4 The procedure of structural complexity management

The consideration of complexity in product design shows that managing complex structural dependencies represents both a major challenge and a success factor for enterprises. Complexity not only appears in specific sections of product design, but it is also a concomitant feature throughout the entire process in all relevant process domains and their linkages. Methods applied to complexity management generally focus on specific development tasks (e.g., identification of conflicting requirements) or particular objectives (e.g., product modularization). Therefore, they do not fulfill the requirements of a comprehensive structure consideration that controls and even benefits from existing complexity. In this chapter a methodical approach to structural complexity management is presented that closes the gap between the established methods and allows the comprehensive analysis, control, and optimization of structure-based complexity in product design. The approach comprises a fundamental method and suggests several known methods as special use cases. The general outline will be presented first, followed by detailed discussions on the particular steps of the approach in the following chapters.

4.1 Applicability of conventional complexity management

Typically, product structures that are taken from development processes only depict a portion of the complex environment developers have to operate within, e.g., the component decomposition of a product. If specific aspects are considered independently from their holistic embedding, such isolated views may lead to measures that are harmful in the entire context.

In order to avoid the disadvantages of considering incomplete parts of the entire system, some approaches to the managing of product structures include multiple aspects, e.g., general impact networks [Lindemann 2007a, p. 72ff]. Consequently, the complexity of these models increases because of a higher quantity of elements considered and a more intense connectivity. Besides the extensive requirements for visualization, one further disadvantage of such approaches is their minimal suitability for computational analysis (as will be shown in Chapter 5). The depiction of multiple aspects results in the simultaneous existence of different element and dependency types, which does not allow the application of algorithms or interpretations of structural characteristics.
The content of complex systems cannot be entirely represented on a detailed level; the information required has to be selected according to the use case. In practical application, users may fail to grasp the graph or matrix in its whole, if hundreds of elements are depicted simultaneously in matrix or graph representations. A survey on the user friendliness of matrix structures showed that small matrices containing only a few elements can easily become too complex to be handled by developers [Maurer et al. 2006]. Browning even states that “individuals may have difficulty building DSMs with more than ten elements” [Browning 2001]. Large system structures are often visualized in graph representations, where the positioning of elements can be freely chosen; however, the elements’ relative location to each other is important in order to perceive the representation. The positioning of elements in graphs can be understood according to specific aspects, e.g., following a horizontal time line or the hierarchical decomposition of elements; unfortunately, some other aspects are often neglected by such alignments. Appropriate possibilities of representing complex product structures will be discussed in Chapter 6.

Generally, two basic methods exist for avoiding a system modeling that is too complex. On the one hand, subsets or system views may be extracted from the entire system for closer consideration. Therefore, the complexity of a model can be reduced, but system analysis may not be useful, because the embedding of the subset has not been considered. On the other hand, a holistic system structure can be processed if it is created on a more abstract level. This also reduces the quantity of system elements considered, but unfortunately the analyses attained may result in more general findings.

4.2 Procedure of structural complexity management

The existing possibilities for interacting with complexity argue for the provision of a systematic approach for managing complex structures in product design. The procedure that is presented here is based on established problem-solving approaches as provided by Daenzer & Huber, Ehrlenspiel, and Lindemann from an engineering point of view and by Ulrich & Probst from a holistic cybernetics point of view [Daenzer & Huber 1999, p. 96; Ehrlenspiel 2007, p. 79ff; Lindemann 2007, p. 45ff; Ulrich & Probst 2001, p. 112ff]. It enhances the systematic structure analysis process for DSMs, as proposed by Yassine et al. [Yassine et al. 1999]. The outline is given in Figure 4-1 and comprises five general steps leading from the initial problem to the improved system management or design.

The starting point can be a handling problem or a design problem, both resulting from a system’s complexity. A handling problem can occur if a product or a development process already exists, but the demand for adaptation generates problems of system controllability. Even if a specific adaptation request is clearly specified and does not appear to be complex, system dependencies may lead to numerous subsequent adaptations (change propagation). Such after-effects are often