DESIGNING INFORMING SYSTEMS: WHAT RESEARCH TELLS US

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Outline

- Designing Informing Systems
- Design Science Research (DSR)
  – Concepts, Models, and Guidelines
  – Three Cycles of Design Activities
- Positioning and Presenting DSR
  – The Knowledge Contribution Matrix
- A Fitness/Utility Model of DSR

Informing Systems

- Design Science is a creative research paradigm that informs multiple audiences:
  - Researchers: Design principles and mid-range design theories
  - Practitioners: Artifact (product and process) instantiations
  - Managers: Work and application system controls
  - Government: Economic and social welfare

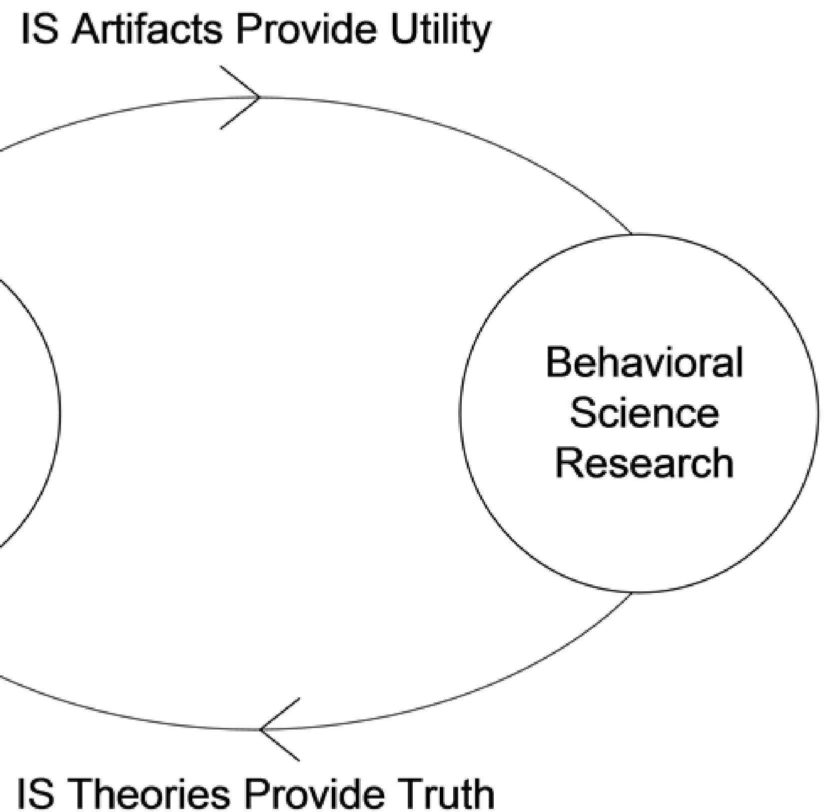
Design Science Research

- Sciences of the Artificial, 3rd Ed. – Simon 1996
  - A Problem Solving Paradigm
  - The Creation of Innovative Artifacts to Solve Real Problems
- Design in Other Fields – Long Histories
  - Engineering, Architecture, Art
  - Role of Creativity in Design
- DSR in Information Systems
  - A. Hevner, S. March, J. Park, and S. Ram, "Design Science Research in Information Systems," Management Information Systems Quarterly, Vol. 28, No. 1, March 2004, pp. 75-105.
  - S. Gregor and D. Jones, "The Anatomy of a Design Theory," Journal of the Association of Information Systems, (8:5), 2007, pp. 312-335.

Research in Information Systems

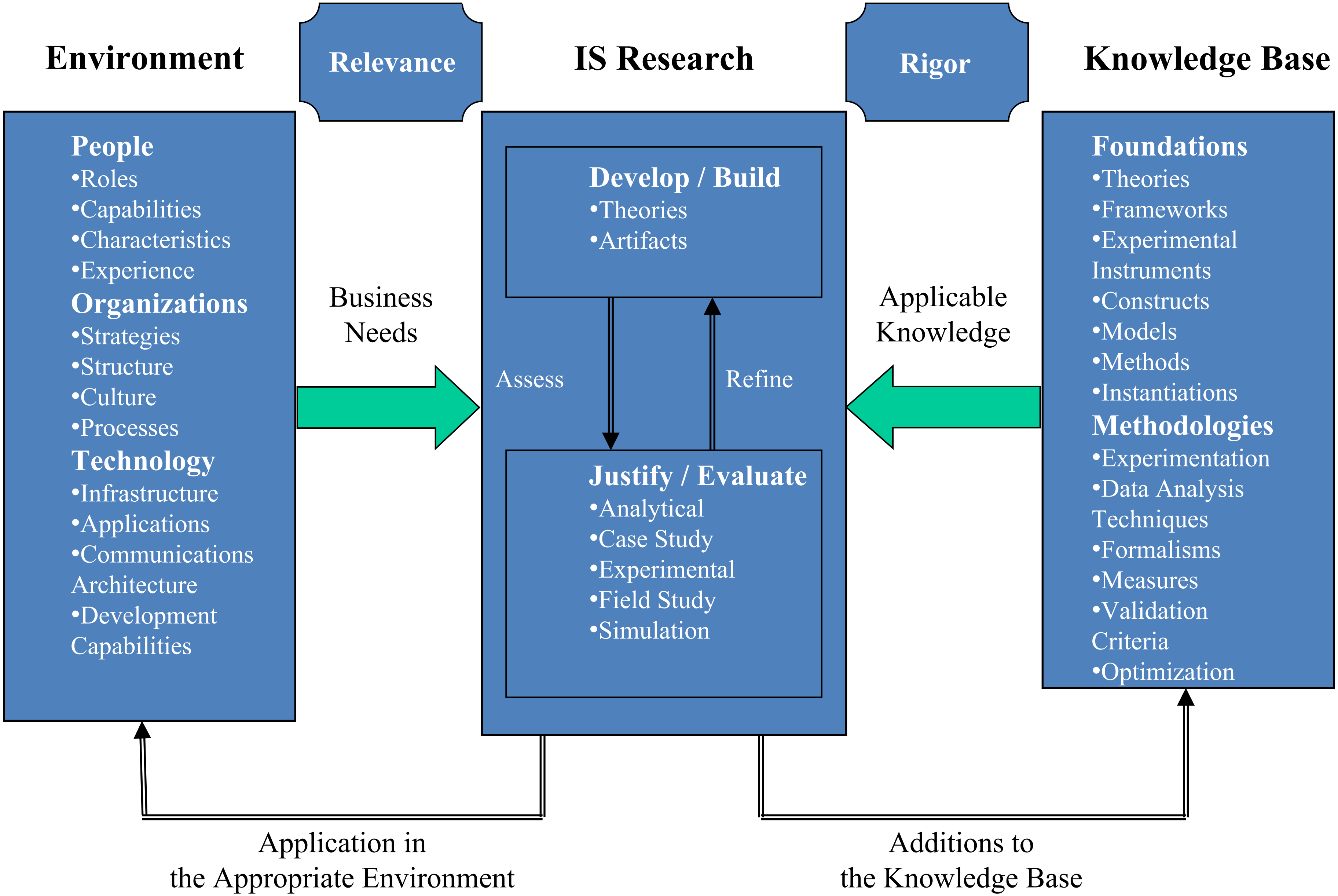
- Information Systems (IS) are complex, artificial, and purposefully designed.
- IS are composed of people, structures, technologies, and work systems.
- Two Basic IS Research Paradigms
  - Behavioral Research – Goal is Truth
  - Design Research – Goal is Utility (and Truth!)

IS Research Cycle



Design Thinking

- Design is an Artifact (Noun)
  - Constructs
  - Models
  - Methods
  - Instantiations
- Design is a Process (Verb)
  - Build
  - Evaluate
- Design is a Wicked Problem
  - Unstable Requirements and Constraints
  - Complex Interactions among Subcomponents of Problem and resulting Subcomponents of Solution
  - Inherent Flexibility to Change Artifacts and Processes
  - Dependence on Human Cognitive Abilities - Creativity
  - Dependence on Human Social Abilities - Teamwork

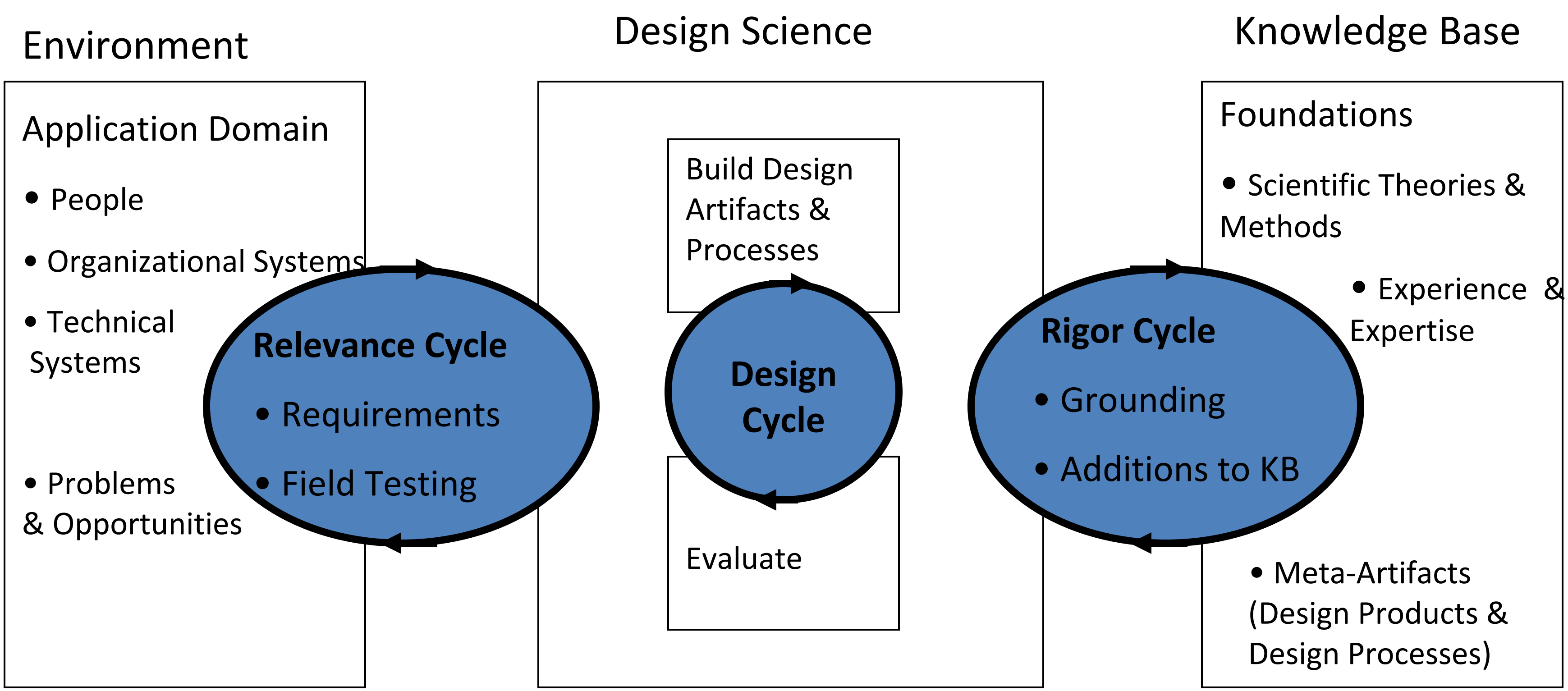

Environment
Relevance
IS Research
Rigor
Knowledge Base
People
•Roles
•Capabilities
•Characteristics
•Experience
Organizations
•Strategies
•Structure
•Culture
•Processes
Technology
•Infrastructure
•Applications
•Communications Architecture
•Development Capabilities
Business Needs
Develop / Build
•Theories
•Artifacts
Assess
Refine
Justify / Evaluate
•Analytical
•Case Study
•Experimental
•Field Study
•Simulation
Applicable Knowledge
Foundations
•Theories
•Frameworks
•Experimental Instruments
•Constructs
•Models
•Methods
•Instantiations
Methodologies
•Experimentation
•Data Analysis Techniques
•Formalisms
•Measures
•Validation Criteria
•Optimization
Application in the Appropriate Environment
Additions to the Knowledge Base

Design Research Guidelines

Guideline	Description
Guideline 1: Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

Three Cycles of DSR

Ref: A. Hevner, "A Three Cycle View of Design Science Research," *Scandinavian Journal of Information Systems*, Vol. 19, No. 2, 2007, pp. 87-92.



The Relevance Cycle

- The Application Domain initiates Design Research with:
  - Research requirements (e.g., opportunity, problem, potentiality)
  - Acceptance criteria for evaluation of design artifact in application domain
- Field Testing of Research Results
  - Does the design artifact improve the environment?
  - How is the improvement measured?
  - Field testing methods might include Action Research or Controlled Experiments in actual environments.
- Iterate Relevance Cycle as needed
  - Artifact has deficiencies in behaviors or qualities
  - Restatement of research requirements
  - Feedback into research from field testing evaluation

The Rigor Cycle

- Design Research Knowledge Base
  - Design Theories
  - Engineering Methods
  - Experiences and Expertise
  - Existing Design Artifacts and Processes
- Research Rigor is predicated on the researcher's skilled selection and application of appropriate theories and methods for constructing and evaluating the artifact.
- Additions to the Knowledge Base:
  - Extensions to theories and methods
  - New experiences and expertise
  - New artifacts and design processes

Design Cycle

- Rapid iteration of Build and Evaluate activities
  - The hard work of design research (1% inspiration and 99% perspiration - Edison)
- Build – Create and Refine artifact design as both product (noun) and process (verb)
- Evaluation – Rigorous, scientific study of artifact in laboratory or controlled environment
- Continue Design Cycle until:
  - Artifact ready for field test in Application Environment
  - New knowledge appropriate for inclusion in Knowledge Base

Useful Knowledge

Ω – Descriptive Knowledge

- **Phenomena** (Natural, Artificial, Human)
  - Observations
  - Classification
  - Measurement
  - Cataloging
- **Sense-making**
  - Natural Laws
  - Regularities
  - Principles
  - Patterns
  - Theories

Λ – Prescriptive Knowledge

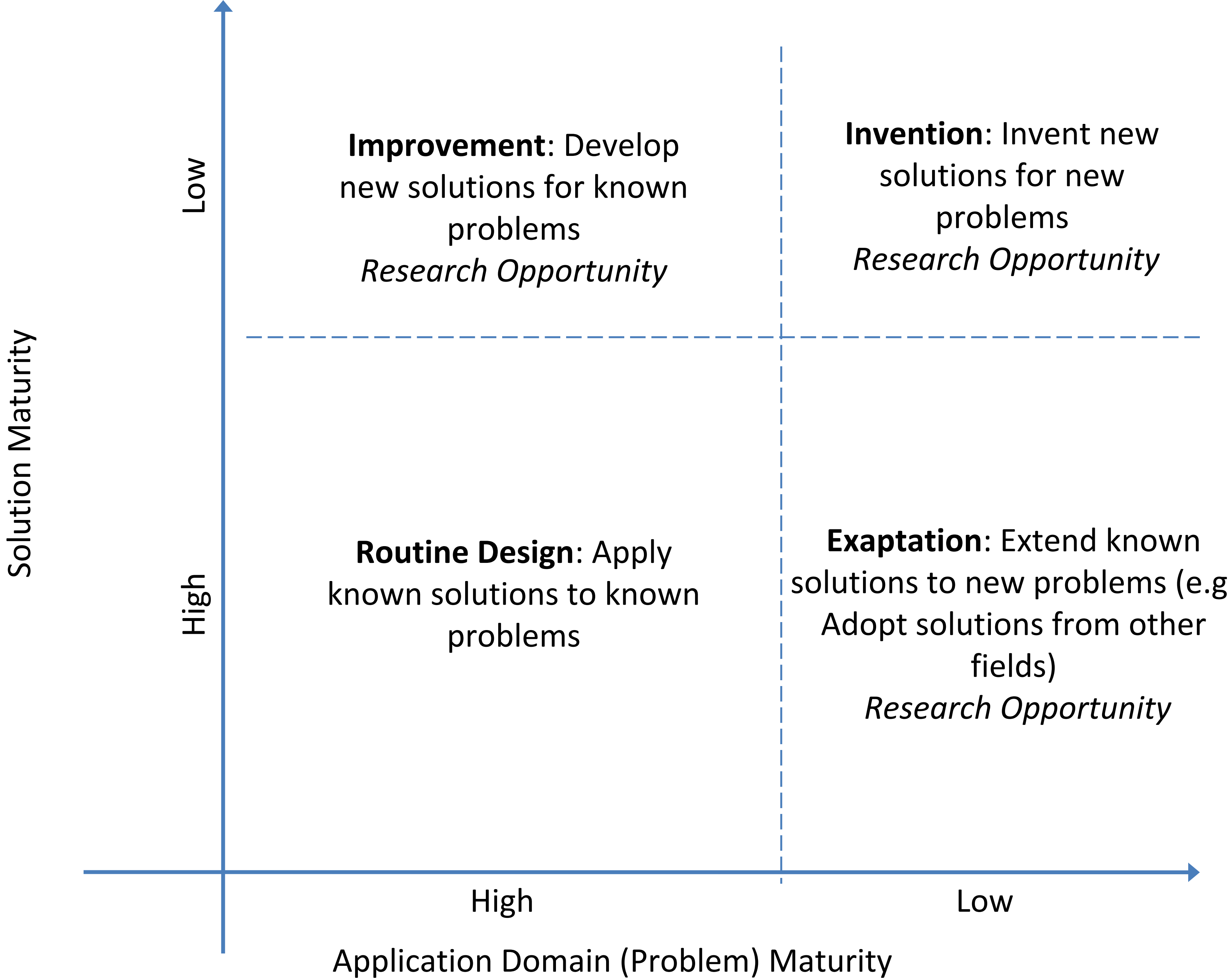
- **Artifacts**
  - Constructs
    - Concepts
    - Symbols
  - Models
    - Representation
    - Semantics/Syntax
  - Methods
    - Algorithms
    - Techniques
  - Instantiations
    - Systems
    - Products/Processes
- **Design Theory**

The Artifact as Knowledge

	Contribution type	**Examples**
More abstract, complete, and mature knowledge	Level 3. Well-developed design theory about embedded phenomena	Design theories (mid-range and grand theories)
↕ ↕ ↕ ↕	Level 2. Nascent design theory – knowledge as operational principles/architecture	Constructs, methods, models, design principles, technological rules.
More specific, limited, and less mature knowledge	Level 1. Situated implementation of artifact	Instantiations (software products or implemented methods)

DSR Knowledge Contribution Framework

- A Guideline for Positioning DSR with respect to Knowledge Contribution
- Two dimensions:
  – Maturity of Application Domain (Opportunities/ Problems)
  – Maturity of Solutions (Existing Artifacts)
- Difficulties:
  – Subjectivity – where to draw the lines
  – Everything builds on something else, nothing entirely new


Improvement: Develop new solutions for known problems
Research Opportunity
Invention: Invent new solutions for new problems
Research Opportunity
Routine Design: Apply known solutions to known problems
Exaptation: Extend known solutions to new problems (e.g. Adopt solutions from other fields)
Research Opportunity
Solution Maturity
Low
High
High
Low
Application Domain (Problem) Maturity

Invention Quadrant

- An invention is a radical breakthrough; a departure from accepted ways of thinking and doing
- DSR projects in which little understanding of the problem context exists and no effective artifacts are available as solutions
- Research contributions are novel artifacts or inventions
  - Level 1 artifacts
- The newness of artifact makes this research difficult to publish
  - Insufficiently grounded in theory
  - Design is incomplete and not fully evaluated
  - Understanding is insufficient to provide new contribution to theory via the design

Improvement Quadrant

- An improvement is a better artifact solution in the form of more efficient and effective products, processes, services, technologies, or ideas
- DSR projects in which the problem context is mature but there is a great need for more effective artifacts as solutions
- Improvement DSR is judged by:
  - Clearly grounding, representing, and communicating the new artifact design
  - Convincing evaluation providing evidence of improvements over current solutions
- All levels of artifact knowledge contribution can be made

Exaptation Quadrant

- An exaptation is the expropriation of an artifact in one field to solve problems in another field
- DSR projects in which the problem context is not well understood but there exist mature artifacts in other fields that can be exapted as effective solutions
- Exaptation DSR is judged by:
  – Clearly grounding, representing, and communicating the exapted artifact design
  – Convincing evaluation providing evidence of how well the new artifact solves the given problem
- All levels of artifact knowledge contribution can be made

Routine Design Quadrant

- Professional design or system building to be distinguished from DSR
- However, evolving or best practices may be observed and documented in “extractive case study” work (Van Aken)
  - Study of best practices in routine design may lead to empirical generalization
  - Example – Davenport’s observation of BPR (Davenport & Short SMR 1990)

A Fitness-Utility Model for DSR

- Rethinking the Dependent Variable in DSR
- How can we make the results of DSR (e.g., artifacts, design theories) more sustainable ?
- T.G. Gill and A. Hevner, “A Fitness-Utility Model for Design Science Research,” ACM Transactions on Management Information Systems, 2013.
  - DESRIST 2011 Herbert Simon Best Paper Award

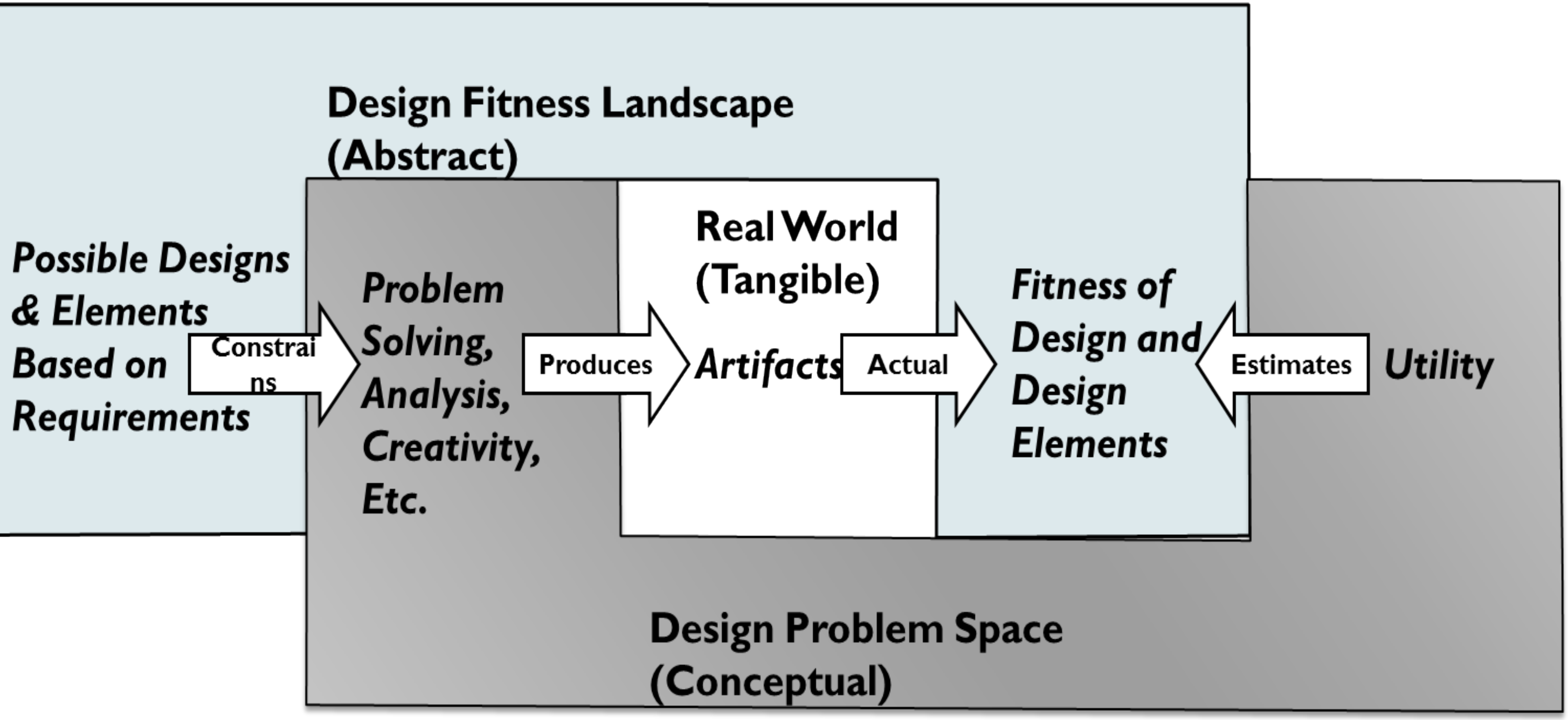
The DSR Dependent Variable

- Usefulness
  - Aligns with current MIS research paradigms
  - Well understood in academia and practice
  - Measurable with current instruments
  - Why look elsewhere?
- Extend the search for DSR dependent variables
  - Explore ‘goodness’ ideas from other fields
  - Design Fitness (Biology)
  - Design Utility (Economics)
- Goal is to complement and extend current DSR thinking

Design Fitness Landscape

- In evolutionary biology, the term fitness landscape is used to describe a functional mapping between some abstract representation of an entity—such as a listing of attributes and traits or, even, as a DNA sequence—and its associated fitness that captures the entity's ability to survive, reproduce, and evolve from generation to generation.
- This concept can be generalized to design situations, whereby a design is represented as a collection of traits and its fitness represents the likelihood that all or some pieces of the design (which we informally refer to as design DNA) will continue to exist and evolve from generation to generation.

Design Process Elements



Design Fitness

- Definition 1 – The fitness of an organism describes its ability to survive as a high level of capacity over time.
- Definition 2 – The fitness of an organism describes its ability to replicate and evolve over successive generations.
- Two definitions are not correlated
  - Empirical data refutes Malthus' proposition
- Focus on Design Fitness as Definition 2

Design Utility

- IS Artifact Utility typically means Usefulness
  - Efficacy to perform task
  - Ease of Use, Ease of Learning
  - Cost-Benefit vis-à-vis other artifacts
- Economic Utility involves a complex Utility Function used to rank alternatives in order to Maximize Utility
  - Utility = u(x1, x2, …, xN)
- Utility Characteristics
  - Income and consumption
  - Expectations and goals
  - Social context
  - Utility Function will vary for different application contexts

Fitness-Utility Model applied to DSR

- A design artifact has an associated fitness that designers estimate via design utility functions
- Artifacts perform two roles in the design search process:
  - They provide evidence that a particular design candidate is feasible, has value, can be effectively represented, and can be built. This serves to help us better estimate the shape of the design fitness landscape
  - They provide a mechanism for communication between designers and for retaining information that might be imperfectly stored during the design process
- Intentionality – Creative guidance that differentiates ICT design/evolution from human evolution
- Search on the design space changes the design space by modifying the utility function of design fitness

Re-Framing DSR with Fitness-Utility

- The goal of DSR is to impact the design space so as to ensure a continuous flow of high fitness design artifacts. This impact is accomplished in two ways: through the production of artifacts that demonstrate the feasibility of new designs and through improving the utility function that we use to assess the fitness of evaluation artifacts.

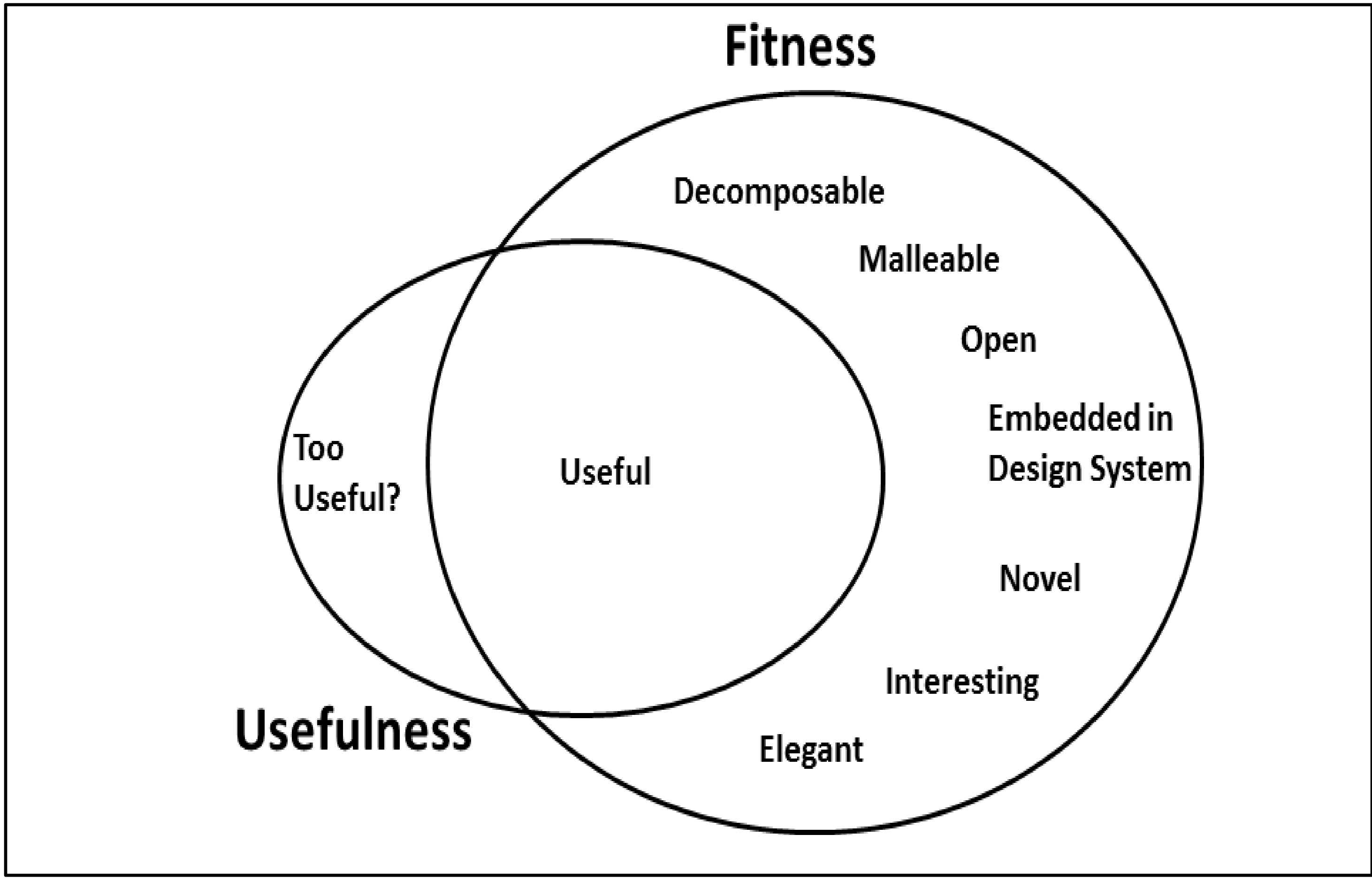
DSR Evaluation with Fitness-Utility

- As opposed to just Usefulness, the evaluation would be based on a more extensive and detailed utility function that estimates the evolutionary fitness of the artifact
- Utility Function Attributes:
  - Support the design's ability to evolve incrementally;
  - Encourage experimentation by users and other designers; and
  - Are effective memes, meaning that they contain ideas of a form that propagate and replicate.

Fitness Characteristics

Questions:

- How to measure the fitness characteristics?
- How to select appropriate characteristics for application environment?
- How to combine and weigh characteristics in utility function?
- How to evolve utility function as environment changes?



Designs That are Too Useful?

- Situations where a design artifact becomes so useful that it inhibits future design activity
- The tendency of organizations to stick with designs that have proven useful is a well-documented phenomenon known as the Innovator's Dilemma (Christensen, 1997)
  - Disk Drives
  - Printers
  - Mini-computers

Decomposable Designs

- Systems evolve from nearly decomposable subsystems (Simon, 1996)
- Decomposability supports:
  - Independence of modules
  - Information hiding
  - Maintenance and evolution of modules separately from whole system
  - Robustness
- Exemplar – Open Source Software

Malleable Designs

- The malleability of an artifact represents the degree to which it can be adapted by its users and respond to changing use/market environments
- Types of malleability
  - Customization
  - Exaptation
  - Integration
  - Extension

Open Designs

- Openness is the degree to which artifacts are open to inspection, modification, and reuse
- Open designs—particularly when also imbued with decomposability and malleability—encourage further design evolution by making it easier both to see how an artifact is constructed and to modify existing components of the artifact
- Exemplar – UNIX vs. LINUX

Embedded in a Design System

- We would expect design artifacts that are the product of a sustainable design system environment to evolve more rapidly than artifacts that are produced in a context where design is an unusual activity
- The particular purpose that such systems play is encouraging communication within and throughout the design process
- A design system can also manifest itself as a community of users and designers, providing contributors with intrinsic motivation to contribute

Design Novelty

- A design may be considered novel if it originates from an unexplored region of the design fitness landscape
- While a particular novel design may be less individually fit than existing counterparts, where the landscape is dynamic the fitness of the population as whole benefits from having a sub-population of designers seeking novelty for its own sake, thereby ensuring design diversity

Interesting Designs

- Designs are interesting when
  - An artifact may demonstrate unexpected emergent behaviors that are worthy of subsequent investigation and the creation of subsequent artifacts
  - An artifact may be constructed in an unexpected way that intrigues other designers or design researchers
- The benefit of an interesting design is its propensity to diffuse—to be an effective meme

Design Elegance

- The Form of an artifact describes aesthetic elements such as appearance that do not necessarily serve a useful purpose, yet nevertheless increase the user's utility
- Like quality, elegance is hard to define in a rigorous manner and yet characteristics that might be associated with it—such as compactness, simplicity, transparency of use, transparency of behavior, clarity of representation—can all lead to designs that invite surprise, delight, imitation, and enhancement

Fitness Characteristics and Outcomes

Characteristic	Outcome
Decomposable Malleable Open	Promotes Modification (Mutation, Recombination)
Embedded in Design System	Promotes Quality, Consistency, Motivation
Novel	Promotes Diversity
Interesting	Promotes Diffusion
Elegant	Promotes Longevity

Conclusions

- The Fitness-Utility Model of DSR provides a new approach for viewing the building and evaluating of design artifacts
- Design characteristics beyond usefulness are important in rapidly changing application environments
- Future Research
  - Empirical studies evaluating utility functions in context and for general applications
  - Case studies of historical designs based on fitness-utility
  - Adapting Evolutionary Economics concepts to DSR