This description of design and designing applies equally to problems of designing simple and complex systems, with the principal distinction being that for systems requiring a great deal of novelty and innovation the process may be nested: what appears to be an element of a system in the design process outlined above may be an un-designed system in its own right, so that specifying its element-level requirements in preliminary design of the super-system may be identical to specifying its operational level requirements in conceptual design of the subsystem.

4 Design in Systems Analysis

4.1 Analogy of Engineering and Analysis

Design in systems methodology is the combination of two interactive loops, one addressing the relationship of the design object to its environment, the other addressing the relationship of the design object to its parts. In systems engineering, the two loops are called preliminary design and detailed design, while in systems analysis they are called expansion and reduction. Viewed from the perspective of an arbitrary element Y_b, a functionally specified constituent of a system X, preliminary design of X and expansion of Y_b both determine the function of Y_b as a contribution to the comprising whole X, while detailed design of X and reduction of Y_b determine the structure of Y_b and how it works.

The relationship between the systems engineering design of X and the systems analysis of one of its elements Y_b is illustrated in figure 2 above for a system X consisting of elements Y_i, each of which in turn consists of sub-elements Z_{ij}. In figure 2, the nesting can continue indefinitely in both directions: X can be an element of some other larger comprising super-system W, and each Z_{ij} can in turn be an object of either design or analysis, so that the preliminary design of X may also be part of the detailed design of W, and the detailed design of X may comprise the preliminary designs of the Y_i and the conceptual designs of the Z_{ij}.

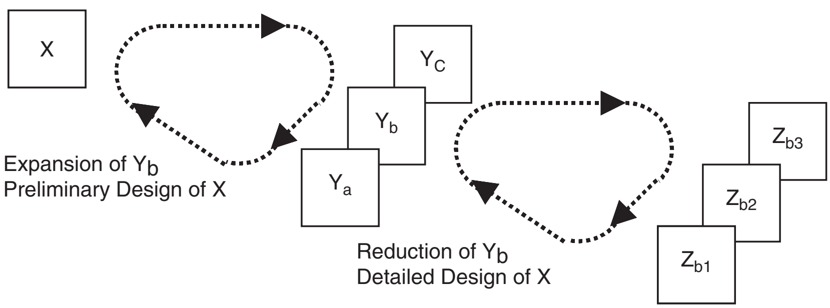

Fig. 2 Nested design loops of systems methodology

Figure 2 offers an opportunity to distinguish functions from purposes using Bertalanffy's definition of system. Consider the relations R_{zb} found among the elements Z_{bj} in the reduction of Y_b, and the relations R_y found among the elements Y_i in the expansion of Y_b. The functions of the elements Z_{bj} serve purposes inherent in Y_b, and the function of Y_b serves a purpose inherent in X. The question to consider is whether the function of Y_b and the purposes inherent in Y_b are identical. Systems analysis answers no, except by coincidence, because the function of Y_b is among those properties that Y_b has in virtue of relations R_y rather than any alternative R'_y, while the purposes inherent in Y_b are among those properties that Y_b has in virtue of relations R_{zb} rather than any alternative R'_{zb}. The function of Y_b and the purposes inherent in Y_b are both at the same hierarchical level, i.e., they are both in Y_b, but they are determined by distinct relations R_y and R_{zb} at adjacent hierarchical levels, and therefore they are not identical, though they may correspond to one another.

4.2 *Difference on Function Between Systems Engineering and Analysis*

An important difference between design as implemented in systems engineering and as rationalized in systems analysis is in the peripheral role of the concept of function in the former, and its central role in the latter. The difference stems from the difference in relationship between the engineer and his system on the one hand, and the analyst and the object of her inquiry on the other.

The engineer works from concrete customer needs, and is concerned to transform these needs into verifiable requirements at the system and subsystem levels. To the engineer, functional analysis is only a means to requirements, which latter are quantifiable, testable, and verifiable. Once functional requirements are set, they are specific to elements, and compliance can be judged independently.

The analyst works from a concrete system, and is concerned with developing information, knowledge, and understanding. For the analyst, her objectives are descriptive, relative, and functional rather than imperative, absolute, and normative. Functional descriptions are interdependent and relational, and are developed jointly for ensembles of elements.

The relevance of the distinction is illustrated by failure analysis of a system. If the external inputs to the system all conform to specifications, but some external outputs of the system are nonconforming, then the system is a suitable object for failure analysis, in which the analyst, either the designer of the system or a systems analyst, attempts to analyze the failure, attributing failure either to an element of the system or to the system as a whole.

For the design engineer, any element whose output is not in specification while its inputs are all within specifications is nonconforming, regardless of function. Specifications on a system or an element are contingent on inputs, so