# ARCHITECTURE (DISAMBIGUATION): MAPPING A RESOURCE-BASED DESIGN PROCESS SYSTEM

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ABSTRACT: The process of designing and developing a building from conception to realization is indeed a sequence of creative and rigorous activities that combine the art of architecture with its scientific, engineering and financial aspects. Like other creative activities, the design process charts a path that is not always straightforward and, in fact, is likely to include multiple investigative sub-design procedures. Previous attempts to define the architectural design process have been vague and confusing to those in other disciplines. In this paper, we introduce a novel method of integrating system thinking into architectural design by mapping its processes in a standard modeling language. We present a decision-support framework using process mapping in order to incorporate sustainable building materials and resource reuse decisions into architectural design practice. We turned to other disciplines' knowledge bases, such as Business Information Technology (BIT), to develop a workflow system for the Design-Bid-Build (DBB) process. Mapping both current and the proposed design processes, including their activities, workflow, processes and decision nodes, was critical in defining roles, processes, and subsequent decisions. A literature review suggests that there are five types of design processes, which are somehow defined as linear, divisional, centralized, cyclical and investigative. However, no attempts have been made to map their processes using a systematic methodology. In this study, we utilized a qualitative methodology to capture the required knowledge from industry experts in resource-based design and then integrated our findings into a set of process maps to support the materials decisions of the architectural design team.

KEYWORDS: Architecture, System Thinking, Process Design, Resource-Based Design

## INTRODUCTION

When asked what architecture would be like in fifty years and what we could anticipate in the interim, Louis Kahn simply responded, “You cannot anticipate.” Then, he recalled his meeting with a group of General Electric executives who presented him with a depiction of what a “spacecraft” would look like fifty years hence. Kahn listened carefully, then responded with conviction, saying:

> It will not look like that, because if you know what a thing will look like fifty years from now, you could do it now. But you don't know because the way a thing will be fifty years from now is what it will be. (Kahn and Ngo 1998).

Kahn relayed this exchange to a group of architecture students at Rice University in the spring of 1968. Nearly fifty years have passed, and Kahn's statement remains valid today. Unlike Kahn, Ulrich Beck argued that the current era is defined by increasingly global problems, the mitigation of which ultimately require “anticipation” (Beck 1992). Whether we agree more with Kahn or with Beck, we realize the inherent difficulty in anticipating solutions for the complexities of the architectural discipline of tomorrow, especially given that we cannot even define our current design process. Like Kahn, we might not be able to completely anticipate the future of architecture in addressing increasingly global problems, but we might still find it valuable to attempt to redefine the complexity of our current architectural design process through its integration with common mapping language.

Literature searches for “architecture of complexity” led us to a foundational article with the same title, written in 1962 by Herbert Simon, then a professor of computer science and psychology at Carnegie Mellon University. His work focused on artificial intelligence, psychology, administration and economics. Simon, in his article, argued that the “architect” of complexity uses hierarchy as the central structural scheme of a system. He defined four aspects of the architecture of complexity, as illustrated in Fig. 1: frequency in the form of hierarchy; the relationship between structure and time; the dynamic properties of hierarchy; and, finally, the relationship between the complex system and its description (Simon 1962). In his later book, The Sciences of the Artificial, Simon defined design as the process by which “we devise courses of action aimed at changing existing situations into preferred ones” (Simon 1969). Simon's work, which heavily borrowed terminologies from the discipline of architecture (such as design, architect, architecture, structure and hierarchy), leaves us wondering precisely to which domain he was referring: architecture or computer science? In today's nomenclature, and as a result of the exponential growth of the information technology (IT) and information systems (IS) domains, understanding the terminology at it pertains to its underlying intent can be difficult.

In the last fifty years, the fields of artificial intelligence (AI), information technology and computer science have significantly repositioned these terms. For example, in IT, the term "architecture" refers to the system architecture; the term "design" refers to system design or process design, and "architect" refers to the system engineer. The enormous growth of big data, systems and information raises the following questions: How can architects cope with the increasing complexity of the built environment? How can architects move their design process from ambiguous to defined territories?

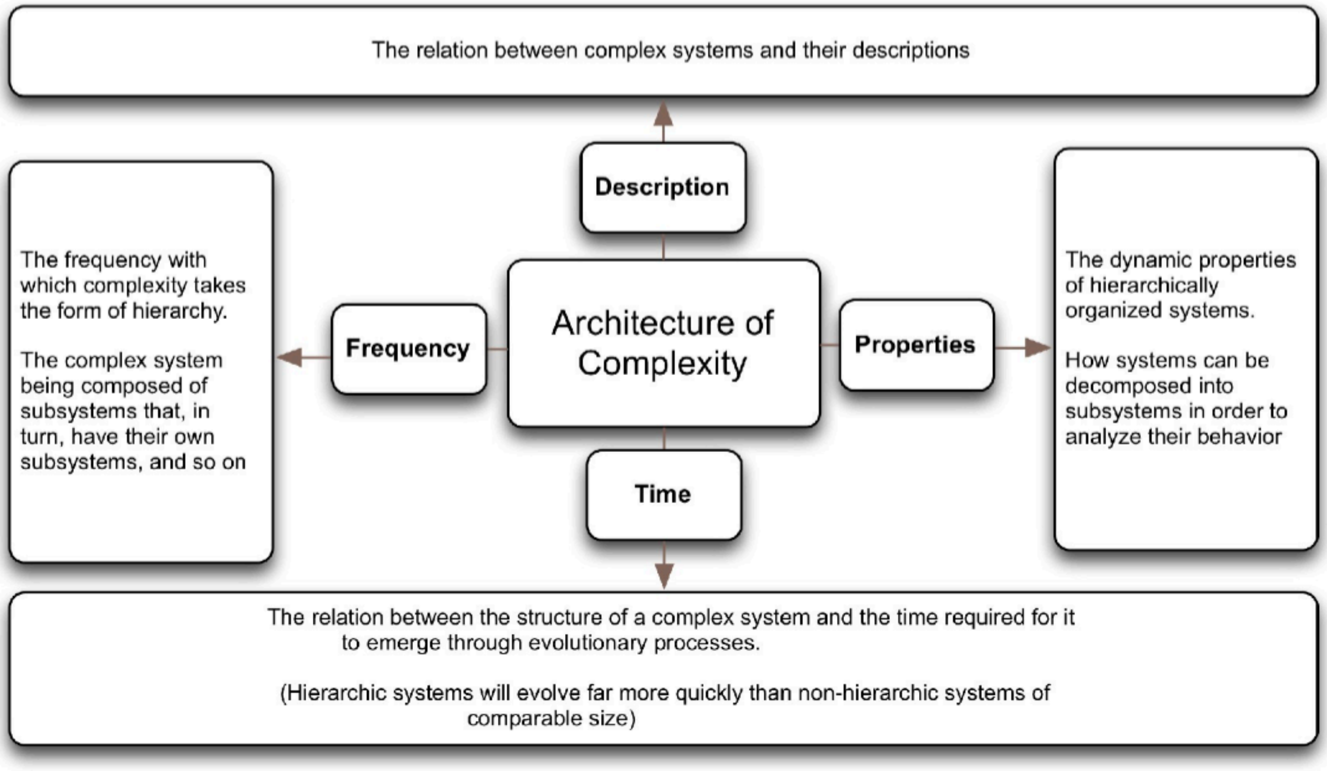

**Figure 1:** Simon's four aspects of the "architecture of complexity." Source: (Author 2017)

## 1.0. THE DESIGN PROCESS AND THE ARCHITECT

To answer these questions, we must begin by acknowledging that architecture, as a discipline, is not solely a commercial transaction, a service activity, or a manufacturing process. It is neither an engineered system nor a mathematical model. Although the general public might perceive that architectural practice is nothing but a business providing services and products, this misconception doesn't take into consideration the artistic, scientific and creative essence of architecture. In this paper, we refer to architecture as the "physical built environment," but also acknowledge the wide use of the term in reference to the components of a system for processing information. Inevitably, architects are now asked to navigate new knowledge domains that integrate the possibilities provided by the information age, and therefore, must seek to resolve the conflict that arises in the established practice of passing on traditional skills. As a result, the architect is under pressure to make buildings that are influenced by today's information age. A distinction between being a process-oriented and a product-driven architect is explained in the book *101 Things I Learned in Architecture School*. Frederick's distinction of being a process-oriented architect characterizes certain qualities regarding the way one assesses design problems, makes decisions and implements solutions (Frederick 2007).

If we adopt Simon's definition of design as a "process by which we devise courses of action aimed at changing existing situations into preferred ones," we are likely to have a foundational base for building a design theory. Design theory relies on human (or "tacit") knowledge, because design thinking is outside the boundary of verbal discourse (Daley 1982). Under the scientific paradigm, where findings are presented as description, designers and architects find it very difficult to specifically describe what they think when they design, because design thinking is better expressed through the use of examples and by showing how design is done, rather than through merely describing the process. Here comes our dilemma in the realm of epistemology, which deals with little-objectified knowledge. Design knowledge pertains more to a knowing or a guiding intellectual capacity embedded in human actions and practices (Cross 2001). Therefore, while design knowledge might be difficult to describe, it is not inaccessible for research purposes. Friedman argued that design knowledge grows in part from practice, and therefore, overlaps with design research (Friedman 2003). The cornerstone of our epistemology is the distinction between tacit and explicit knowledge, where the key to knowledge creation lies in the mobilization and conversion of tacit knowledge. Friedman uniquely defines the position of design relative to science. His view of theory-construction in design research as “design sets on . . . science’s three legs,” is illustrated in Fig. 2.

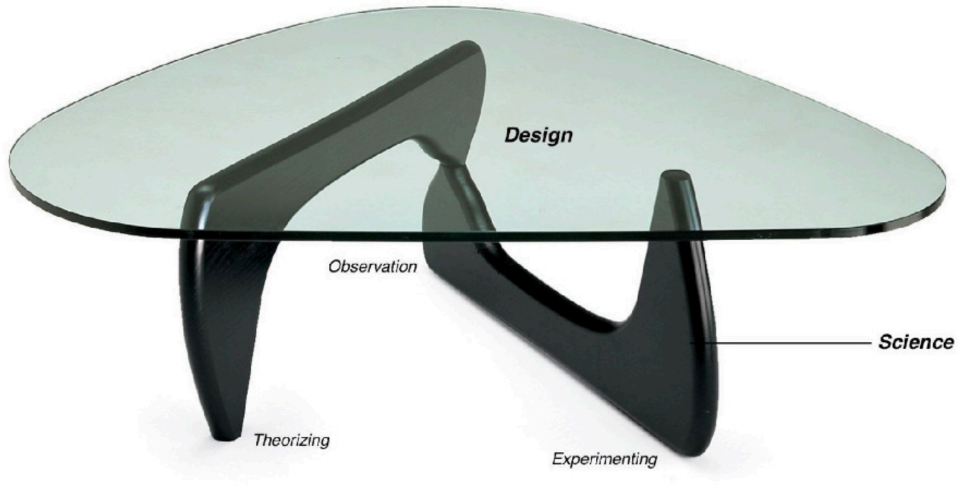

**Figure 2:** Friedman’s view of theory construction “design sets on . . . science’s three legs." Source: (Author 2017)

### 1.1. Constructing a Design Theory

To provide the underpinning theoretical framework for why we are concerned with modeling the design process, we should explain how to construct a design theory. In this study, we primarily deal with prescriptive theory, while acknowledging the fundamental intuition of design as a creative activity, which cannot readily be mapped or prescribed. The work presented here is related to the overlapping territory between the two frameworks of theory. Friedman, in his work on theory building, stated that one should consider a process of forming “models” for the research problem and continue refining these models and repeating the process until one has the simplest possible model that demonstrates all the phenomena under consideration. Models, in Friedman’s view, can be simple representations of reality because a model is supposed to reveal the essence of what is going on and should be reduced to just those pieces that are required to be workable (Friedman 2003). The importance of modeling in theory construction is to visually clarify how things work (again, with similarity in the use of terminology to physical and digital modeling in architectural design). This leads us to the question of prescriptive theory, as prescription furnishes a sort of certainty that our experiences or thoughts are real, rather than mere byproducts of our imagination. Primarily, prescriptive theories seek to make truth a real, viable category rather than a relative term. If a prescriptive theory is true, then the ground of reality has been reached. In epistemology, a prescriptive theory is the most abstract and general theory; it is the theory that grounds all other theories. Some argue that all major scholars in epistemology have sought to lay out a theory of prescription to ground their theories (Östman 2005). Prescriptive theories are abstract, general frameworks for knowledge within which the individual can reach certain conclusions that cannot be proven in and of themselves. They are axiomatic; that is, the means of proving anything. So how could knowledge evolve from constructing a design theory through modeling? Thomas Kuhn stated that science undergoes periodic “paradigm shifts” instead of progressing in a linear and continuous way, and therefore, design also goes through a paradigm shift (Kuhn 1996).

### 1.2. Design Process and Process Design

Modeling a design process requires an understanding of the difference between design process and process design. A typical design process might be described as a linear sequence of events that has a starting point and an ending point, is often investigative and is sometimes circular, as new information takes shape. Design usually begins with a precise definition of the problem to be addressed, and also is concerned with decisions of taste, choice and sensitivity that rely on human value judgments. In contrast to a design process, a process design (or the design of a “process”) refers to the planning and structuring of the routine steps of a process apart from the expected result. In process design, processes generally are treated as a product of design, not a method of design. The term “process design” originated from the industrial designing of chemical processes and with the increasing complexities of the information age, consultants and executives have found the term useful to describe the design of business, as well as manufacturing, processes (Korber 2002). According to William Miller, design is defined as “the thought process comprising the creation of an entity, and it consists of many smaller processes” (Miller 2004). Sub-design processes are defined as detailed, smaller processes that are linked in a network of precedent relationships. Models formation, as previously defined by Friedman, can thus be divided into two parts: a decision model, which is a structure of data elements and its mathematical relationships, as well as an information model that in our case could be the Building Information Modeling (BIM) database, which includes the parameters for the decision model (Ali, Badinelli, and Jones 2013). Like many other creative activities, the overall design process is linked to a path that is not always straight, and in fact is likely to include investigative sub-design processes. Some designers call this a "spiral" process because it has both a forward direction and a tendency for self-questioning along the way to ensure that it is going in the right direction. Literature suggests that there are the following five types of the architectural design processes:

- Linear: "Design process is a continuing sequence of basic linear steps" (Reekie 1972)
- Divisional: "Design process includes choosing the best solution out of several options of design solutions" (Jones 1992)
- Centralized: "There are no steps in the design process, everything is happening at the same time" (Lawson 2006)
- Cyclical: "Design process is a series of endless repetitive cycles" (Snyder 1970)
- Investigative: "Each step in the design process is based on a selective investigation process on options of ideas and solutions" (Kalay 1987)
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Any of these design processes occur within a number of established project delivery methods known to the practice. The current trend is to move toward an integrated project delivery method; however, the traditional Design-Bid-Build process is still widely accepted as the industry standard. In the next section, we explain the workflow of the DBB and our attempt to model both the current workflow and our proposed workflow. We call the proposed workflow a "resource-based" design, which primarily deals with the catastrophic amount of solid, nonhazardous waste that accounts for nearly 40% of all solid waste generated by the building industry.

## 2.0. WORKFLOW IN THE (DESIGN-BID-BUILD) PROCESS

In this paper, we primarily focus on the most widely adopted project delivery process in practice, the traditional project delivery method known as Design-Bid-Build. We illustrate the current and our proposed resource-based design workflows in detail using two different modeling languages. We realized through research that incorporating decisions of resource reuse to the DBB method may require an early integration during the programming and pre-design phases. The overall traditional design process typically starts with a program, creative idea(s) and an estimated budget, and then proceeds through several levels of development. Traditionally, in practice, there exist seven phases of a typical project, starting from abstract information gathering and conceptual design to the precise construction documents, and then construction administration culminating with occupation (AIA 2007). The entire process is initiated through communication between a prospective client and an architect. At this time, the architect typically asks the client about the program or intended use of the proposed building, proposed budget for the project, location of the proposed project and expected time frame for completion. This information represents the primary critical inputs to the pre-design or programming phase. This information is mostly quantifiable, with variables such as program, size, budget, location and schedule. We will only present here mapping of the schematic design (SD) phase, as other phases of the process are documented in previous publications (Ali and Badinelli 2016).

## 3.0. RESEARCH METHODOLOGY

We utilized a qualitative, grounded theory approach using an inductive mode and an intensive, open-ended and iterative process that simultaneously involved data collection, coding (data analysis) and memoing as a method for theory building (Wang and Groat 2013). The author used a knowledge-capturing approach from a medium sample of experts involved in the area of architectural design with resource reuse, design for disassembly and building deconstruction. The knowledge-capturing process was developed through a multi-phase questionnaire, face-to-face interviews and structured Delphi focus workgroups. The knowledge captured was compared to the data extracted from the literature and case studies to form a consistency check. Findings from the qualitative analysis were evaluated through a triangulation method to test the validity of the proposed design workflow. The proposed framework in this study constituted an effort to collect, organize and present available knowledge on building materials and resource reuse in a readily usable form. The number of attributes and variables in the design process with used building materials was overwhelming; therefore, we used standard mapping language to streamline the paradigm shift within the typical architectural design process. The preferred solution ultimately was based on some trade-offs that the design team would have to evaluate and choose from; therefore, there was a need to weigh these trade-offs in a rational and explicit method in order to assist the design team by using the decision support framework. Some inputs to this framework emerged from personal interviews, analysis of selected case studies and online surveys, which helped in identifying some evaluative categories. Each category contained a set of variables that was considered and integrated into the framework.

### 3.1. Standard Modeling Languages

Following several attempts to map the design process using bubble diagrams (known as a conventional method in architectural design), we realized that a standard modeling language was essential to map the resource-based design process. It was critically important to follow a consistent, representational repertoire and to build a common understanding with the IT and IS disciplines. After studying the available modeling languages, we found that each has capabilities and limitations. We initially adopted the Unified Modeling Language (UML) in mapping the current traditional design process (DBB) and the activity diagram of the proposed building material reuse workflow. However, after investigating further, other modeling languages, such as the Business Process Modeling Notation (BPMN) appeared to address more details in the process. Literature suggests that process modeling should consist of static and dynamic elements. For static components of a system, especially the architecture and design of a system, there are design patterns. The dynamic aspects of a system are abstracted and captured as process patterns. Using patterns in the modeling of systems helps keep the design standardized, and more importantly, minimizes repetition in the system design. Events are used to communicate a relationship between a context, a problem and a solution, and bring in and reuse the previous modeler experience. An example of mapping the flow of activities in the DBB process that typically includes a sequence of activities and processes is shown in a UML map of the SD phase (Fig 3).

### 3.2. Unified Modeling Language (UML)

Initially, we selected UML language to map the current DBB process. UML is an easy language for non-IT professionals to understand. UML activity diagrams are simple to learn and are similar to flowcharts (Rhem 2006). They are graphical representations of a workflow of stepwise activities and actions with support for choice, iteration and concurrency. Activity diagrams are used to describe the business and operational step-by-step workflows of components in a system. Activity diagrams show the overall flow of control; they are constructed from a limited repertoire of shapes connected with arrows, as shown in Fig. 3. The most common representation symbols are rounded rectangles, representing activities; diamonds representing decisions; bars representing the start (split) or end (join) of concurrent events; and arrows that run from the start toward the end, representing the order in which activities happen. Decisions are represented as “nodes” where each decision would have information inputs. Decision needs should be specified as alternatives, decision variables, Key Performance Indicators (KPIs) and parameters. The component of the decision model is beyond the scope of this work.

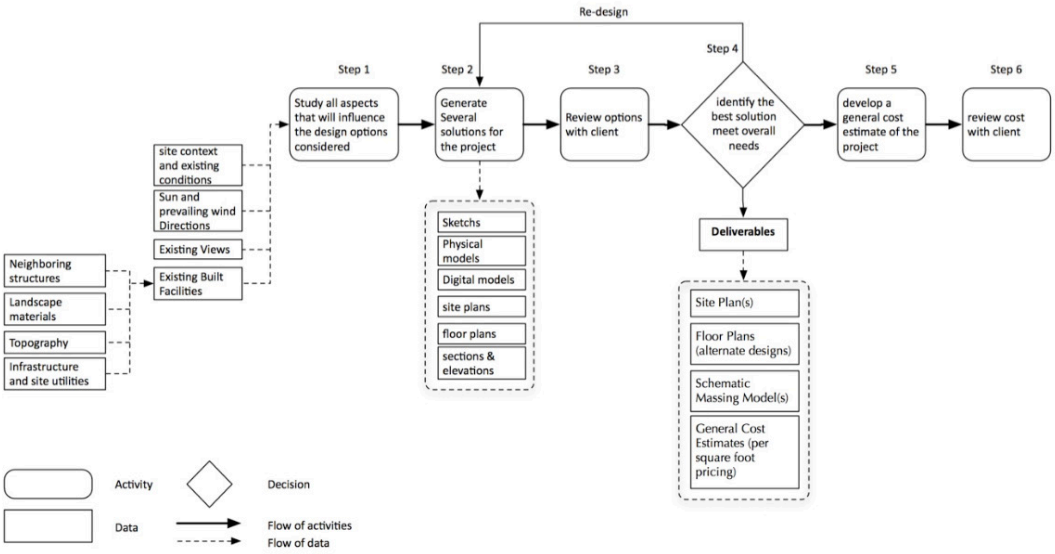

**Figure 3:** UML process design map of the DBB schematic design (SD) phase. Source: (Author 2016)

### 3.3. Business Process Modeling Notation (BPMN)

We used Business Process Modeling and Notation (BPMN) in revising the initial DBB design processes maps using UML. It is a graphical representation for specifying business processes in a process model. BPMN language allowed us to include more details in modeling, such as project phase, responsible stakeholder and a cross-referencing system similar to construction documents standards. In the revision of the workflow, a thorough review of all the boxes in the knowledge and data section was considered in a hierarchical structure. The specification of knowledge elements went from general to specific in a hierarchal method. A sample representation of BPMN map can be seen in Fig. 4, illustrating the SD phase.

## 4.0. BUILDING THE PROCESS MODEL

The resource-based design process that we propose is an effort to collect, organize and build relationships between activities, processes, knowledge, data and information in a standardized workflow language from start to end. The value-added component of resource reuse to the current DBB process needed to be seamlessly integrated into the process. The previously presented UML activity maps illustrated the captured knowledge from the literature and from the expertise of professionals (Ali and Badinelli 2016). Several project stakeholders and consultants are usually involved in the activities and processes related to design, demolition, procurement, and so on. Some of the process activities are performed concurrently and some, sequentially. The initial UML activity maps represented some of these relationships in the SD phase. The SD phase is presented on three detailed level maps based on the complexity of a project. First is Level 0, a traditional DBB process modified from UML to BPMN. Second is Level 1, with a new BPMN process, including preliminary resource reuse activities. Third, Level 2 has a new BPMN process, including detailed resource reuse processes (Fig. 4,5).

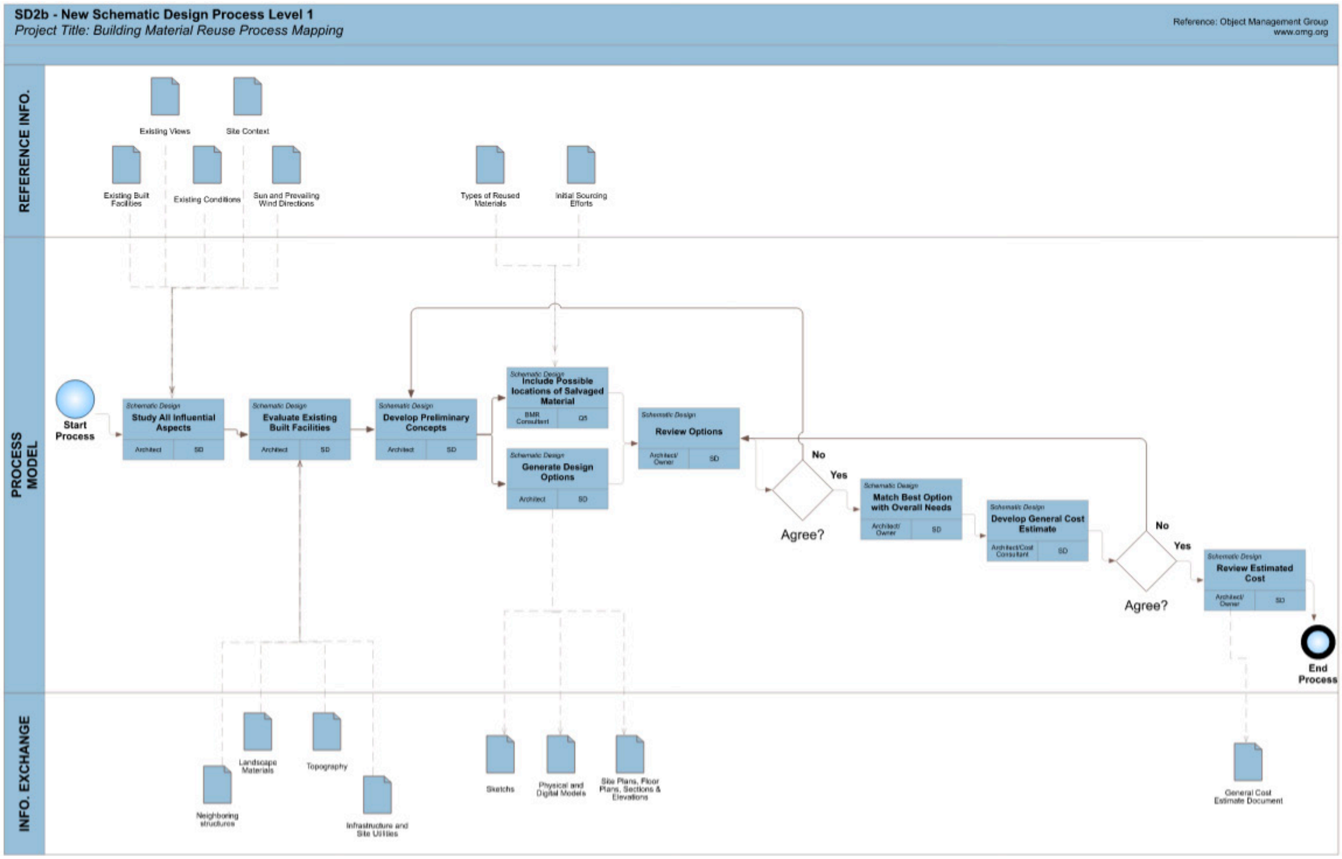

**Figure 4:** Resource-based schematic design process level 1 (map # SD2b). Source: (Author 2012)

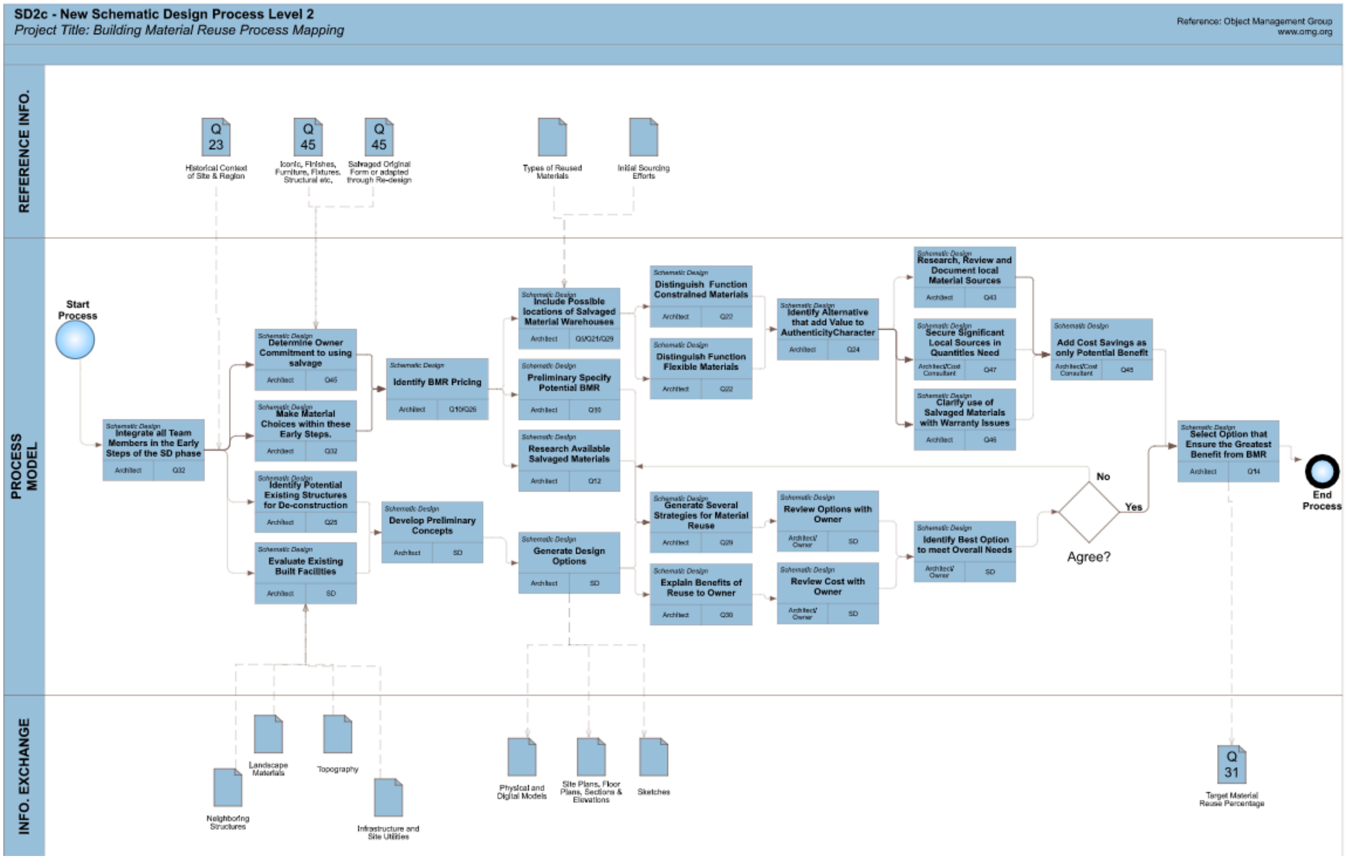

**Figure 5:** Resource-based schematic design process level 2 (map # SD2c). Source: (Author 2012)

## CONCLUSION

Architecture as a discipline is known for its slow adoption of paradigm shifts, and architects typically are reluctant to drastically change their design process. In his book, *Complexity and Contradictions in Architecture*, Robert Venturi noted that the growing complexities of our functional problems must be acknowledged (Venturi and Museum of Modern Art (New York N.Y.) 1966). What we propose in this study is often what an architect thinks about while approaching the problem of building design. Nevertheless, he or she could be required to alter the design process to include, for example, resource reuse of materials. Process design offers a clear and systematic workflow that makes design decisions less ambiguous and brings the knowledge gathered for one project to the next without depending entirely on the tacit knowledge of the project's designers. As noted by Herbert Simon, a structure's complexity or simplicity is critically dependent on the way we describe the structure. The architecture of complexity for the built environment can benefit from the architecture of complexity for information systems. The latter provides the backbone of the information flow to the architect and allows him or her to focus on the creative aspects of design. A structured framework such as the one we propose allows for the apparent integration of dynamic decisions, which includes the specific parts, linkages and networks of such a dynamic system. In a world where complexity has to evolve from simplicity, the hierarchy of systems helps in process disambiguation and synthesizes the architecture of complexity. We hope that architects will find this method beneficial for streamlining the nearly limitless parts of the design process. So, now we return to Ulrich's question: How can we ensure that the same fate is not repeated for future generations?

The work presented in this study is an important step toward solving the problem of waste in the building and construction industry. The proposed decision support framework, which includes redefining the traditional design process to incorporate resource reuse, anticipates a major societal contribution of reducing 40% of the total solid waste stream. This paradigm shift requires changing our practice and perspective toward the environment, economics, and the social and cultural aspects of design. Without rigorous governmental restrictions regarding waste required of the AEC industry in building design and construction activity, waste reduction will remain a low priority. The lack of interest from the AEC industry due to the lack of information on BMR can be now mitigated by this proposed dynamic knowledge base and decision-making framework. The straightforward process of incorporating BMR to design is evident throughout this work and can be implemented with minimal unknown factors.

The resource-based design process, as a system approach, is dynamic, although we have presented it as cause-effect relationships between activities, data and processes. Our mapping attempts to reorganize design practice. The decision support framework offers a holistic approach to the built environment. While defining the extent of the system and its parts anticipation for the architecture of tomorrow might not be possible, the current architecture of complexity is readable, rigorous and meaningful.

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