product variants, including their revenue share, are not given by the portfolio.

The BCG matrix compares the business units by their market share and growth. The revenue can also be shown by the circular diameter of a business unit. The BCG matrix is mainly used for a comparison of the existing units and to elaborate their strategic options. The matrix gives a rough overview about

the products and their market situation, but detailed economic figures and product variants are not analysed.
In *Product Structuring*, [Schuh 2005] uses the variety tree as a product visualisation method. The tree represents the hierarchical product structure and the assembly sequence. The variety tree aims to optimise the part and assembly numbers; simultaneous consideration of product families is not focussed.
In the structuring of Products and Platforms, [Mortensen et al. 2005] use five platform levels in their work on Multi Product Development. The five levels represent transition stages when a company shifts from Single Product Development to Multi Product Development through elaboration of Platforms and Architectures. Harlou's Product Family Master Plan (PFMP) [Harlou 2006] elaborates on the three views of customer, engineering and part domain of a product family. The PFMP supports decision making as it investigates the connections between customer requirement, functional organ and physical part. A distinct investigation of the future market situation is not adressed.
In Multi Product Development, modular structures can reduce the internal variety and support specific development aims such as manufacturing or after-sales. [Krause 2011] states that Modularity is a granularity property of a product Family, fulfilled by five criterions:

- Commonality of modules. Components or modules are used at various positions within a product family.
- Combinability of modules. Products can be configured by combining components or modules.
- Function binding. There is a fixed allocation between functions and modules.
- Interface standardization. The interfaces between the modules are standardised.
- Loose coupling of components. The interactions between the components within a module are significantly higher than the interactions between components of various modules.

However, the literature review indicates that each research area according to Figure e 2 offers distinct methods for supporting different goals. The Future Planning methods tend to have a long-term planning perspective, and the Product Structuring methods focus mostly on product family level. Project experience showed us that conceptual consideration of the whole Product Program architecture instead of only product families is desirable for Engineering, since a broader impact of carryover concepts can be realised. The planning of the program should be based on an elaboration of its future structure since it might be subject to market or strategy shifts.

3. Aims for a new method

As formulated in Section 1, the method presented in this paper shall support the structuring of the whole Product Program of a company. It delivers the input for the subsequent development phases of Design for Variety on component level [Kipp 2010] and Life Phases Modularization on product family level [Blees 2010]. Aim is to give program-wide carryover concepts which then are input for modularization. The aim is to combine product structuring with future planning. Therefore, an investigation of market and company trend factors is necessary, as well as a derivation of their impact on the future structure of the program.
The method shall also address following secondary aims:

- SME-applicable
- Mid-term view of business development (roughly 3…5 years)
- Support and guide communication between the planning stakeholders, particularly Engineering, Sales/Marketing and Management
- Structure and document the decisions

4. Research approach

The methodical approach consists of two major phases (Figure 4). Phase 1 regards the strategic planning of the Product Program. Using an analysis of the current state of the program, its products and the business trends, the Workshop Unit derives scenarios for the future structure of the program. The scenarios are visualised in the Program Structuring Model (PSM). Phase 2 regards an elaboration of potential carryover-components for each scenario. The carryover-candidates are elaborated based on an inverted tree of variety and visualised in the Carryover assignment Plan (CAP).

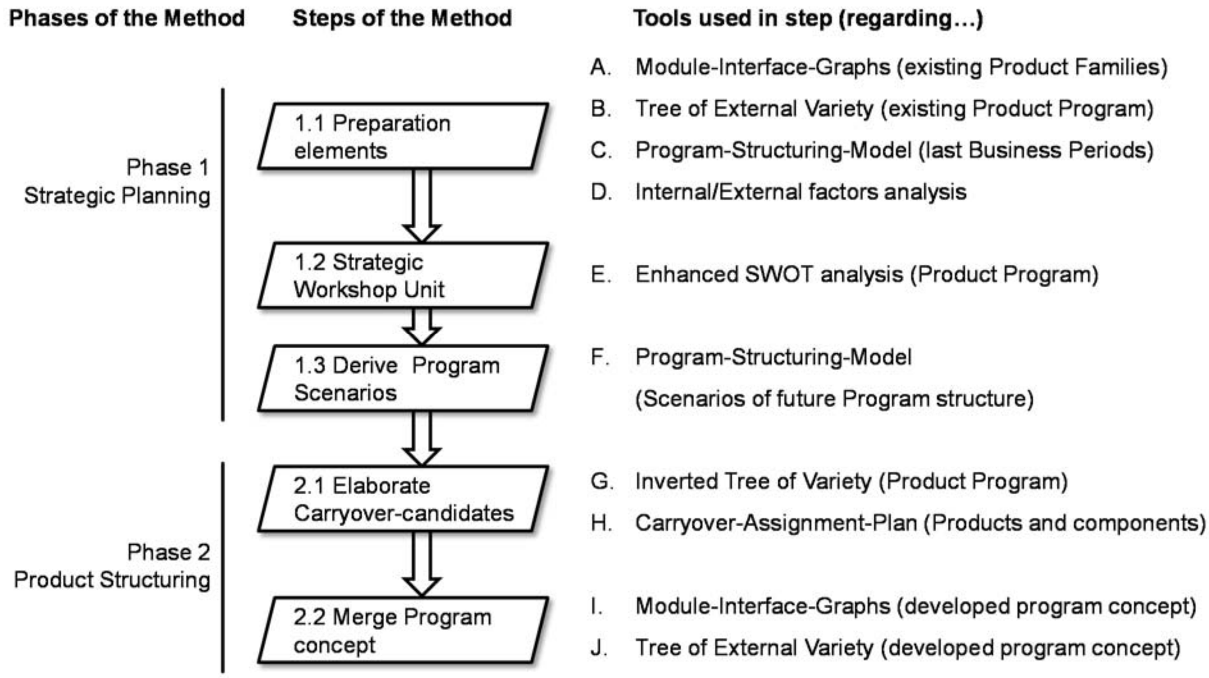

Figure 4. Steps and tools of the method developed

The method presented in Figure 4is new and the subject of this publication. Some of the tools it uses have been presented in earlier publications described below. The five steps of the method, including tools and in/outputs, will subsequently be described. The descriptions always refer to Figure 4.

4.1 Preparation elements

The initial step contains analyses of the current state. Using tool A, the Module Interface Graph (cp. [Blees 2010]), 2-dimensional sketches roughly visualise the components, geometries and media flows of all the existing product families. A *component* is understood here as being able to be either an assembly or a part. The question of how much is content by a component depends on the level of granularity wanted for the current consideration. If in a Product Family there is any modularity existing yet, the module boundaries are also shown in the Module-Interface-Graphs (MIG). If not, the MIG in this stage only shows components and media flows. Tool B, the Tree of External Variety (cp. [Kipp 2010]), shows the resulting variety of a product family based on the customers configuration choices.

Tool C, The Program Structuring Model (PSM), introduced in [Jonas 2011], shows on one hand the hierarchy of the current product program and on the other economic key figures as dimensions (Figure 5). Additionally, the margin can be added as colour of an element. If the margins of all products of a family are known and have been included, the resulting margin for the family is then calculated and visualised one level up. This can lead up to program level.

Tool D contains questionnaires regarding the current and future business and market situation and is not detailed here. The questionnaire clarifies success factors from internal and external perspectives. The addressees are primarily product line experts, an incorporation of management and customers/stakeholders is desirable. The external analysis investigates influences on the business units and trends of the stakeholders of the company. The internal analysis focuses on the core competencies of the company and investigates buyer decisions of each business unit. A competitor analysis adds value to the preparation step but is not considered as mandatory here.

Tool D is the preparing basis for the strategic Workshop Unit, which will be described next.

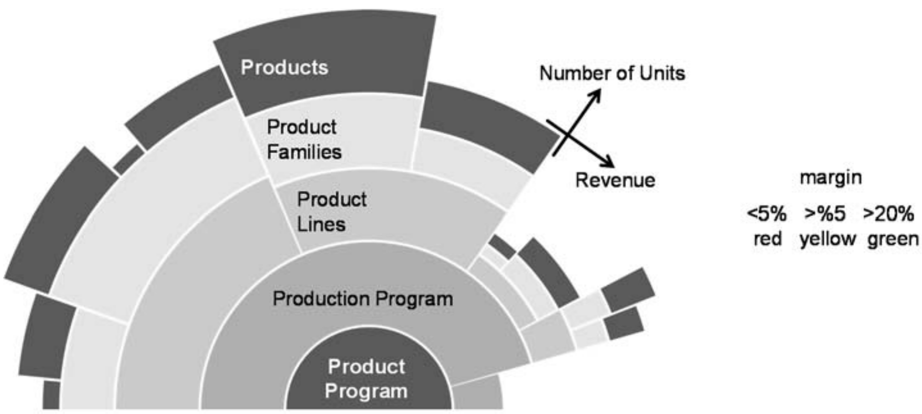

Figure 5. Program Structuring Model (PSM)

4.2 Strategic Workshop Unit

Based on the preparation elements, particularly the Program Structuring Model (PSM), the Workshop Unit creates scenarios for the future structure of the Product Program. The core of this Unit is Tool E, an enhanced SWOT (strengths/weaknesses vs. opportunities/threats) analysis (Figure 6).

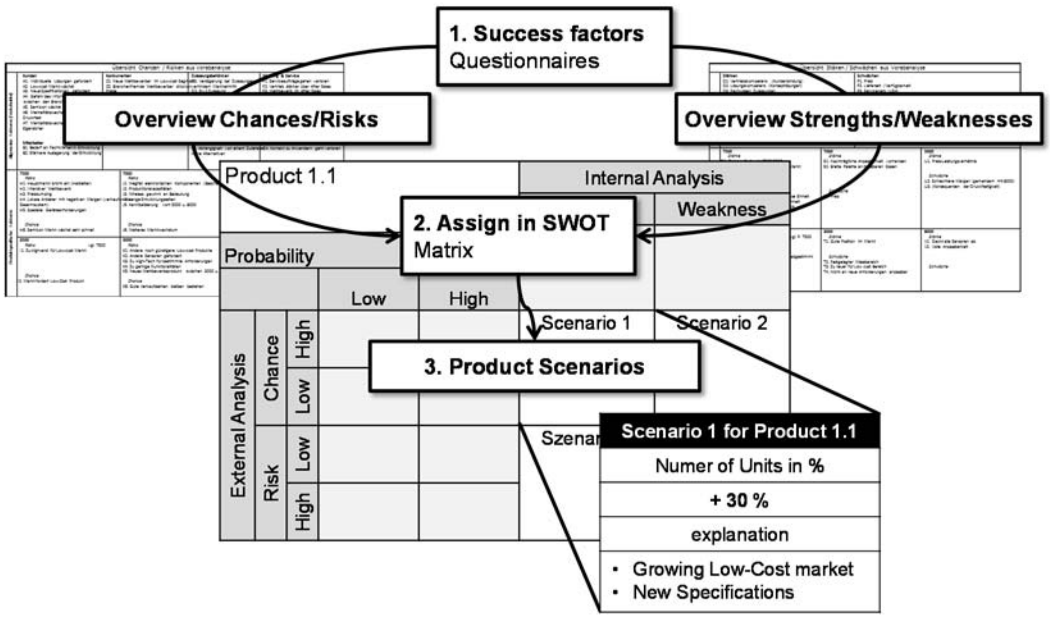

Figure 6. Enhanced SWOT analysis

The previously investigated success factors are included in the SWOT matrix. The analysis is performed on product level, which leads to several SWOT analyses, depending on the number of products considered. The SWOT method was chosen to be used on product level because it allows good usability for different workshop members as well as a traceable resolution for every investigated product. The relevant factors of the internal analysis (tool D) are included in strengths/weakness rows; external factors are included in the chances/risks columns. In addition to the classical SWOT matrix, the factors can be ranked by their probability by the workshop participants. This helps later when prioritising the influences of the factors. Finally, the fields of the matrix describe the effects of the factors on the product considered in different scenarios.

4.3 Derive program scenarios

After tool E independently generated scenarios for the different products, the next step contains the development of scenarios for the whole program. The Program Structuring Model (Figure) is used for visualisation. A challenge in this step is handling the theoretically high number of possible combinations of product scenarios towards whole program-scenarios. A practical way to overcome this barrier is to compose first best and worst case scenarios for the whole program. The input values for best and worst case scenarios are directly taken from the product-specific SWOT fields. Using best and worst case also ensures that extreme trends are not overlooked. On this basis, trend scenarios of the program can be elaborated.

4.4 Elaborate carryover-candidates

As soon as the scenarios for the whole program have been derived, step 2 of the method (Figure 4) starts. The aim is to conceptualise strategic carryover-components for each scenario. As a basis for this, all products and components gained by tool A are shown in a list.
Using an inverted tree of variety, tool G (Figure 7), all components of the program are then compared against each other. The components are compared by primary and secondary properties. If two or more components share their primary properties, they are a candidate for becoming a strategic carryover-component. These candidates are then visualised by the Carryover-Assignment Plan (tool H) in Figure 8. Primary property means that candidates necessarily need to have a match; secondary properties may point at sub-ordinary aspects that can be adapted by design or oversizing. It is also possible to investigate feasible adaption concepts for primary properties.

Products	Components	Primary properties of...				Secondary properties	
		Circuit boards	Housings	Displays	Mechanics	Safety certificate	...
1.1	Housing 1.1		Low water proof			up to 1m	
	Display 1.1			2-row			
	Mainboard 1.1	basic features				yes, coated	
	Frontcover 1.1				snap lock		
1.2	Housing 1.2		Low water proof				
	Display 1.2			4-row			
	Mainboard 1.2	premium features				yes, coated	
	Chipset 1.2	ethernet/profibus					
2.1	Housing 2.1		Deep water proof			up to 30m	
	Enclosure 2.1		3-stack fit				
	Mainboard 2.1	basic features				none	
...							

Figure 7. Identification of carryover-candidates

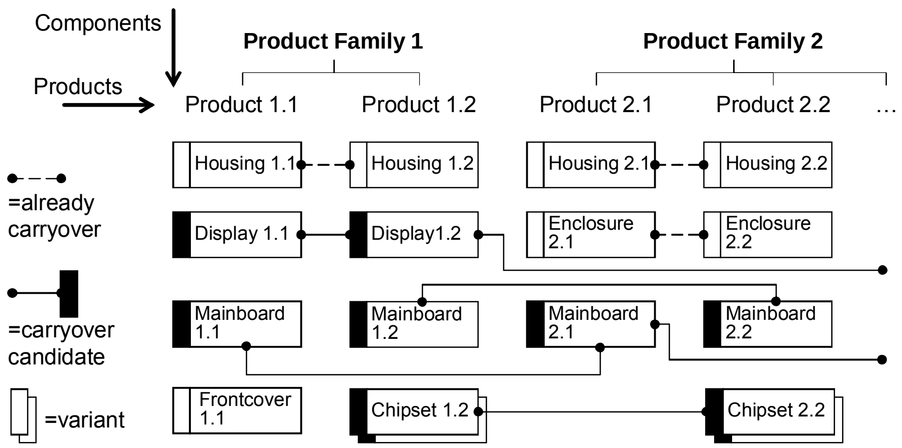

Figure 8. Carryover Assignment Plan (CAP)

4.5 Merge program concept

Step 1 of the method developed scenarios for the future composition of the Product Program and Step 2 derived strategic carryover-candidates for each scenario. In the final step of this method, the alternative scenarios need to be merged into one development plan for further development. In this context, it is desirable to achieve certain robustness. This means that distinct elements of elaborated scenarios can be combined in the final plan to cover the important options. The final outcome of the method is documented by the tools I and J, which are the Tree of Variety and Module Interface Graphs for the whole conceptualised program. The Module Interface Graphs show all products, including their conceptualized carryover-components. This result also represents the requirements of the life phase 'product strategy' in a final module definition in the method of Life Phases Modularization [Blees 2010] performed later on. The Tree of Variety of the elaborated program plan serves as input for the method of Design for Variety [Kipp 2010], which is a step towards component embodiment design for variety optimization.

5. Case study example

This section gives an industrial case example, which is shown modified for confidentiality reasons. The subject is an existing product program of measurement systems for water quality for use in different kinds of applications, from the chemical industry to waste water treatment. The program shown in Figure 9 contains four Product Lines, all including eleven Products. Different kinds of contents to be measured can be configured using different sensors within a product. The product variety is mainly given by the measuring depth (low water or deep water), the kind of contents to be measured (different chemicals), and the kind of communication protocol (e.g. analog signal, ethernet, profibus). Deep water devices are equipped with housing to protect against ingress of water. Low water devices allow an immersion of one meter. The circuit boards are coated for better water resistance in case of housing failures. They offer two kinds of displays: status or measurement notification. Different communication interfaces are provided by different circuit boards.
More variant properties of these devices are:

- an optional water pump type for constant sampling
- an optional remote detector set for sampling from distant points (suitable for low water)
- an optional internal data logging function.

Despite a very similar set of main functions, the design and market positions of the products alter between deep and low water devices. Coming from a different development history, hardly any components other than software and a few sensors are commonly used across these two kinds of product. This aspect becomes relevant when looking at the Carryover Assignment Plan, which shows the use of all components across the product lines.

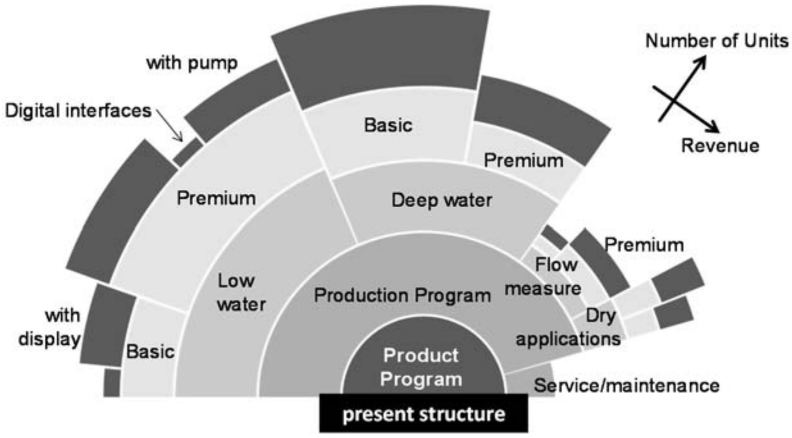

Figure 9. Present program structure of water measurement systems

Another relevant aspect of the current program is caused by the program marketing. A basic product line offers a fairly cheap solution for the market but lacks extra features, such as digital communication or optional data logging. A desire for any extended functionality always leads the customer to the premium products that provide all extra features and options as well as a certain scope of possible product modifications during use. Such modifications are the options mentioned above and change the kind of contents to be measured. All this extended functionality is provided by an additional chip set on a specific circuit board, which also realizes the interface protocol function. Figure shows the graphs of four products of the program.

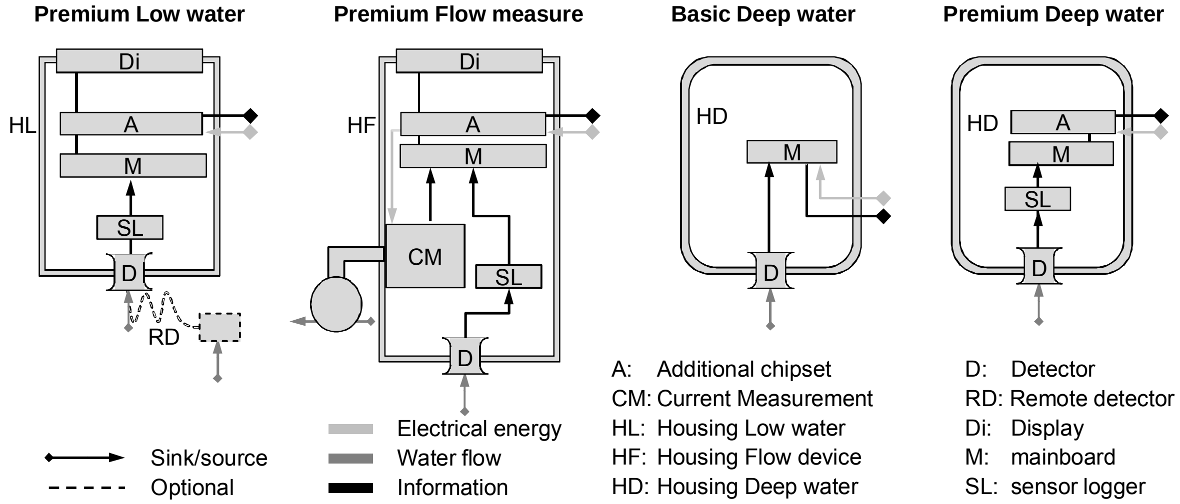

Figure 10. MIGs showing the configuration concept of several product variants

5.1 Strategic scenarios

As a result of Phase 1 of the method, two elaborated scenarios of the future structure of the Product Program are shown in Figure 11. The two scenarios were the outcomings of the Workshop Unit (Tool E in Figure 4) and are visualized using the Program Structuring Model.

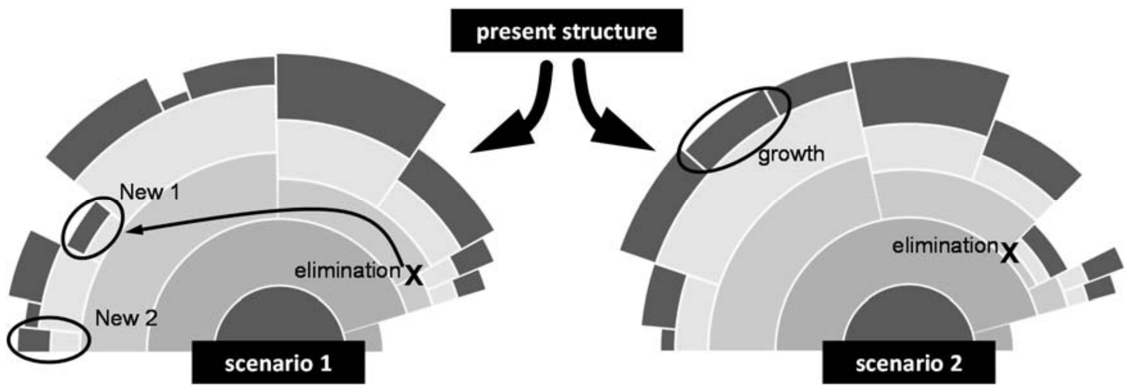

Figure 11. PSM of elaborated scenarios

In Scenario 1, expiring of the flow measurement systems has been prospected due to the very uncertain development of its market niche. This will lead to elimination of this unprofitable product family. It is still meaningful to offer a product that can cover this niche since it can act as an opener for the system sales. Therefore, 'New 1' will be aligned to the low-depth product line, which then has to perform a flow measurement option.

It was identified that there is a need for low-cost product in the low-depth segment. Therefore, 'New 2' is proposed to be introduced. Development costs shall be kept at a minimum. To avoid cannibalism with the dry applications, it should be clearly positioned in the low-depth segment.

Scenario 2 only eliminates the basic flow measurement system, for the premium one it sees still market potential. In this aspect, it contradicts Scenario 1. In the low-depth applications, a high growth in the digital interfaces units is prospected. No standardized protocol has been established on the market; therefore, it is not possible to predict which type of interface will grow. It is proposed to hold flexibility here in order to react to a possible technology push.

5.2 Product structuring

In Phase 2 of the method, potential carryover candidates were developed. Figure 12 shows the common Carryover Assignment Plan of both scenarios, therefore it serves directly for the outcoming Program Plan.

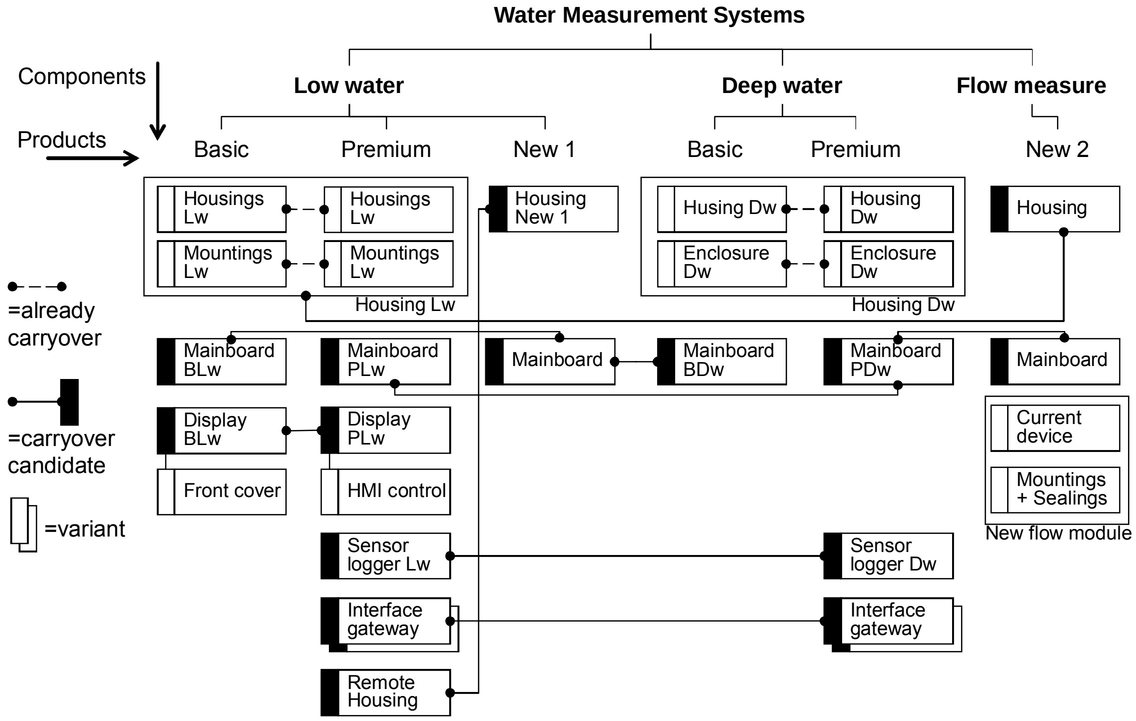

Figure 12. Carryover Assignment Plan (CAP)

As represented by the CAP in Figure , the following concepts have been developed:

- Use all mainboards as strategic carryover – 2 variants only in the program (by compromises)
- 'New 1' can be realised mostly with existing components
- Flow measurement can be realized with an extra module for premium low water
- Sensor loggers can be standardized, interface gateways standardized and decoupled
- Low water displays can be standardised with major compromises

Selected product concepts are also shown by their Module Interface Graphs (MIG) in Figure 13. The premium low water device is equipped with the carryover mainboard, carryover display, the decoupled interface gateway (previously realised with the additional chipset), standardised sensor logger and the optional remote detector. 'New 1' is based on the remote housing and the mainboard of the low water devices. 'New 2' is based on the premium low water device and is enhanced by a flow measurement module. It can serve the desired market niche but has relatively low development and production costs due to the high carryover share. The basic deep water device is now equipped with the proposed carryover mainboard.

The study showed general applicability of the method; in different workshops members of engineering, marketing and management have been involved together for developing the business scenarios as well as the carryover concepts. The developed carryover concepts set an important milestone in the internal product development process and will be used as development input for the subsequent phases. Regarding verification of the presented method, a larger case study involving even more product families would be interesting. Aim of the method was to address whole company programs; a larger scale application might affect usability and applicability.

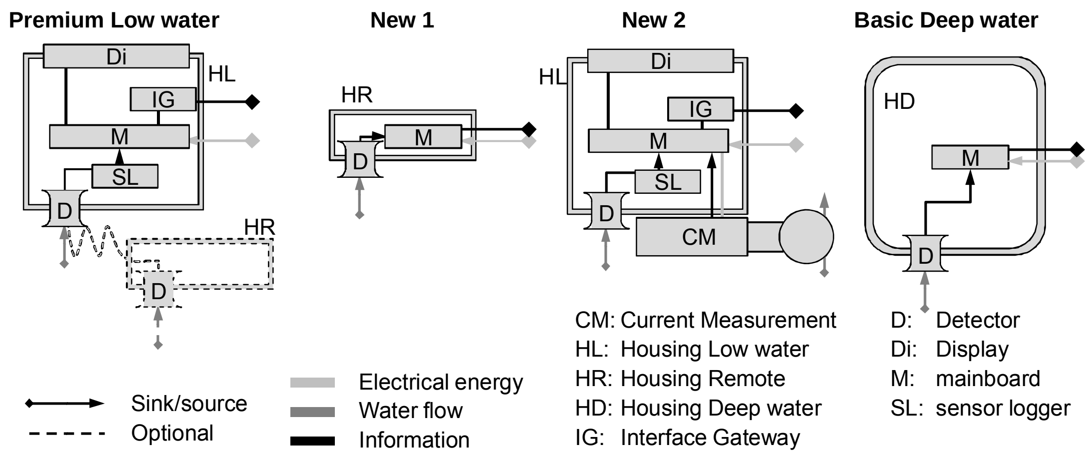

Figure 13. Concept MIGs

6. Conclusion

For the management of product variety, the program planning phase and therefore generation of variety set crucial input for the subsequent phases. This paper outlined the state of the art and introduced a new method for Product Program Planning. The method consists of two major steps. First, the future structure of the program is developed in different scenarios; secondly, strategic carryover-components are conceptualized. For application of the method, a simplified case study was given. Future work will have to involve a larger case study that investigates the usability of the method in a field application of a relatively large product program, preferably in an SME application.

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