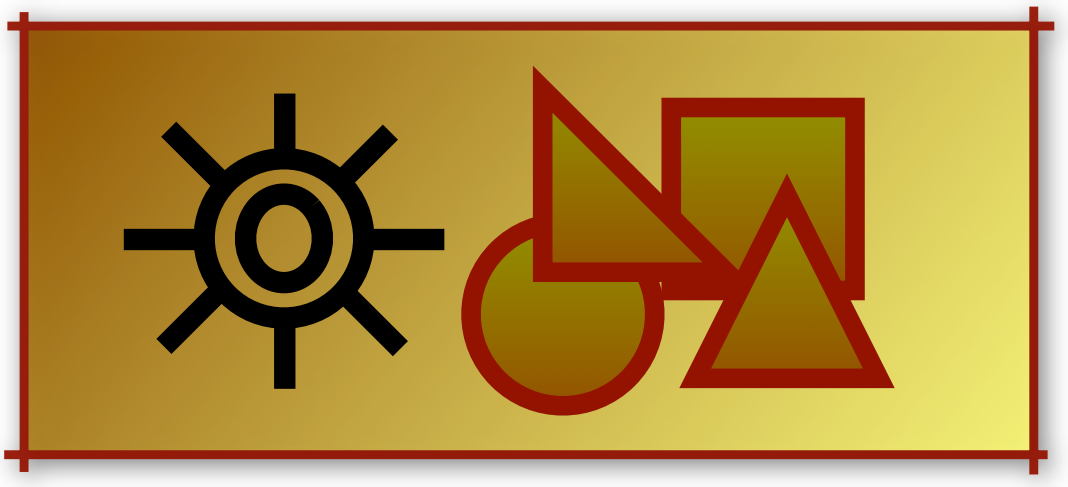
D E S I G N I N G A N D B U I L D I N G
T H R I V I N G S Y S T E M S

Project White Paper
October 11, 2010

THRIVING SYSTEMS DESIGN QUALITIES



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Characterizing the Field-Effect of Choice Properties

An information system (like any system) is an arrangement of interacting and interrelating components. Waguespack[1] recounts Alexander's revelation of the properties that express the quality of the interaction and interrelating occurring in a system of architectural components. This paper explores the interaction and interrelating of the information system ***choice*** properties mapped to Alexander's ***center*** properties. I investigate the ***choice*** property interrelationships themselves and characterize the fundamental interaction as quality features that bespeak of great design in what I propose to call a ***thriving system***.

1 The "Field-Effect" of Choice Properties

Wholeness (as Alexander describes it) is a "field" of interrelationships among ***centers*** in a "space" where the interaction of the ***centers*** resonates with the "self" of the "observer." Alexander puts it this way:

> The more carefully we think about each property and try to define it exactly, the more we find out that each property is partly defined in terms of the other fifteen properties. Although the fifteen properties seem distinct at first, they are in fact intertwined and interwoven.[2]

When these properties are mapped to ***choice*** properties that "field" of interrelationships reveals the intensities as qualities that those ***choices*** of modeling and design reflect in the stakeholders' experience of the system. Design quality results from the strength of the interaction of all fifteen ***choice*** properties as perceived in that ***choice***. Properties individually may seem significant, others less so and still others virtually absent in that ***choice***. Individuals or groups of stakeholders are more or less sensitive to certain qualities. They experience them differently because of their perception of property intensities and the aspects of their particular concerns or investment in a system. However insensitive to an individual or subset of ***choice*** properties stakeholders may be, nonetheless it is the confluence of those property intensities that resonates with them in some manner to form their satisfaction with the system. Just as it is humanly impossible to observe the intensity of any one of Alexander's fifteen ***center*** properties in the absence of any others, it is likewise impossible to experience a design ***choice*** as solely qualified by a single ***choice*** property.

Each ***choice*** property (as each ***center*** property) is experienced in a confluence of all fifteen. And although some may appear to predominate in that mix, none can be meaningfully isolated from the rest without diminishing the experience. This is both the mystery of art and the majesty of human perception and understanding. Human perception and understanding achieve

an enormous feat of recognition, pattern recognition and classification that allows such a confluence of qualities to be experienced and assessed in composite, as a whole. And the satisfaction that is experienced (and sought) in design is a resonance of "self" with that whole conveying to the observer a sense of the ***wholeness*** of the system, a sense of order that is to each stakeholder – natural. Through the analysis of property interactions that follows I will parse the field-effect of properties and associate property interactions with stakeholder perceived design qualities. Some of these qualities are familiar to systems developers while others offer a new lens through which to assess design quality.

2 Choice Property Coherence

Alexander's insight into the interrelationships of the ***center*** properties identifies which of the fifteen properties are "supported" by which others. A "supporting" property is depended upon or necessary for the understanding of the property it supports.[3] His matrix not only gives insight into the meaning of each property (and contributes to the rationale for mapping them to ***choice*** properties), but also provides a means of grouping or clustering the properties by way of their supporting properties; and clustering the ***choice*** properties as well. To that end I propose a measure of the affinity between ***choice*** properties based upon the coincidence of their supporting properties. I call this measure ***coherence***. (See Table 1 below.)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	1.58	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-
3	1.17	0.67	0.00	-	-	-	-	-	-	-	-	-	-	-	-
4	0.75	1.33	1.00	0.00	-	-	-	-	-	-	-	-	-	-	-
5	0.50	1.13	1.13	1.13	0.00	-	-	-	-	-	-	-	-	-	-
6	1.25	1.71	1.13	0.83	1.25	0.00	-	-	-	-	-	-	-	-	-
7	1.50	1.17	1.58	1.17	0.88	1.25	0.00	-	-	-	-	-	-	-	-
8	1.58	1.00	1.33	1.00	1.42	1.42	1.17	0.00	-	-	-	-	-	-	-
9	1.58	1.00	1.33	1.00	1.42	1.13	1.17	1.33	0.00	-	-	-	-	-	-
10	1.21	1.07	1.07	1.07	0.66	1.20	1.21	0.76	1.69	0.00	-	-	-	-	-
11	1.17	1.33	1.33	0.67	1.42	0.54	1.58	1.33	1.00	1.38	0.00	-	-	-	-
12	1.58	1.00	1.33	1.33	0.83	1.13	1.58	1.33	1.33	0.76	1.00	0.00	-	-	-
13	1.17	1.33	1.33	1.33	0.83	1.13	0.75	1.33	1.33	1.07	1.33	1.33	0.00	-	-
14	1.55	0.90	1.63	1.27	1.03	1.35	1.55	1.27	1.27	0.97	1.27	0.90	1.63	0.00	-
15	1.61	1.38	1.38	1.38	1.20	0.93	1.21	1.38	0.45	1.71	1.07	1.38	1.07	1.66	0.00

Table 1 Distance Measures Between Properties Based on Coherence

Coherence is calculated between two properties as the sum of the overlap of their supporting properties – their interrelationship or influence on one another. The overlap of property A over property B is determined by the fraction of B's supporting properties that are found among A's supporting properties. If half of B's supporting properties are found in A's supporting properties then the overlap of A over B is 0.5. The overlap in the opposite direction determines the overlap of B over A. The sum of the two overlaps yields a number between 0 and 2. A value of 2 indicates complete bilateral overlap while 0 would indicate none. Based upon ***coherence***, a "distance" separating the two properties results by subtracting each overlap sum from 2 (i.e. the value 0 indicates complete ***coherence*** or no "distance" while 2 indicates maximum "distance," independence). For example, each property is completely coherent with itself, a "distance" value of 0 – no separation. Table 1 above depicts the complete tabulation of paired property ***coherence*** measures as "distance." Note that there are no "distance" values of 2.0 (total independence)!

3 Choice Property Clustering

Using these measures as indications of ***coherence*** between properties it is possible to develop groupings that indicate related properties that share supportive characteristics. The process of determining these groupings is cluster analysis.[4] [5] [6] The clustering technique in use here is hierarchical, agglomerative clustering where clusters are formed as pairs of nearest "proximity." Once formed the cluster is treated as a single element in the determination of the next cluster in the successive construction of pairs until all individual elements are assimilated.

The criteria for grouping is a "distance" measure that in this case is the ***coherence*** measure. The result of this pairwise clustering is a tree-structure where adjacent leaves depict elements so "close" as to be paired. The result of the clustering is found in Figure 1 below.

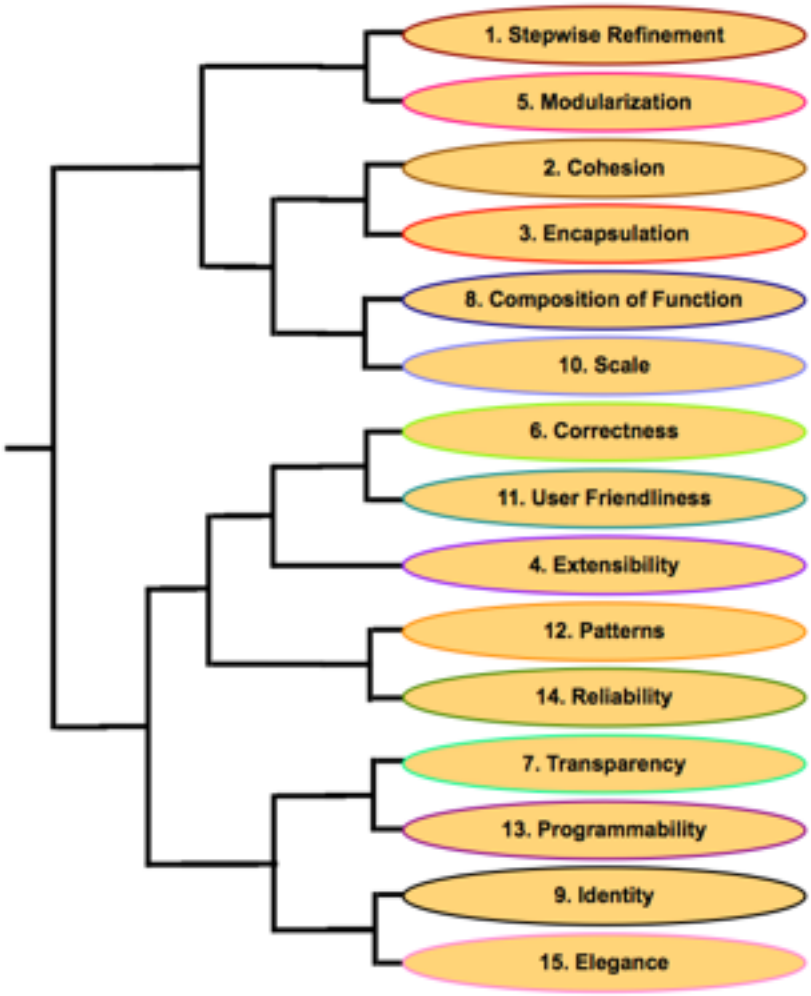

Figure 1 *Choice* Property Clustering Derived by *Coherence*

The tree may be partitioned by trimming off "clusters of leaves" by snipping the inner branches at some level from the root (at the far left). Snipping at every branch results in the fourteen clusters as depicted in Figure 2 below.

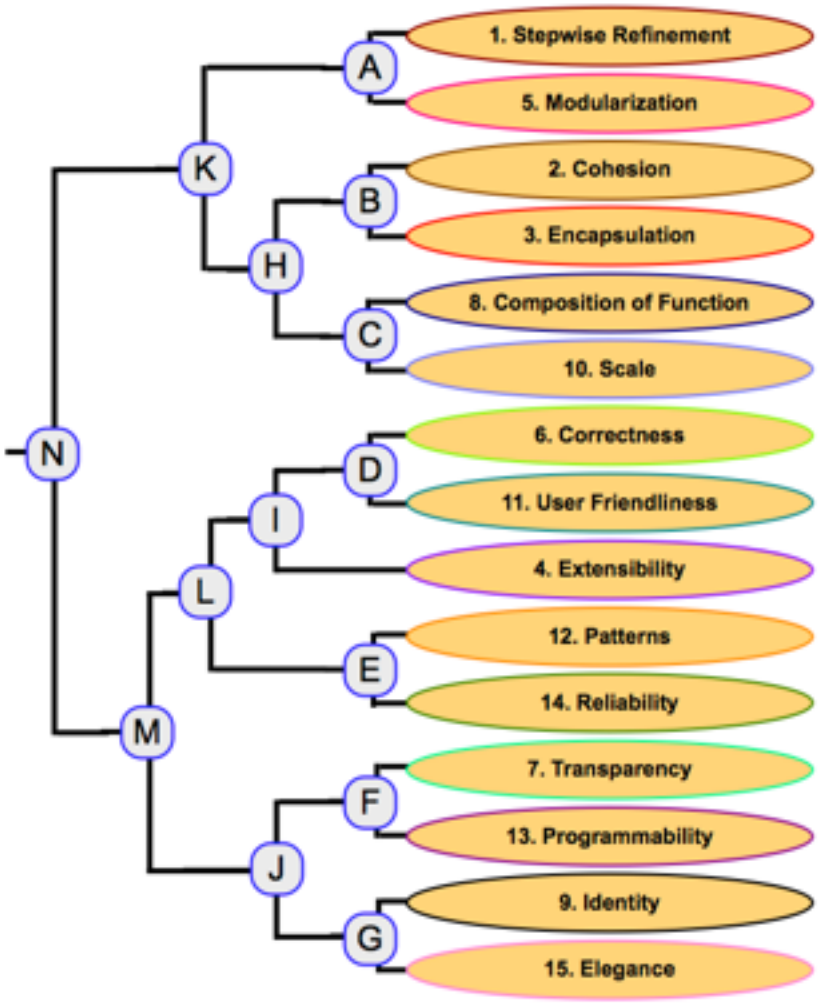

Figure 2 *Choice* Property Clusters Labeled by Branch

In the hierarchical, agglomerative clustering technique there is no prescribed or definitively useful "snipping point." The clusters represent "prospectively useful groups" indicating the proximity or affinity of the member properties. Indeed at one extreme the final clustering indicated by the root of the tree, "N," groups all the properties into a single cluster. The subdivision of this "super" cluster into constituent clusters offers the opportunity to explain the proximity, the affinity, the stakeholder perceived quality, of design ***choices*** and exposes property patterns that contribute to the ***wholeness*** of a system design.

Clusters A through G are the finest granules of interdependency or property support. Observers, stakeholders, are more likely to recognize the effect of these clusters in the fine-grained ***choices*** they examine. Higher levels of agglomeration (i.e. clusters H, I and J) reveal a greater confluence of effects as the combination of lower level clusters (in some sense more discrete)

combine in a more complex convergence of effects. Clusters K, L, M and finally N grow into the full confluence of all fifteen ***choice*** properties. Each cluster is a framework for interpreting a palpable "field" of quality resonance in a design or modeling ***choice*** – simple or complex. I consider each cluster below in turn.

4 Choice Property Cluster Contribution to Wholeness

Each of the clusters of ***choice*** properties represents a different emphasis or nuance of ***living*** structure features. At the same time they remain interwoven in the field-effect of properties contributing in concert to the intensity of each ***choice***. In the discussions of clusters that follow, the properties remain the same in whichever cluster they participate, however their influence is nuanced by the confluence of all the properties in that cluster. As this review of clusters proceeds from those with the least number of properties per cluster to those with the greatest the reader will note a growing degree of abstraction that describes the clusters' resonance as the weave of the interrelationships appears to shift the focus from the resonance of individual ***choices*** to the ***wholeness*** of an entire system.

Table 2 below lists the 14 clusters determined by the branches of the clustering tree. It also lists the supporting properties of each property in the cluster. Properties found to support every property composing a cluster are noted in the darker shading. I refer to these as primary support properties. Support properties relate the effects of the cluster on observer perceptions to a greater degree than the rest of the supporting properties and provide a logical focus for explaining the cluster's character as a confluence in the cluster's field-effects.

Cluster		Property Tree Cut at Branches															
		Fourteen Clusters															
		Row item supported by column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	1	Stepwise Refinement		2	3			6			9						
	5	Modularization	1	2	3			6	7		9		11		13		
B	2	Cohesion				4			7		9	10			13		15
	3	Encapsulation		2		4			7	8	9	10					
C	8	Composition of Function				4	5			8	9		11	12			15
	10	Scale	1	2					7		9		11	12			15
D	6	Correctness	1	2			5	6		8		10		12		14	
	11	User Friendliness		2			5	6				10				14	15
E	12	Patterns	1					6	7			10	11				15
	14	Reliability						6	7					12	13		15
F	7	Transparency	1				5				9				13		
	13	Programmability	1		3		5		7		9					14	
G	9	Identity			3		5			8	9	10			13		15
	15	Elegance			3		5			8		10	11		13	14	
H	2	Cohesion				4			7		9	10			13		15
	3	Encapsulation		2		4			7	8	9	10					
	8	Composition of Function				4	5			8	9		11	12			15
	10	Scale	1	2					7		9		11	12			15
I	4	Extensibility		2			5	6		8	9						15
	6	Correctness	1	2			5	6		8		10		12		14	
	11	User Friendliness		2			5	6				10				14	15
J	7	Transparency	1				5				9				13		
	9	Identity			3		5			8	9	10			13		15
	13	Programmability	1		3		5		7		9					14	
	15	Elegance			3		5			8		10	11		13	14	
K	1	Stepwise Refinement		2	3			6			9						
	2	Cohesion				4			7		9	10			13		15

	3	Encapsulation		2		4			7	8	9	10					
	5	Modularization	1	2	3			6	7		9		11		13		
	8	Composition of Function				4	5			8	9		11	12			15
	10	Scale	1	2					7		9		11	12			15
L	4	Extensibility		2			5	6		8	9						15
	6	Correctness	1	2			5	6		8		10		12		14	
	11	User Friendliness		2			5	6				10				14	15
	12	Patterns	1					6	7			10	11				15
	14	Reliability						6	7					12	13		15
M	4	Extensibility		2			5	6		8	9						15
	6	Correctness	1	2			5	6		8		10		12		14	
	7	Transparency	1				5				9				13		
	9	Identity			3		5			8	9	10			13		15
	11	User Friendliness		2			5	6				10				14	15
	12	Patterns	1					6	7			10	11				15
	13	Programmability	1		3		5		7		9					14	
	14	Reliability						6	7					12	13		15
	15	Elegance			3		5			8		10	11		13	14	
N	1	Stepwise Refinement		2	3			6			9						
	2	Cohesion				4			7		9	10			13		15
	3	Encapsulation		2		4			7	8	9	10					
	4	Extensibility		2			5	6		8	9						15
	5	Modularization	1	2	3			6	7		9		11		13		
	6	Correctness	1	2			5	6		8		10		12		14	
	7	Transparency	1				5				9				13		
	8	Composition of Function				4	5			8	9		11	12			15
	9	Identity			3		5			8	9	10			13		15
	10	Scale	1	2					7		9		11	12			15
	11	User Friendliness		2			5	6				10				14	15
	12	Patterns	1					6	7			10	11				15
	13	Programmability	1		3		5		7		9					14	
	14	Reliability						6	7					12	13		15
	15	Elegance			3		5			8		10	11		13	14	

Table 2 Property Clusters and Supporting *Choice* Properties

5 Exploring the "Field-Effect" of the Clusters

I explore each of the clusters produced from cluster analysis based upon the ***coherence*** measure relating ***choice*** properties. Each section includes a figure depicting the cluster

with its members and primary support properties. In addition an accompanying table recounts a thumbnail description of each property involved in the cluster as a reader's reference. Finally, each cluster is "named" as shorthand to characterize the overall quality resonance effected by the cluster. Some of these names may be familiar to systems developers, but the reader should be careful not to assume a particular interpretation independent of the specific ***choice*** property interactions described herein.[7]

5.1 Divisibility – The Field-Effect of Cluster "A"

Cluster "A" is composed of ***stepwise refinement*** and ***modularization*** supported by ***cohesion***, ***encapsulation***, ***correctness*** and ***identity***.

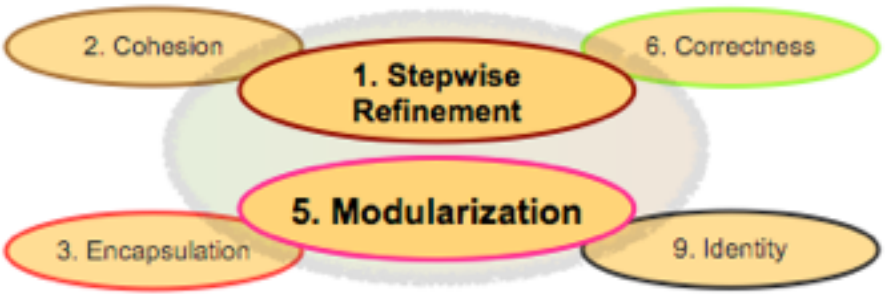

Figure 3 *Divisibility* – Cluster "A"

The following table recalls the thumbnail description of each property member of the cluster and the properties found to support every member of the cluster.

Cluster	Thumbnail Property Descriptions
A	#1 ***Stepwise refinement*** reveals itself in a system when components scale-up or scale down to reflect divide and conquer analysis and design allowing an observer to "zoom in" and "zoom out" and still retain a useful perspective effectively representing the system's primary concerns.
	#5 ***Modularization***: A system is appropriately modularized when its subsystems are crafted to always work in combination with other subsystems to achieve their collective purpose for which individually they may be ignorant; reflecting a separation of concerns.
	#2 ***Cohesion***: System components are cohesive when the well-defined design choices they embody reinforce their contribution to the system as a whole; the concerns central to each component are clear and distinct from the components that
	#3 ***Encapsulation***: A system module is properly encapsulated when its separateness is balanced by a straightforward and intelligible description of "what" (defined by its interface) that module does to cooperate with the collective
	#6 ***Correctness*** is the presence of germane and essential system behaviors as specified by the requirements combined with the absence of extraneous behaviors.
	#9 ***Identity*** is the clarity of distinctiveness between modules in a system which prevents system components from addressing the same purpose and causing confusion within the design of the system as a whole.

Table 3 *Divisibility* Cluster with Supporting Property Descriptions

In life the construction and maintenance of every element in nature involves the presence of parts. The presence of these parts or modules is essential to the distribution of responsibility and the tolerance of complexity, both in evolution and survival. In human cognition problem solving is universally predicated on the ability to decompose situations in order to analyze and understand the whole as a system of parts, ***choices***. Therefore ***modularization*** is essential to structure both in construction and comprehension.

divisible |di'vizəbəl|
adjective
capable of being divided *without a remainder* .

(*Definitions noted in this section are derived from the New Oxford American Dictionary*.)[8]

Parts in and of themselves are not necessarily valuable. In fact commonly in everyday life parts exist as things that are broken; usually taken to mean no longer useful or usable. No longer existing as it was in the whole of its parts, it no longer retains the ***identity*** that it once was as the whole. Parts therefore may or may not be beneficial.

Beneficial parts emerge from a process that does not fracture the order that allows those parts to coexist (and cooperate) in a whole. ***Stepwise refinement*** reflects a goal-directed process of dividing a whole into parts that leaves the ***identity*** of the whole in tact – disassembled but not destroyed. The process leaves the impression that the resulting parts still reflect the whole. The directing goal may be to derive divisions that reflect stakeholder familiarity, regulatory or professional standards, partitions for which known "solutions" exist or any number of strategies aimed at some form of effectiveness or efficiency. In any case the goal is to render in parts and not diminish the ***essence*** of the whole; what it was or what the stakeholders perceived it to be still exists. For these reasons ***divisibility*** is an apt name for the resonant quality, the field-effect of this cluster grouping ***stepwise refinement*** and ***modularization***.

5.2 Factorability – The Field-Effect of Cluster "B"

Cluster "B" is composed of ***cohesion*** and ***encapsulation*** supported by ***extensibility***, ***transparency***, ***identity*** and ***scale***.

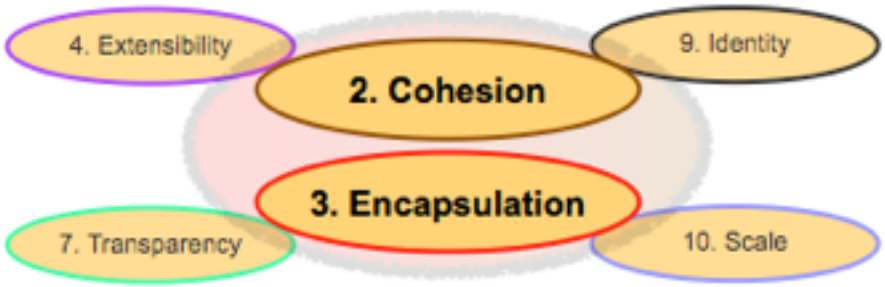

Figure 4 *Factorability* – Cluster "B"

The following table recalls the thumbnail description of each property member of the cluster and the properties found to support every member of the cluster.

Cluster	Thumbnail Property Descriptions
B	#2 ***Cohesion***: System components are cohesive when the well-defined design choices they embody reinforce their contribution to the system as a whole; the concerns central to each component are clear and distinct from the components that surround it.
	#3 ***Encapsulation***: A system module is properly encapsulated when its separateness is balanced by a straightforward and intelligible description of "what" (defined by its interface) that module does to cooperate with the collective
	#4 ***Extensibility***: Modules that are conceived to be reused and re-tasked after they have been implemented are said to be extensible offering the potential for the system's function to be expanded even after the modules have been crafted.
	#7 ***Transparency*** is being able to observe discernible structure in a system; how things fit and work together and exposing the "patterns" and "weave" of their interconnectedness.
	#9 ***Identity*** is the clarity of distinctiveness between modules in a system which prevents system components from addressing the same purpose and causing confusion within the design of the system as a whole.
	#10 ***Scale*** is the elaboration of system detail appropriate to the needs of particular observers used in complexity management in analysis, in design, in implementation and in documentation.

Table 4 *Factorability* Cluster with Supporting Property Descriptions

Cohesion reflects the self-sufficiency of a ***choice***; a ***choice*** that is well-formed and thus is justified in its existence independent of the collection of ***choices*** around it. As small or as large a part of the domain it may be each ***choice*** represents a stable, explicable, recognizable, namable granule of the whole.

factorize |'faktəˌrīz|
verb [trans.] Mathematics
express (a number or expression) as a product of factors.

While ***cohesion*** faces inward ***encapsulation*** turns outward. The clustering of ***cohesion*** with ***encapsulation*** accentuates the ***choice***'s boundaries while providing a contractual interface through which it interacts and participates in the collection of ***choices*** around it. The protection implied through ***encapsulation*** insulates the ***choice***'s inner details and promotes its stability while at the same time providing a published means of consistent collaboration with its surrounding ***choices***. This combination of property effects denotes the ***choice***'s role as a stable, credible part in the ***wholeness*** of the system – a contributing factor. For these reasons ***factorability*** is an apt name for the resonant quality, the field-effect of this cluster grouping ***cohesion*** and ***encapsulation***.

5.3 Constructibility – the "Field-Effect" of Cluster "C"

Cluster "C" is composed of ***composition of function*** and ***scale*** supported by ***identity***, ***user friendliness***, ***patterns*** and ***elegance***.

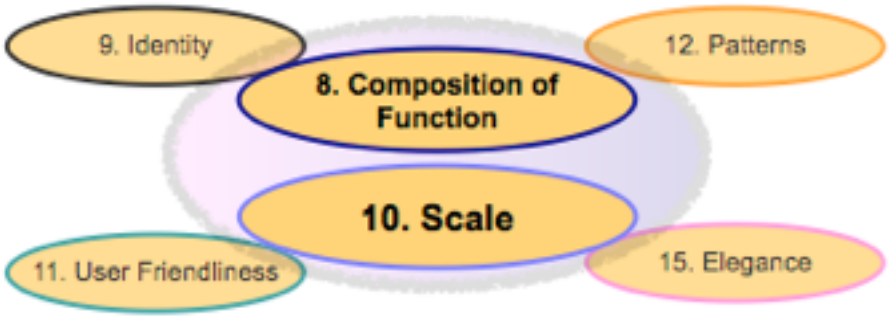

Figure 5 *Constructibility* – Cluster "C"

The following table recalls the thumbnail description of each property member of the cluster and the properties found to support every member of the cluster.

Cluster	Thumbnail Property Descriptions
C	#8 ***Composition of function*** implements its required functionality by combining components that interoperate with super-ordinate components to support a combined purpose. They tend to recede into the "shadows" as they perform their role largely anonymously forming new choices of function or behavior.
	#10 ***Scale*** is the elaboration of system detail appropriate to the needs of particular observers used in complexity management in analysis, in design, in implementation and in documentation.
	#9 ***Identity*** is the clarity of distinctiveness between modules in a system which prevents system components from addressing the same purpose and causing confusion within the design of the system as a whole.
	#11 ***User friendliness*** is achieved when the system is matched to the expectations of its users; the range and granularity of interface options reflecting the nature of the needs of the users in accomplishing their individual tasks.
	#12 ***Patterns*** in a system expose symmetry of purpose; similarities and parallels are reflected explicitly often described in standards, guidelines and frameworks.
	#15 ***Elegance***: System models that are consistent, clear, concise, coherent, cogent and transparently correct exude elegance.

Table 5 *Constructibility* Cluster with Supporting Property Descriptions

Scale has the effect of focusing attention on a particular level of detail; rendering aspects at that granularity clear and discernible. ***Composition of function*** has the effect of constructing assemblies of progressive size and complexity by combining ***choices*** and combina-

tions of ***choices***. Once combined these assemblies effectively fuse forming a new ***choice*** at a new level of ***scale***.

construct
verb |kən'strəkt| [trans.]
• form (an idea or theory) by bringing together various conceptual elements, typically over a period of time.

The opportunity for combination of ***choices*** into more complex ***choices*** relies on the clarity of purpose and functionality that preexists in each constituent ***choice***. The combining process usually follows a strategy or predefined pattern of assembly that permits expansion in both cardinality and complexity. When the "pieces" come together seamlessly or at least can be observed without undue regard for the "pieces" as "pieces," the overall impression is one of simplicity that reduces the barriers to usefulness and effective application. The expression of this quality in ***choices*** encourages stakeholders to consider adding capacity and function first by seeking out combinations of existing ***choices*** rather than creating new ones. For these reasons ***constructibility*** is an apt name for the resonant quality, the field-effect of this cluster grouping ***composition of function*** and ***scale***.

5.4 Confidence – the "Field-Effect" of Cluster "D"

Cluster "D" is composed of ***correctness*** and ***user friendliness*** supported by ***cohesion***, ***modularization*** and ***correctness***.

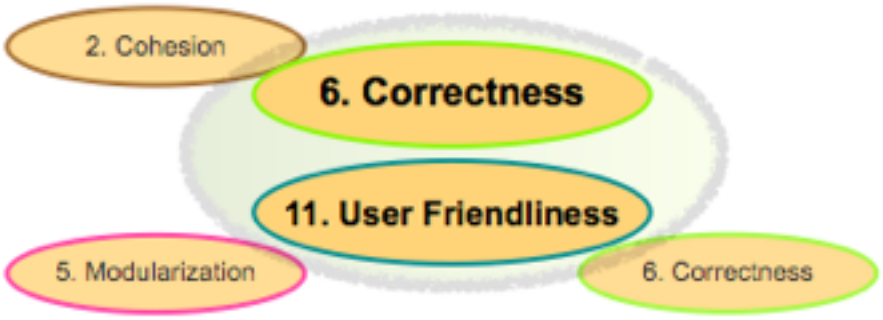

Figure 6 *Confidence* – Cluster "D"

The following table recalls the thumbnail description of each property member of the cluster and the properties found to support every member of the cluster.

Cluster	Thumbnail Property Descriptions
D	#6 ***Correctness*** is the presence of germane and essential system behaviors as specified by the requirements combined with the absence of extraneous behaviors.
	#11 ***User friendliness*** is achieved when the system is matched to the expectations of its users; the range and granularity of interface options reflecting the nature of the needs of the users in accomplishing their individual tasks.
	#2 ***Cohesion***: System components are cohesive when the well-defined design choices they embody reinforce their contribution to the system as a whole; the concerns central to each component are clear and distinct from the components that
	#5 ***Modularization***: A system is appropriately modularized when its subsystems are crafted to always work in combination with other subsystems to achieve their collective purpose for which individually they may be ignorant; reflecting a separation of concerns.
	#6 ***Correctness*** is the presence of germane and essential system behaviors as specified by the requirements combined with the absence of extraneous behaviors.

Table 6 *Confidence* Cluster with Supporting Property Descriptions

Correctness is the proper alignment of ***choice*** with stakeholder intentions. In that sense there is no "absolute" ***correctness*** independent of stakeholder intentions. ***Correctness*** is a "moving target;" when intentions change alignment must be adjusted. ***Correctness*** may be the first and most critical property of all. If stakeholder intentions cannot be expressed with ***choice***(s) exhibiting strong ***correctness*** the rest of the properties have no chance of delivering satisfaction. This is underscored by the fact that ***correctness*** is a supporting property of ***correctness*** (the only property so reflexive!). ***Correctness*** is at least transitive if not cumulative in its affects.

confidence |'känfədəns; -fə¸dens|
noun
the feeling or belief that one can rely on someone or something; firm trust .

As in the ***composition of function*** the strength of the ***correctness*** property of the whole is dependent on the strength of the ***correctness*** property of the constituent parts. Those parts must be credible divisions of the whole and be individually credible. ***Correctness*** and ***user friendliness*** reinforce each other as the alignment of the ***choice*** with the stakeholder intentions coincides with the user's expectations and their very perception of "what is natural!" Being able to "see" what you expect to find in a ***choice*** is vital to maintaining reliance and trust. For these reasons ***confidence*** is an apt name for the resonant quality, the field-effect of this cluster grouping ***correctness*** and ***user friendliness***.

5.5 Predictability – the "Field-Effect" of Cluster "E"

Cluster "E" is composed of ***patterns*** and ***reliability*** supported by ***correctness***, ***transparency*** and ***elegance***.

Figure 7 *Predictability* – Cluster "E"

The following table recalls the thumbnail description of each property member of the cluster and the properties found to support every member of the cluster.

Cluster	Thumbnail Property Descriptions
E	#12 ***Patterns*** in a system expose symmetry of purpose; similarities and parallels are reflected explicitly often described in standards, guidelines and frameworks.
	#14 ***Reliability***: Reliable systems function as designed without interruption eschewing extraneous detail thus avoiding unwanted or unexpected side effects that lead to unwanted and unnecessary system maintenance.
	#6 ***Correctness*** is the presence of germane and essential system behaviors as specified by the requirements combined with the absence of extraneous behaviors.
	#7 ***Transparency*** is being able to observe discernible structure in a system; how things fit and work together and exposing the "patterns" and "weave" of their interconnectedness.
	#15 ***Elegance***: System models that are consistent, clear, concise, coherent, cogent and transparently correct exude elegance.

Table 7 *Predictability* Cluster with Supporting Property Descriptions

If a problem-solving approach succeeds repeatedly that may be the simplest and clearest indication that the approach subsumes the problem's ***essence***. To successfully apply the familiar to the unknown is very comforting (and satisfying). The accumulation of the "successful familiar," those tactics and strategies that lead to repeated success, is a sign of vitality. Successful systems are composed of successful ***choices*** that are born of the repeated

application of proven ***patterns*** developed through experience. The success of matching pattern to problem depends upon the detection of those aspects to which the pattern is applicable and to the naturalness that the alignment between pattern affects and problem issues reveals to the observer. In those instances where the alignment is "perfect" the use of the pattern embodies an elegant solution.

predictable |pri'diktəbəl|
adjective
behaving or occurring in a way that is expected.

Devising and accumulating patterns that apply consistently and yield consistent successes embodies the property of ***reliability***. The most common risk in reapplying solutions of experience to new situations is the unexpected side effect; the case where the pattern's applicability nearly, but incompletely matches the situation at hand. The remedy involves standard assessments that predict (if not certify) that a pattern is applicable before it is used. These assessments can be gathered into norms or frameworks that predict side effects and thus permit wasted effort and ***choice*** rework to be minimized. ***Choices*** that are formed by a well balanced presence of ***patterns*** and ***reliability*** promote ***predictability*** and eschew the unexpected and unwelcome surprises. For these reasons ***predictability*** is an apt name for the resonant quality, the field-effect of this cluster grouping ***patterns*** and ***reliability***.

5.6 Usability – the "Field-Effect" of Cluster "F"

Cluster "F" is composed of ***transparency*** and ***programmability*** supported by ***stepwise refinement***, ***modularization*** and ***identity***.

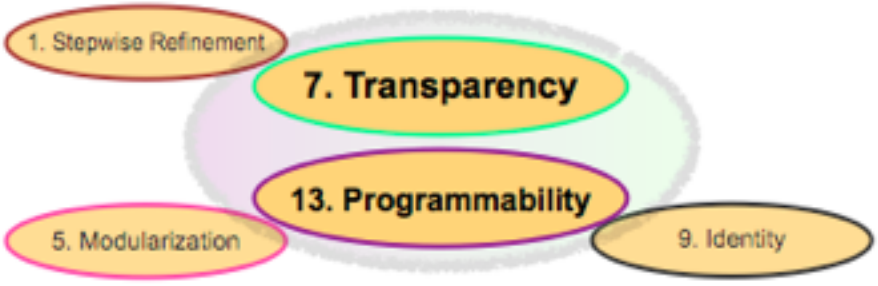

Figure 8 *Usability* – Cluster "F"

The following table recalls the thumbnail description of each property member of the cluster and the properties found to support every member of the cluster.

Cluster	Thumbnail Property Descriptions
F	#7 ***Transparency*** is being able to observe discernible structure in a system; how things fit and work together and exposing the "patterns" and "weave" of their interconnectedness.
	#13 ***Programmability*** provides users with the means to dynamically re-target the system over time; supporting a range of purpose achieved primarily by aggregating various collections rather than multiplying choices.
	#1 ***Stepwise refinement*** reveals itself in a system when components scale-up or scale down to reflect divide and conquer analysis and design allowing an observer to "zoom in" and "zoom out" and still retain a useful perspective effectively representing the system's primary concerns.
	#5 ***Modularization***: A system is appropriately modularized when its subsystems are crafted to always work in combination with other subsystems to achieve their collective purpose for which individually they may be ignorant; reflecting a separation of concerns.
	#9 ***Identity*** is the clarity of distinctiveness between modules in a system which prevents system components from addressing the same purpose and causing confusion within the design of the system as a whole.

Table 8 *Usability* Cluster with Supporting Property Descriptions

Except in the most abstract of circumstances ***choices*** are subject to ***accidents of implementation*** where the "technology" used to represent the ***choice*** diverges from the mode of stakeholder expression. The closer the representation is to the stakeholders' conception of the ***choice*** the greater the strength of the ***transparency*** property in that ***choice***. When the intention of the ***choice*** is clear it is easier for the stakeholder (user) to recognize and thus apply it to their task. On the contrary a ***choice*** that obscures the intention is likely to be overlooked at best or misapplied at worst.

usable |'yoōzəbəl| (also **useable**)
adjective
able or fit to be used.

An important aspect of the applicability of a ***choice*** is the versatility that it offers. If its applicability is narrow and inflexible the range of its use will also be narrow. If it is flexible its range of use is likely to be broader and draw stakeholder (user) attention more readily and frequently. Frequent use results in familiarity; familiarity promotes a sense of naturalness and that sense promotes reuse! The property of ***programmability*** is an expression of the versatility a ***choice*** provides through parameters, dialogs, inheritance, etc. For these reasons ***usability*** is an apt name for the resonant quality, the field-effect of this cluster grouping ***transparency*** and ***programmability***.

5.7 Intuitiveness – the "Field-Effect" of Cluster "G"

Cluster "G" is composed of ***identity*** and ***elegance*** supported by ***encapsulation***, ***modularization***, ***composition of function***, ***scale*** and ***programmability***.

Figure 9 *Intuitiveness* – Cluster "G"

The following table recalls the thumbnail description of each property member of the cluster and the properties found to support every member of the cluster.

Cluster	Thumbnail Property Descriptions
G	#9 ***Identity*** is the clarity of distinctiveness between modules in a system which prevents system components from addressing the same purpose and causing confusion within the design of the system as a whole.
	#15 ***Elegance***: System models that are consistent, clear, concise, coherent, cogent and transparently correct exude elegance.
	#3 ***Encapsulation***: A system module is properly encapsulated when its separateness is balanced by a straightforward and intelligible description of "what" (defined by its interface) that module does to cooperate with the collective
	#5 ***Modularization***: A system is appropriately modularized when its subsystems are crafted to always work in combination with other subsystems to achieve their collective purpose for which individually they may be ignorant; reflecting a separation of concerns.
	#8 ***Composition of function*** implements its required functionality by combining components that interoperate with super-ordinate components to support a combined purpose. They tend to recede into the "shadows" as they perform their role largely anonymously forming new choices of function or behavior.
	#10 ***Scale*** is the elaboration of system detail appropriate to the needs of particular observers used in complexity management in analysis, in design, in implementation and in documentation.
	#13 ***Programmability*** provides users with the means to dynamically re-target the system over time; supporting a range of purpose achieved primarily by aggregating various collections rather than multiplying choices.

Table 9 *Intuitiveness* Cluster with Supporting Property Descriptions

Identity and ***elegance*** combine to characterize perceived naturalness. ***Identity*** fuses the conceptual with the linguistic when the name and the ***choice*** are indivisible in thought and expression. In the stakeholders' domain it is usually assumed that names and concepts are perfectly aligned. Requirements engineers however, are careful to test that alignment throughout the requirements analysis activity to detect conceptual "synonyms" and "homonyms" that are often unnoticed by the stakeholders themselves in complex environments. Strengthening ***identity*** results from properly bounding ***choices*** (***modularization***), protecting them from adulteration (***encapsulation***), matching them with complementary ***choices*** (***composition of function***), describing them in the proper context (***scale***) and defining an appropriate range for their applicability (***programmability***).

intuitive |in't(y)oōitiv|
adjective
using or based on what one feels to be true even without conscious reasoning; instinctive.

The field effect of ***elegance*** harmonizes a ***choice***'s ***identity*** with the whole; balancing its impact and responsibility in the community of the whole. Its presence, its existence, its position in the whole are as if they could not have been conceived of differently; as if the ***choice*** as presented *is* the intention of the stakeholders. The strength of ***elegance*** is the resonance of the ***choice's*** contribution to the ***wholeness*** of the system where the experience of the whole is greater than the sum of its parts. (In choral music this phenomenon is expressed as the detection of an additional note in a chord as in hearing a 5th note in the chord sung by a barbershop quartet!) For these reasons ***intuitiveness*** is an apt name for the resonant quality, the field-effect of this cluster grouping ***identity*** and ***elegance***.

5.8 Scalability – the "Field-Effect" of Cluster "H"

Cluster "H" is composed of ***cohesion***, ***encapsulation***, ***composition of function*** and ***scale*** supported by ***identity***.

Figure 10 *Scalability* – Cluster "H"

The following table recalls the thumbnail description of each property member of the cluster and the properties found to support every member of the cluster.

Cluster	Thumbnail Property Descriptions
H	#2 ***Cohesion***: System components are cohesive when the well-defined design choices they embody reinforce their contribution to the system as a whole; the concerns central to each component are clear and distinct from the components that surround it.
	#3 ***Encapsulation***: A system module is properly encapsulated when its separateness is balanced by a straightforward and intelligible description of "what" (defined by its interface) that module does to cooperate with the collective
	#8 ***Composition of function*** implements its required functionality by combining components that interoperate with super-ordinate components to support a combined purpose. They tend to recede into the "shadows" as they perform their role largely anonymously forming new choices of function or behavior.
	#10 ***Scale*** is the elaboration of system detail appropriate to the needs of particular observers used in complexity management in analysis, in design, in implementation and in documentation.
	#9 ***Identity*** is the clarity of distinctiveness between modules in a system which prevents system components from addressing the same purpose and causing confusion within the design of the system as a whole.

Table 10 *Scalability* Cluster with Supporting Property Descriptions

This cluster combines the properties that compose ***constructibility*** with those of ***factorability***. Where ***factorability*** reflects a soundness of individual choices for their internal stability and structural independence, ***constructibility*** reflects the capacity for joining ***choices*** in combinations that permit the building of larger and more complex arrangements.

scalable |'skāləbəl|
adjective
able to be changed in size or scale.

Interchangeability in connection, if not in function, is critical to the stability of structures. The opportunity to arrange by mixing and matching provides the range of options from which to choose the most appropriate (e.g. effective, efficient, economical, etc.). Component-based architectures are the "poster-child" of this quality where the product is composed of parts with the potential of many different combinations with a minimum of cost for rearranging them to achieve gains in capacity or complexity. For these reasons ***scalability*** is an apt name for the resonant quality, the field-effect of this cluster grouping ***cohesion***, ***encapsulation***, ***composition of function*** and ***scale***.

5.9 Fidelity – the "Field-Effect" of Cluster "I"

Cluster "I" is composed of ***correctness***, ***user friendliness*** and ***extensibility*** supported by ***cohesion***, ***modularization*** and ***correctness***.

Figure 11 *Fidelity* – Cluster "I"

The following table recalls the thumbnail description of each property member of the cluster and the properties found to support every member of the cluster.

Cluster	Thumbnail Property Descriptions
I	#4 ***Extensibility***: Modules that are conceived to be reused and re-tasked after they have been implemented are said to be extensible offering the potential for the system's function to be expanded even after the modules have been crafted.
	#6 ***Correctness*** is the presence of germane and essential system behaviors as specified by the requirements combined with the absence of extraneous behaviors.
	#11 ***User friendliness*** is achieved when the system is matched to the expectations of its users; the range and granularity of interface options reflecting the nature of the needs of the users in accomplishing their individual tasks.
	#2 ***Cohesion***: System components are cohesive when the well-defined design choices they embody reinforce their contribution to the system as a whole; the concerns central to each component are clear and distinct from the components that
	#5 ***Modularization***: A system is appropriately modularized when its subsystems are crafted to always work in combination with other subsystems to achieve their collective purpose for which individually they may be ignorant; reflecting a separation of concerns.
	#6 ***Correctness*** is the presence of germane and essential system behaviors as specified by the requirements combined with the absence of extraneous behaviors.

Table 11 *Fidelity* Cluster with Supporting Property Descriptions

For whatever reason ***extensibility*** did not participate in any of the binary property clusters.[9] It's affinity did not outweigh that of any of the other pairings. Combined with the cluster ***confidence*** its importance to stakeholders is pronounced. Where ***confidence*** relates to a strength of reliance on *what is*, the addition of ***extensibility*** shifts the effect from the present into the evolving incorporation of *what will be* the changing nature of both stakeholder intentions and the system's response to the changes in and among ***choices***.

fidelity |fə'delətē|
noun
faithfulness to a cause, demonstrated by continuing loyalty and support.

Accommodating the future, the inevitable change that it brings, influences the nature and ***essence*** of ***choices*** as they must in their aspiration toward ***cohesion*** and ***correctness*** account for the capacity of ***unfolding***, but without sacrificing the strength of those properties essential to ***confidence***. The challenge is building something that is correct in the now while at the same time is adaptable for the future. For these reasons ***fidelity*** is an apt name for the resonant quality, the field-effect of this cluster grouping ***correctness***, ***user friendliness*** and ***extensibility***.

5.10 Effectiveness – the "Field-Effect" of Cluster "J"

Cluster "J" is composed of ***transparency***, ***identity***, ***programmability*** and ***elegance*** supported by ***modularization***.

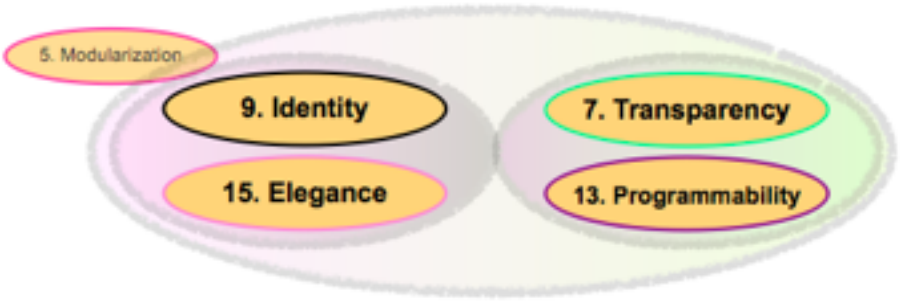

Figure 12 *Effectiveness* – Cluster "J"

The following table recalls the thumbnail description of each property member of the cluster and the properties found to support every member of the cluster.

Cluster	Thumbnail Property Descriptions
J	#7 ***Transparency*** is being able to observe discernible structure in a system; how things fit and work together and exposing the "patterns" and "weave" of their interconnectedness.
	#9 ***Identity*** is the clarity of distinctiveness between modules in a system which prevents system components from addressing the same purpose and causing confusion within the design of the system as a whole.
	#13 ***Programmability*** provides users with the means to dynamically re-target the system over time; supporting a range of purpose achieved primarily by aggregating various collections rather than multiplying choices.
	#15 ***Elegance***: System models that are consistent, clear, concise, coherent, cogent and transparently correct exude elegance.
	#5 ***Modularization***: A system is appropriately modularized when its subsystems are crafted to always work in combination with other subsystems to achieve their collective purpose for which individually they may be ignorant; reflecting a separation of concerns.

Table 12 *Effectiveness* Cluster with Supporting Property Descriptions

This cluster combines the clusters of ***intuitiveness*** and ***usability***. ***Intuitiveness*** reflects the naturalness the stakeholders' perceive in a ***choice***: *what it is about* and how it "instinctively" addresses the intention for which it exists. It is the union of understanding the problem with understanding the solution.

effective |i'fektiv|
adjective
successful in producing a desired or intended result.

Usability reflects the ease with which the stakeholder (user) can grasp and apply the ***choice*** to their purpose. This is promoted by both the clarity with which the ***choice***'s intention is expressed (***transparency***) and with the versatility the ***choice*** offers (***programmability***) in adapting its use to a less than perfectly matched application. ***Intuitiveness*** reflects the ***choice***'s impression as both native to the stakeholders' experience (***identity***) and natural in its representation (***elegance***). Stakeholders perceive ***choices*** possessing strong ***intuitiveness*** and strong ***usability*** to be "a natural ***choice***!" For these reasons ***effectiveness*** is an apt name for the resonant quality, the field-effect of this cluster grouping ***transparency***, ***identity***, ***programmability*** and ***elegance***.

5.11 Robustness – the "Field-Effect" of Cluster "K"

Cluster "K" is composed of ***stepwise refinement***, ***cohesion***, ***encapsulation***, ***modularization***, ***composition of function*** and ***scale*** supported by ***identity***.

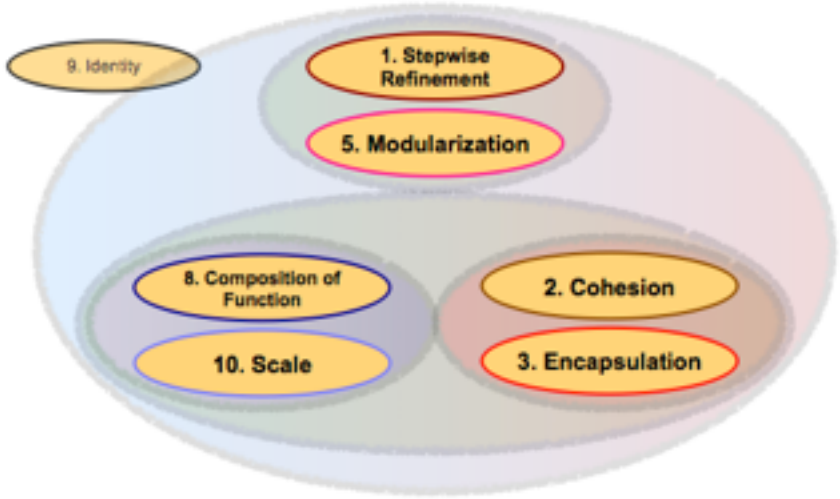

Figure 13 *Robustness* – Cluster "K"

The following table recalls the thumbnail description of each property member of the cluster and the properties found to support every member of the cluster.

Cluster	Thumbnail Property Descriptions
K	#1 ***Stepwise refinement*** reveals itself in a system when components scale-up or scale down to reflect divide and conquer analysis and design allowing an observer to "zoom in" and "zoom out" and still retain a useful perspective effectively representing the system's primary concerns.
	#2 ***Cohesion***: System components are cohesive when the well-defined design choices they embody reinforce their contribution to the system as a whole; the concerns central to each component are clear and distinct from the components that surround it.
	#3 ***Encapsulation***: A system module is properly encapsulated when its separateness is balanced by a straightforward and intelligible description of "what" (defined by its interface) that module does to cooperate with the collective
	#5 ***Modularization***: A system is appropriately modularized when its subsystems are crafted to always work in combination with other subsystems to achieve their collective purpose for which individually they may be ignorant; reflecting a separation of concerns.
	#8 ***Composition of function*** implements its required functionality by combining components that interoperate with super-ordinate components to support a combined purpose. They tend to recede into the "shadows" as they perform their role largely anonymously forming new choices of function or behavior.
	#10 ***Scale*** is the elaboration of system detail appropriate to the needs of particular observers used in complexity management in analysis, in design, in implementation and in documentation.
	#9 ***Identity*** is the clarity of distinctiveness between modules in a system which prevents system components from addressing the same purpose and causing confusion within the design of the system as a whole.

Table 13 *Robustness* Cluster with Supporting Property Descriptions

This cluster combines the clusters of ***divisibility*** and ***scalability***. This cluster is all about sound static structure: the building blocks, their juxtaposition, their connectivity, their individual purposes and how they all "hang together." ***Divisibility*** reflects the iterative decomposition that separates concerns among the ***choices*** and hones the representation of the ***essence*** that each embodies individually and (eventually) in composition. ***Scalability*** acts as the dual of ***divisibility*** by enabling the composition of ***choices*** carefully fusing their independent self-sufficiency into assemblies that can expand to meet the breadth and width of stakeholder intentions in a structure rigid enough to survive, yet pliable enough not to fracture.

robust |rō'bəst; 'rō,bəst|
adjective
(of an object) sturdy in construction. (of a process or system) able to withstand or overcome adverse conditions.

The resulting combination of qualities reflects structural integrity, a dependable foundation upon which to grow an ***unfolding*** system. For these reasons ***robustness*** is an apt name for the resonant quality, the field-effect of this cluster grouping ***stepwise refinement***, ***cohesion***, ***encapsulation***, ***modularization***, ***composition of function*** and ***scale***.

5.12 Sustainability – the "Field-Effect" of Cluster "L"

Cluster "L" is composed of ***extensibility***, ***correctness***, ***user friendliness***, ***patterns*** and ***reliability*** supported by ***correctness***.

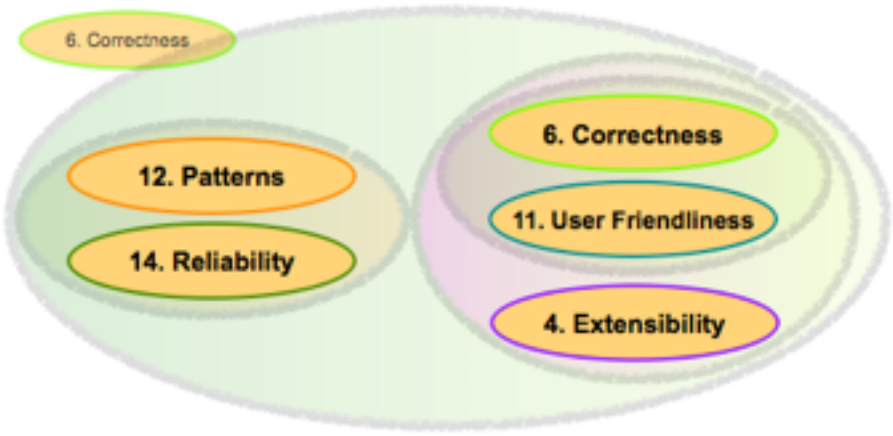

Figure 14 *Sustainability* – Cluster "L"

The following table recalls the thumbnail description of each property member of the cluster and the properties found to support every member of the cluster.

Cluster	Thumbnail Property Descriptions
L	#4 ***Extensibility***: Modules that are conceived to be reused and re-tasked after they have been implemented are said to be extensible offering the potential for the system's function to be expanded even after the modules have been crafted.
	#6 ***Correctness*** is the presence of germane and essential system behaviors as specified by the requirements combined with the absence of extraneous behaviors.
	#11 ***User friendliness*** is achieved when the system is matched to the expectations of its users; the range and granularity of interface options reflecting the nature of the needs of the users in accomplishing their individual tasks.
	#12 ***Patterns*** in a system expose symmetry of purpose; similarities and parallels are reflected explicitly often described in standards, guidelines and frameworks.
	#14 ***Reliability***: Reliable systems function as designed without interruption eschewing extraneous detail thus avoiding unwanted or unexpected side effects that lead to unwanted and unnecessary system maintenance.
	#6 ***Correctness*** is the presence of germane and essential system behaviors as specified by the requirements combined with the absence of extraneous behaviors.

Table 14 *Sustainability* Cluster with Supporting Property Descriptions

This cluster is composed of ***fidelity*** and ***predictability***. ***Predictability*** reflects maintaining a continuous, discernible trajectory of evolution while ***fidelity*** reflects the anchoring of ***choices*** in stakeholder intentions. In combination they address the ecology of the system ***unfolding***. As challenging as it may be to align a system of ***choices*** to the stakeholders' current understanding of reality, the prospect of anticipating how and in which direction that will evolve is even more so. Incorporating that anticipation in the formation and combination of ***choices*** is what this cluster of qualities is all about. Long term viability depends upon the capacity to grow, to adapt, to evolve, to ***unfold*** toward the future.

sustainable |sə'stānəbəl|
adjective
able to be maintained at a certain rate or level. conserving an ecological balance.

Fidelity and ***predictability*** combine to express the quality of continuous movement coupled with continuous vigilance, guarding against changes that might allow the ***essence*** represented in system ***choices*** to drift apart from the evolving reality that stakeholders experience around them. For these reasons ***sustainability*** is an apt name for the resonant quality, the field-effect of this cluster grouping ***extensibility***, ***correctness***, ***user friendliness***, ***patterns*** and ***reliability***.

5.13 Vitality – the "Field-Effect" of Cluster "M"

Cluster "M" is composed of ***extensibility***, ***correctness***, ***transparency***, ***identity***, ***user friendliness***, ***patterns***, ***programmability***, ***reliability*** and ***elegance***.

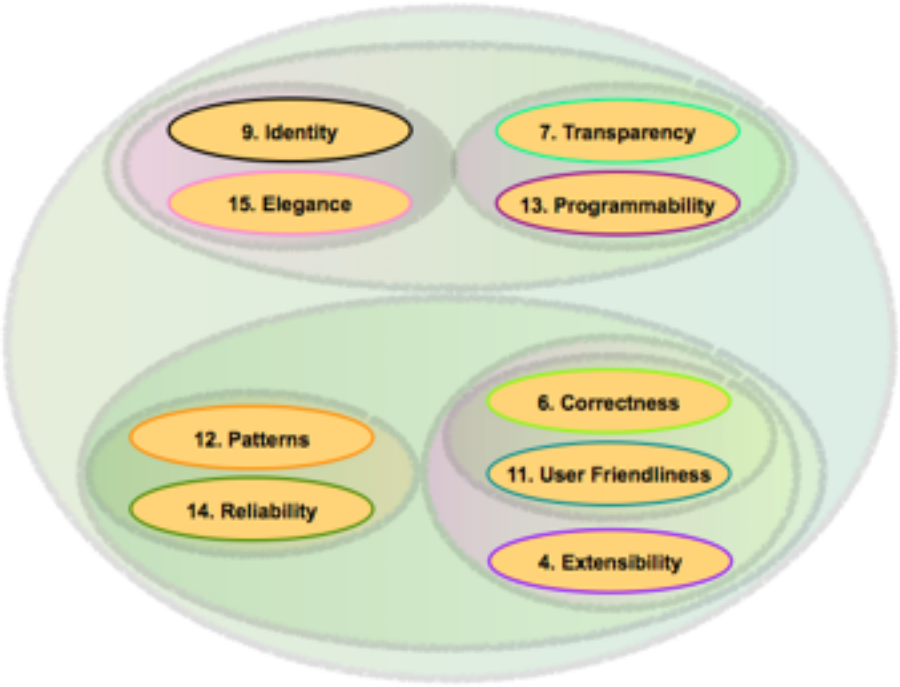

Figure 15 *Vitality* – Cluster "M"

The following table recalls the thumbnail description of each property member of the cluster and the properties found to support every member of the cluster.

Cluster	Thumbnail Property Descriptions
M	#4 ***Extensibility***: Modules that are conceived to be reused and re-tasked after they have been implemented are said to be extensible offering the potential for the system's function to be expanded even after the modules have been crafted.
	#6 ***Correctness*** is the presence of germane and essential system behaviors as specified by the requirements combined with the absence of extraneous behaviors.
	#7 ***Transparency*** is being able to observe discernible structure in a system; how things fit and work together and exposing the "patterns" and "weave" of their interconnectedness.
	#9 ***Identity*** is the clarity of distinctiveness between modules in a system which prevents system components from addressing the same purpose and causing confusion within the design of the system as a whole.
	#11 ***User friendliness*** is achieved when the system is matched to the expectations of its users; the range and granularity of interface options reflecting the nature of the needs of the users in accomplishing their individual tasks.
	#12 ***Patterns*** in a system expose symmetry of purpose; similarities and parallels are reflected explicitly often described in standards, guidelines and frameworks.
	#13 ***Programmability*** provides users with the means to dynamically re-target the system over time; supporting a range of purpose achieved primarily by aggregating various collections rather than multiplying choices.
	#14 ***Reliability***: Reliable systems function as designed without interruption eschewing extraneous detail thus avoiding unwanted or unexpected side effects that lead to unwanted and unnecessary system maintenance.
	#15 ***Elegance***: System models that are consistent, clear, concise, coherent, cogent and transparently correct exude elegance.

Table 15 *Vitality* Cluster with Supporting Property Descriptions

This cluster is composed of ***effectiveness*** and ***sustainability***. ***Effectiveness*** reflects the system's capacity to both effectively represent intentions as well as provide a collection of ***choices*** that are both understandable and applicable by stakeholders. ***Sustainability*** reflects the ***unfolding*** nature of the system where the collection of ***choices*** not only aligns with the current stakeholder reality, but is poised to respond to changes in shifting stakeholder intentions. The system expresses not only a relevant existence in the present, but also the capacity to grow and evolve with the stakeholder intentions into the future.

vital |'vītl|
adjective
indispensable to the continuance of life. full of energy; lively.

Responding to change, continuing to resonate with stakeholder intentions, ***unfolding*** both in the ***essence*** of structure and behavior, these are the underpinnings of a system with ***living structure*** as Christopher Alexander defines it. For these reasons ***vitality*** is an apt name for the resonant quality, the field-effect of this cluster grouping ***extensibility***, ***correctness***, ***transparency***, ***identity***, ***user friendliness***, ***patterns***, ***programmability***, ***reliability*** and ***elegance***.

5.14 Thriving – the "Field-Effect" of Cluster "N"

Cluster "N" is composed of all fifteen ***choice*** properties: ***stepwise refinement***, ***cohesion***, ***encapsulation***, ***extensibility***, ***modularization***, ***correctness***, ***transparency***, ***composition of function***, ***identity***, ***scale***, ***user friendliness***, ***patterns***, ***programmability***, ***reliability*** and ***elegance***.

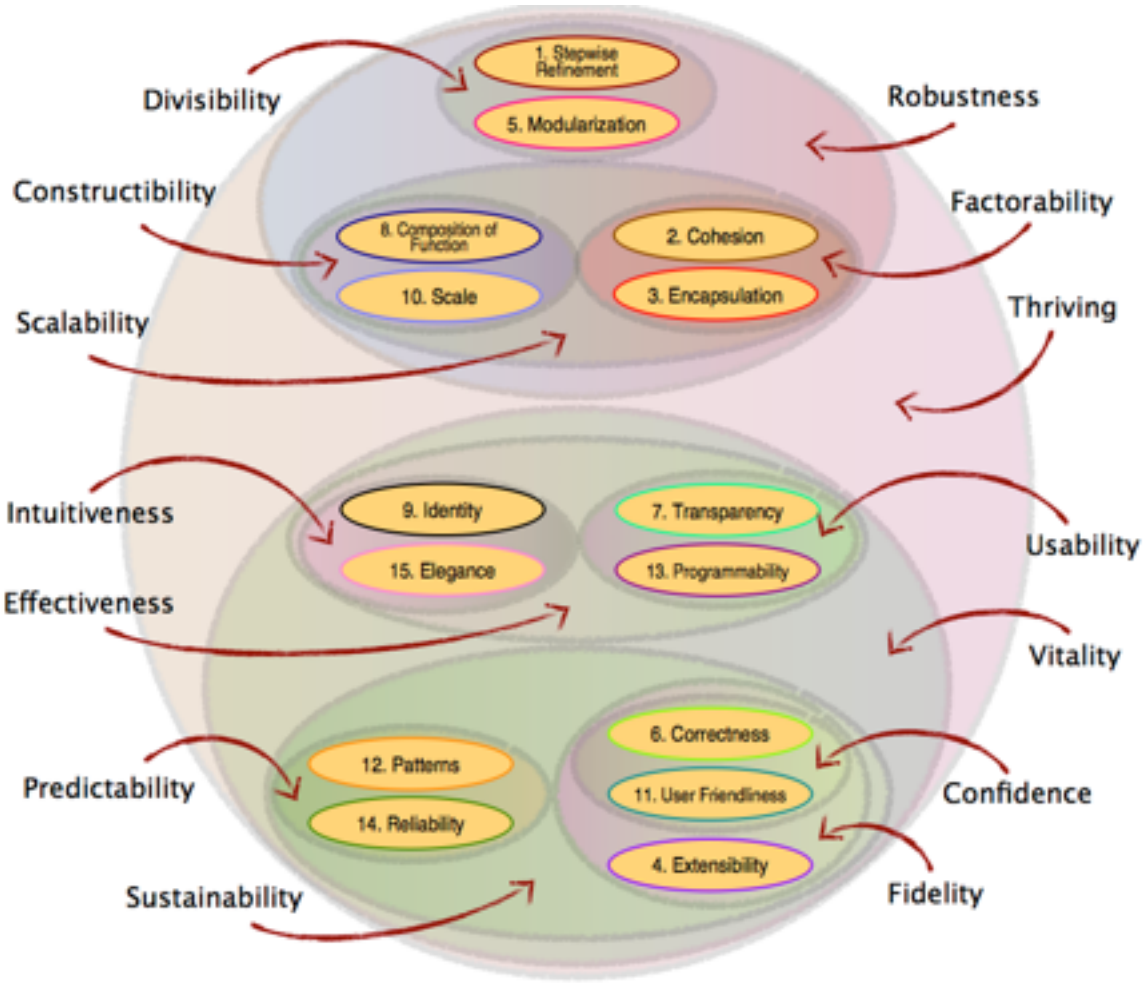

Figure 16 *Thriving* – Cluster "N"

The final cluster combines the ***robustness*** cluster and the ***vitality*** cluster. ***Robustness*** reflects soundness of structure, integrity of form and capacity for survival. ***Vitality*** reflects alignment between ***choices*** and stakeholders' intentions with the capacity for growth and ***unfolding*** over time and change. Conjoined these clusters express a quality beyond survival; beyond being alive. Robust, vital ***choices*** reflect a clarity of purpose, a dynamism, a vigor that emanates from the resonance between the stakeholders' intentions and the ***choices*** that represent them and (in most information systems) implement them.

thrive |θrīv|
verb
grow or develop well or vigorously. • prosper; flourish

A system of ***choices*** strong in qualities of ***robustness*** and ***vitality*** is able to adapt (even predict) and thrive on change. It is able to grow on a path that aligns with the growth path of stakeholder requirements. The alignment reflects a symbiotic coexistence between what the system of ***choices*** achieves with what the system of ***choices*** is supposed to achieve according to the stakeholders.

For these reasons ***thriving*** is an apt name for the resonant quality, the field-effect of this cluster grouping s***tepwise refinement***, ***cohesion***, ***encapsulation***, ***extensibility***, ***modularization***, ***correctness***, ***transparency***, ***composition of function***, ***identity***, ***scale***, ***user friendliness***, ***patterns***, ***programmability***, ***reliability*** and ***elegance***.

6 Directing the "Field-Effect" of Property Clusters

The foregoing exploration of ***choice*** property interactions parses their individual and combined contribution to design quality. In effect the fifteen ***choice*** properties and the fourteen clusters explain twenty-nine hierarchically related, non-discrete aspects of design quality. They lead to prescriptions for strengthening design ***choices***.

In *Modeling Actions Strengthening Life*[10] a transitive verb and the characterization of the results of applying that action verb in ***choice*** formation was associated with each of the fifteen ***choice*** properties. The ***choice*** clusters offer an analogous opportunity to understand the compositional effect of the clusters on ***choice*** formation – in effect indicating a course of action directed toward achieving a design objective. The confluence of the property affects defies the association of a single verb to each cluster. However, reviewing the results of applying the actions associated with the constituent properties of each cluster describes the formative objectives for strengthening that cluster's quality.

Strengthening ***divisibility*** results from strengthening ***stepwise refinement*** and ***modularization*** – which in turn means developing the design elements through an ***unfolding***, elaborative process while employing modules as a fundamental element of construction.

Strengthening ***factorability*** results from strengthening ***cohesion*** and ***encapsulation*** – which in turn means distinguishing and separating each primitive element minimizing cou-

pling between components while defining a contractual interface for each to hide / protect its implementation and facilitate its cooperation with other elements.

Strengthening ***constructibility*** results from strengthening ***composition of function*** and ***scale*** – which in turn means exploiting the opportunity to produce ***choices*** from the combination of existing ***choices*** that retain a relevance in the stakeholders' perception as deriving directly from their understanding of the ***wholeness*** of their intentions, a sense that the parts naturally subdivide and yet, naturally recombine to meet their needs.

Strengthening ***confidence*** results from strengthening ***correctness*** and ***user friendliness*** – which in turn means aligning the ***choice*** in appropriate relationship to others and pursuing relevance, completeness, clarity and conciseness in the rendered choice while accommodating the stakeholders' (users') sense of conformance with their belief of the ***choice***'s purpose and function.

Strengthening ***predictability*** results from strengthening ***patterns*** and ***reliability*** – which in turn means discerning similarities among ***choice***'s that may be repeated to promote the stakeholders' sense that an approach or feature is familiar and consistent which further contributes to their sense of trust in the structure and function of the ***choice*** as "tried and true."

Strengthening ***usability*** results from strengthening ***transparency*** and ***programmability*** – which in turn means choosing ***choice*** features that expose rather than obscure the antecedent intentions so that system functions are "self-evident" in their role contributing to the users' problem-solving approach while at the same time providing a degree of flexibility such that the ***choice*** can be adapted to variations in the approach.

Strengthening ***intuitiveness*** results from strengthening ***identity*** and ***elegance*** – which in turn means unifying the ***choice***'s representation with the intention it addresses such that the two fuse in the mind of the stakeholder. When this alignment between requirement and representation (implementation) occurs seamlessly the naturalness of the fit gives the impression that the ***choice*** *is* the intention.

Strengthening ***scalability*** results from strengthening ***constructibility*** and ***factorability*** – which in turn means recognizing fundamental concepts that may be replicated and combined to render the stakeholders' conception of their intentions; and then by mapping those concepts to "building blocks" (***choices***) that may be combined and arranged to expand system size both in terms of capacity and complexity.

Strengthening ***fidelity*** results from strengthening ***confidence*** and ***extensibility*** – which in turn means achieving strong alignment of ***choices*** with stakeholder intentions now, but looking forward and preparing a structure and function of the ***choice*** that anticipates the inevitable realignment that must occur with the evolution of the context and priorities.

Strengthening ***effectiveness*** results from strengthening ***intuitiveness*** and ***usability*** – which means shaping ***choices*** that both take advantage of the stakeholders' instincts for problem solving and further reinforce those instincts by presenting models with structure and functionality that mirror the stakeholders' perceptions of their needs.

Strengthening ***robustness*** results from strengthening ***divisibility*** and ***scalability*** – which in turn means successfully separating concerns among the ***choices*** clarifying the individual elements of ***essence*** that define the criteria of feasibility in the stakeholders' intentions while carefully formulating a resource of building blocks addressing those elements that may be combined and recombined to satisfy the need for capacity.

Strengthening ***sustainability*** results from strengthening ***fidelity*** and ***predictability*** – which means absorbing change gracefully without damaging the faithful alignment already attained between extant ***choices*** and stakeholder intentions.

Strengthening ***vitality*** results from strengthening ***effectiveness*** and ***sustainability*** – which means ***choices*** that satisfy stakeholder requirements and providing an accessibility to those ***choices*** that is understandable and obvious while maintaining a organization of structure and behavior responsive to an ***unfolding*** environment of stakeholder intentions.

When a system of ***choices*** exhibits strength across the confluence of design qualities described by ***robustness*** and ***vitality***, it is a ***thriving system*** – ***thriving*** as in beyond existing, beyond surviving, beyond functional, beyond acceptable. It thrives because it *promotes* the ***unfolding*** not only of the ***choices*** that support and align with the stakeholders' intentions, but it actually *promotes* the unfolding of those intentions through the conceptual clarity and efficiency with which it represents them. *Thriving Systems Theory* represents the symbiosis that *great design* has with an authentic requirement. The challenge of great design spans two "fields" of perception: a design with strength in all the qualities enumerated above, but inexorably dependent on an authenticated representation of stakeholder intentions. Successful design must meet both "fields" of challenge.

7 The Consequence of Thriving Systems Theory

The fifteen ***choice*** properties are interesting because they offer a taxonomy of observable characteristics that parse the resonance an observer experiences between any given ***choice*** and that which they conceive the ***choice*** should reflect. ***Choice*** properties provide two opportunities for understanding design quality: in assessing existing ***choices*** and in forming (or reforming) new ***choices***.

Indeed several of the ***choice*** properties are commonly part of the systems architects' vocabulary: ***modularization***, ***cohesion***, ***encapsulation*** and ***composition of function***. At the same time other ***choice*** properties are not so common: ***correctness***, ***user friendliness***, ***patterns***, ***reliability***, ***identity*** and ***elegance***. This apparent dichotomy is explained by the fact that systems architecture is more often focused almost exclusively on the soundness of product structure rather than on its faithful reflection of the stakeholder intentions. The named property clusters form an analogous dichotomy between sound structure and representation faithfulness, respectively: ***divisibility***, ***factorability***, ***constructibility*** and ***scalability*** underlying ***robustness*** versus ***confidence***, ***predictability***, ***usability***, ***intuitiveness***, ***fidelity***, ***effectiveness*** and ***sustainability*** underlying ***vitality***. (See Figure 17 below.)

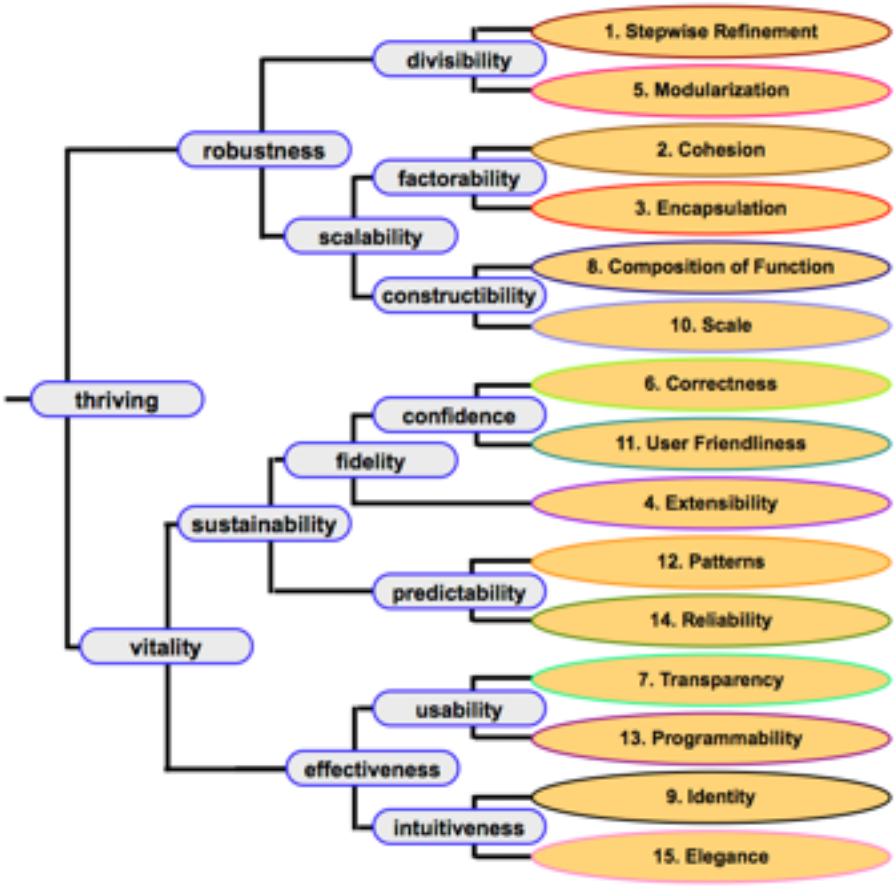

Figure 17 Labeled Cluster Tree Branches

As separate as sound structure and representation faithfulness may appear they interact just as the underlying properties interact. The quality of sound structure emerges from the building blocks that are designed to fit together in various ways giving flexibility and versatility to the built system. The economy of effort that the design of the blocks provides affects the costs (time, money, effort) of the build, but also affects the stakeholders' interpretation of their own intentions. When a structure *can* be built it is natural to *want* to find a reason for building it.

That may explain the success of open source systems to some degree where the intentions of the consumers are in large part motivated by what the open source system is designed to do rather than being grounded first in their "preconceived" stakeholder intentions. In open source (Apache, MySQL, etc.) or proprietary vendor product situations (e.g. Oracle, Microsoft Office, Sun Java, etc.) it is as much the system design shaping the stakeholder intentions as anything else. "If you build it, they will come." Achieving structural and representational harmony is the interplay of both sides of the divide between built system (the side where the ***choices*** of the system are devised to satisfy the stakeholder requirements) and the other side, the side where

the stakeholder intentions are conceived and expressed through requirements. The degree to which the "models" on either side of the divide reinforce one another and are compatible determines the success or failure of the resulting system, the degree of satisfaction that stakeholders experience.

The consequence of the coincidental, yet apparently dichotomous, presence of structural and representational design quality elements argues that great system design is not the perfect juxtaposition of elements in the product of a design process, but rather the effective juxtaposition of the ***choices*** in the design product with the ***essence*** found in the stakeholders' combined understanding of the requirements, their intentions. This latter relationship draws into aspect not only the effective reflection of the status quo, but a comprehensive understanding of the stakeholders' environment, its ecology and the prospects for the evolution of both. Exploring this consequence and the infusion of *Thriving Systems Theory* into systems development is the focus of part two of this monograph.

8 Historical Reverberations

Some two thousand and thirty years ago, Vitruvius set down ten books defining the discipline of physical architecture as it was understood in the Roman universe.[11] As the only surviving treatise on architecture from those times, it provides a fascinating portal into the conceptualization of design in his lifetime. His treatise set forth three driving principles of valuable architecture: *firmitas* (strength), *utilitas* (functionality) and *venustas* (beauty). Although steeped in the culture and spirituality of that ancient time, Vitruvius's principles have echoed across the ages, as in DaVinci's Vitruvian Man and the architecture of the Renaissance, Baroque and Neoclassicist periods. And those principles are echoed here in ***choice*** properties and property clusters. The ***robustness*** and ***vitality*** clusters derived in this writing bear a striking congruence with Vitruvius's expression of *strength* and *functionality*. And when ***robustness*** and ***vitality*** are combined to form the cluster ***thriving*** – that composition embodies Vitruvius's expression of *beauty*.

1 Waguespack LJ Jr, "Hammers, Nails, Windows, Doors and Teaching Great Design," *Information Systems Education Journal*, 6 (45). http://isedj.org/6/45/. ISSN: 1545-679X, 2008. (A preliminary version appears in *The Proceedings of ISECON 2007*: §3324. ISSN: 1542-7382.)

2 Alexander C, The Nature of Order An Essay on the Art of Building and the Nature of the Universe: Book I - The Phenomenon of Life, Berkeley, California: The Center for Environmental Structure, 2002, p 237.

3 Ibid, p 238.

4 Aldenderfer MS and Blashfield RK, Cluster Analysis, Beverly Hills, Sage Publications, 1984.

5 Anderberg MR, Cluster Analysis for Applications, New York, NY, Academic Press, 1973.

6 Jain AK and Dubes RC, Algorithms for Clustering Data, Upper Saddle River, NJ, Prentice-Hall, 1988.

7 In preparing this text a wide variety of sources were searched to find "commonly accepted" definitions for the several familiar terms used to name the clusters. Surprisingly there was little definitive agreement among the sources. The reader may find that the specific characterizations of these terms may challenge some preconceptions. This may be particularly true with the scope of the meanings presented here.

8 McKean E (editor), The New Oxford American Dictionary, Second Edition, 2051 pages, May 2005, Oxford University Press.

9 Since the clustering algorithm performs pair-wise aggregation the odd number of properties necessarily left an "odd man out!"

10 Waguespack LJ Jr, "Modeling Actions Strengthening Life," Designing and Building Thriving Systems project report, Bentley University, Waltham, MA, March 2010.

11 Rowland D and Howe TN, Vitruvius. Ten Books on Architecture. Cambridge University Press, Cambridge 1999.