

Investigating Relationships and Semantic Sets amongst System Lifecycle Properties (Ilities)

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Swiss F/A-18 Experience



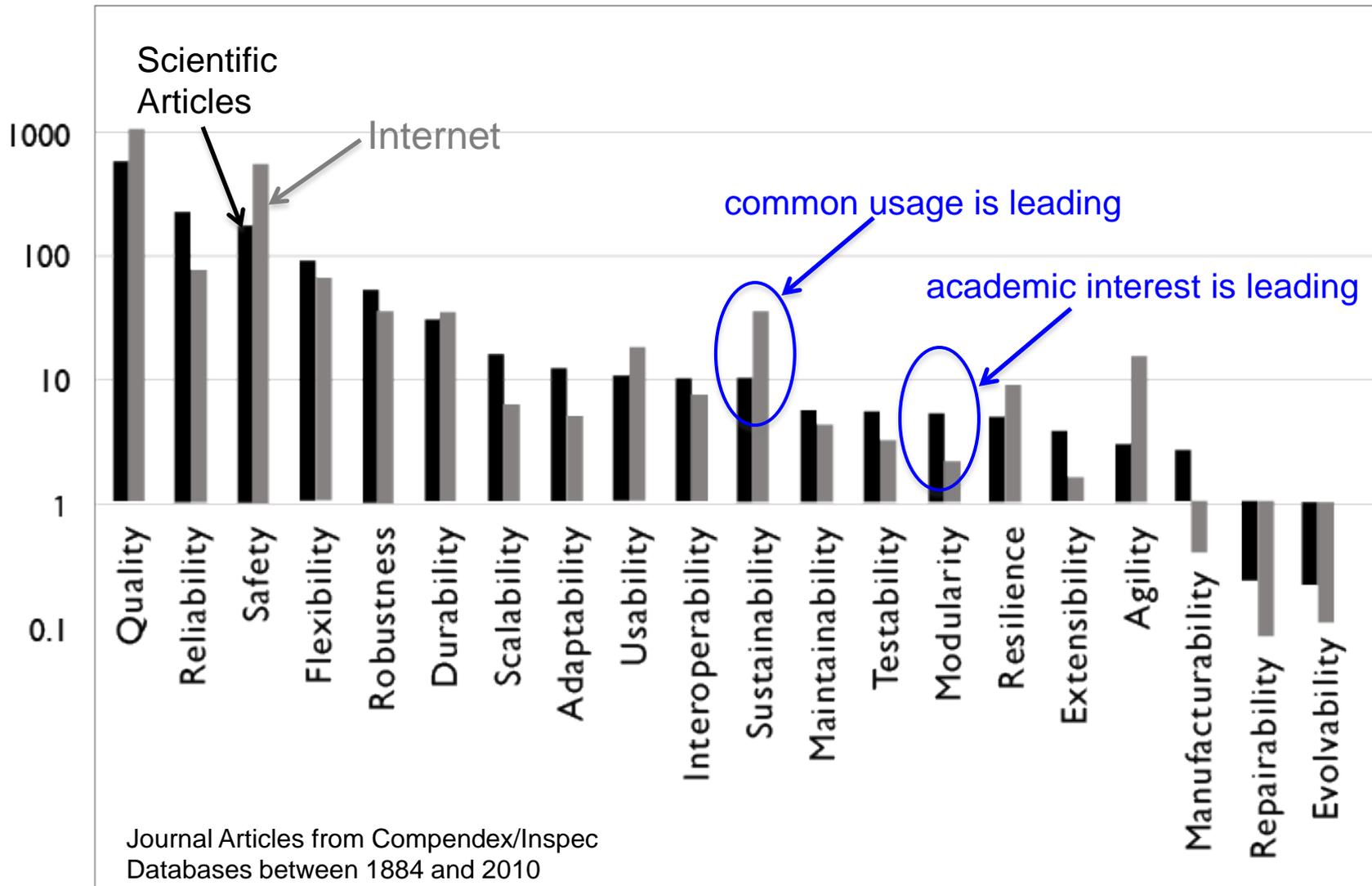
Delft New Train Station Project



What are the “Illities”?

- Complex Engineering Systems live for decades or centuries
- The *ilities* are desired properties of systems, such as flexibility or maintainability (usually but not always ending in “ility”) that often manifest themselves after a system has been put to initial use. These properties are not the primary functional requirements of a system’s performance, but typically concern wider system impacts with respect to time and stakeholders than embodied in those primary functional requirements
 - Most research has looked at the Illities – one at a time.
- Research Questions:
 - What are the most prevalent or most important (top 20) Iilities in the scientific literature and in common use?
 - What are the relationships amongst Iilities? Do they form semantic sets?
 - Can we use this information for better system design?
- Approach:
 - Method 1: Prevalence Analysis using Literature/Web Survey
 - Method 2: Human Cognitive Experiments using Hierarchy Exercise

■ Journal Articles (thousands) ■ Google Hits (millions)

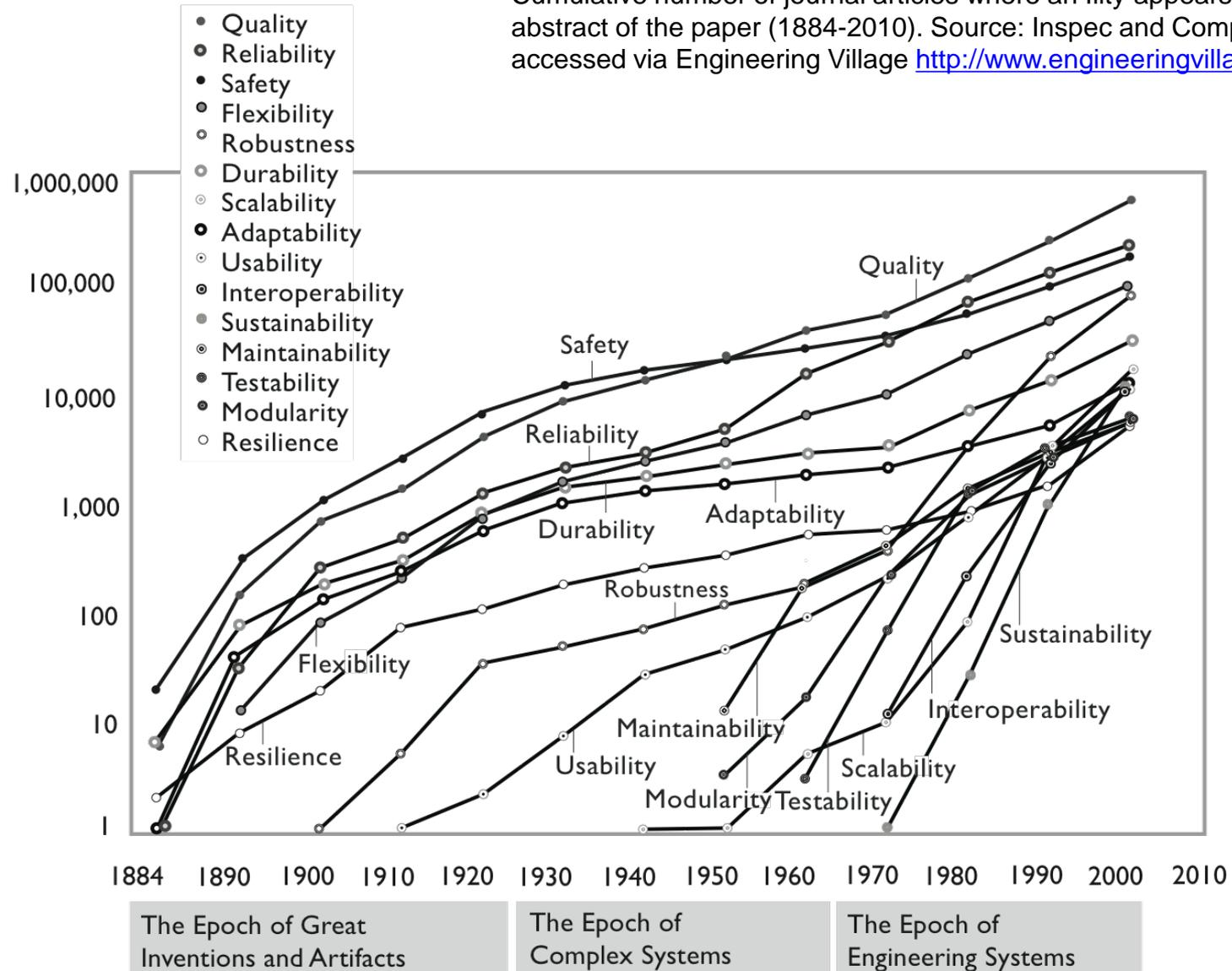


Cumulative Research in Ilities over Time

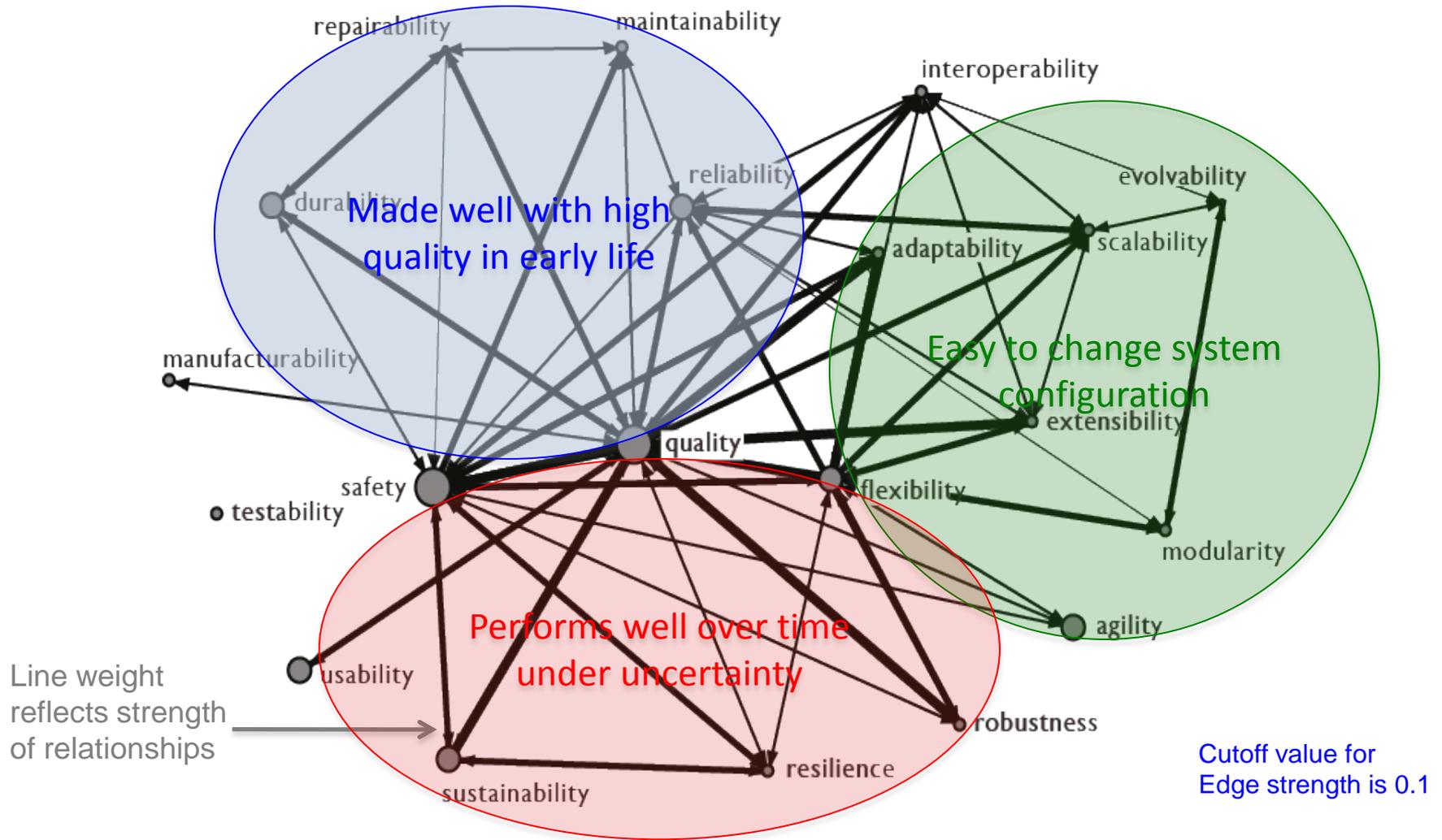
Massachusetts Institute of Technology
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Cumulative number of journal articles where an Ility appears in the title or abstract of the paper (1884-2010). Source: Inspec and Compendex, accessed via Engineering Village <http://www.engineeringvillage.com>

Fig. 4-2



1: Relationships amongst the Illities



Network structure with classical engineering illities at the core and newer emerging ones at the periphery based on co-occurrence

2: Human Experiments with Hierarchy

- Humans have deep, but possibly varied, semantic notions of a hierarchy ofilities
 - Elicit means-ends-hierarchy through direct elicitation and group discussion and interviews
 - Two rounds
 - **Round 1:** 4 groups with 2-4 members each. Find parent-child relationships. Describe means → ends relations
 - Interviews
 - **Round 2:** Revise group findings based on inputs from other groups at the end of round 1
 - **Constructed combined means-ends hierarchy**

12 experienced system designers and researchers were presented with a list of 15 ilities similar to this one

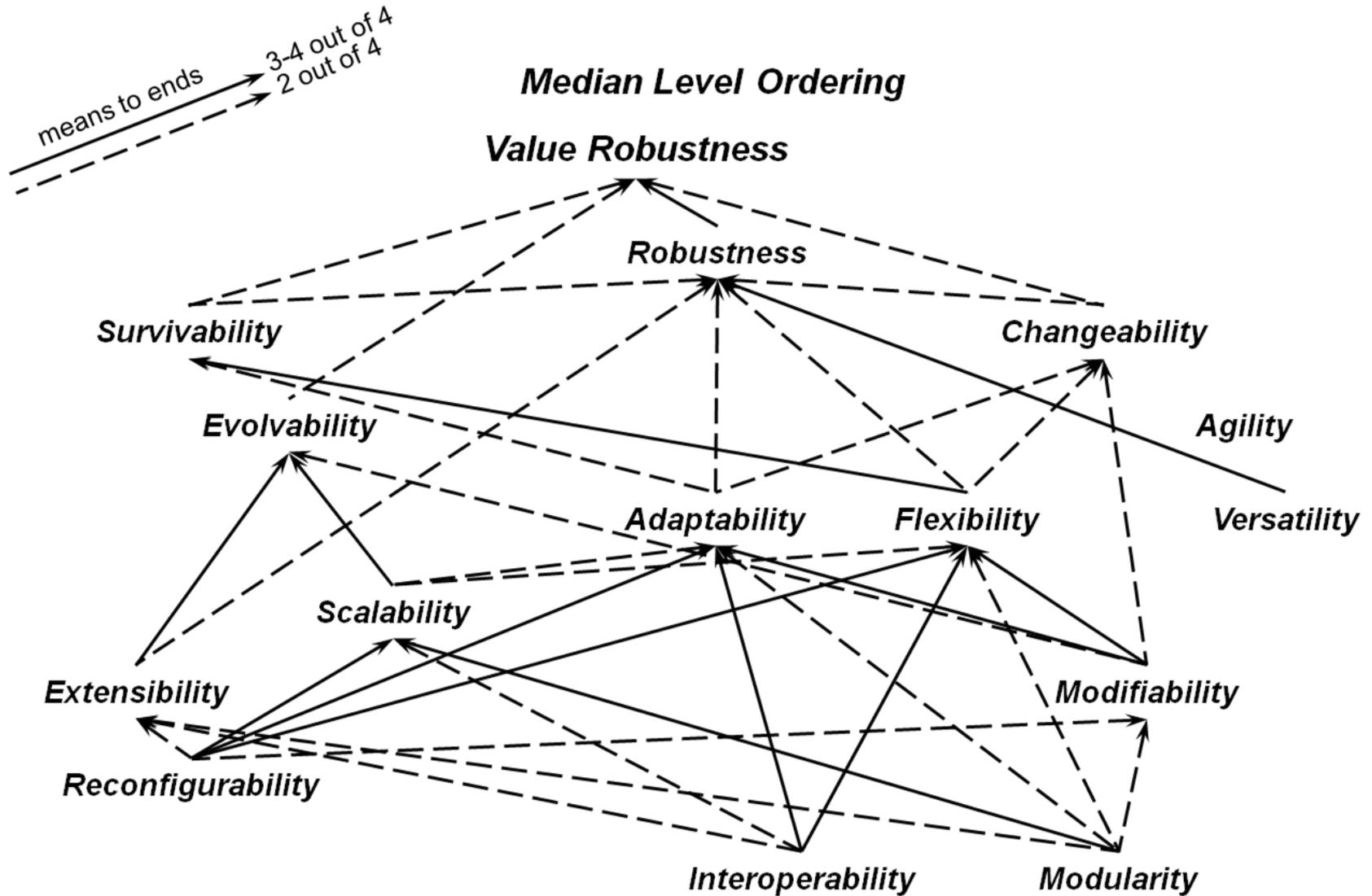


Ility Name	Definition (“ability of a system...”)
adaptability	to be changed by a system-internal change agent with intent
agility	to change in a timely fashion
changeability	to alter its operations or form, and consequently possibly its function, at an acceptable level of resources
evolvability	design to be inherited and changed across generations (over time)
extensibility	to accommodate new features after design
flexibility	to be changed by a system-external change agent with intent
interoperability	to effectively interact with other systems
modifiability	to change the current set of specified system parameters
modularity	degree to which a system is composed of modules (not an ability-type ility)
reconfigurability	to change its component arrangement and links reversibly
robustness	to maintain its level and/or set of specified parameters in the context of changing system external and internal forces
scalability	to change the current level of a specified system parameter
survivability	to minimize the impact of a finite duration disturbance on value delivery
value robustness	to maintain value delivery in spite of changes in needs or context
versatility	to satisfy diverse needs for the system without having to change form (measure of latent value)



What is their relationship?
Do they form a hierarchy?

Combined Means to Ends Hierarchy



- Lifecycle properties (ilities) are critical for long term value
- Despite differences, the two methods led to similar high-level conclusions regarding the relationships amongst ilities:
 - Some ilities are closely related to each other and **form semantic sets** that are tied together by both **synonymy and polysemy relationships**.
 - System value is heavily driven by the ability of a system to be **robust** (despite internal and exogenous disturbances), **flexible or changeable** and **resilient or survivable** over time.
 - A **hierarchy of ilities with two or three levels appears to exist** whereby some ilities, such as modularity and interoperability appear at lower levels and serve as enablers of higher level ilities.
- Future work will apply both methods to larger sets of ilities, with larger groups of test subjects and will use consistent sets of ilities