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How does the order of incorporation of design requirement solutions impacts design outcomes?

Keith Jundanian1,

1 College of Architecture, PhD Program, Georgia Institute of Technology,
keith.jundanian@arch.gatech.edu

ABSTRACT:

Designers organize design criteria and carry out design processes in many different ways. However, all of those methods involve a sequential (but not limited to linear) process of the ordering and incorporation a of design requirement solutions, resulting in a finished design product. A small explorative study was conducted using a short design exercise with freshman design students to investigate the impact that the order in which design requirement solutions are incorporated into the final design product has on that product. The outcome of this study is discussed in relation to its impact on the design process, design process studies, and its potential impact on the information structure of design tools.

KEYWORDS

Design Information Structures, Design Precedents, Design Tools

1. INTRODUCTION

Designers seemingly structure design problem information in as many ways as there are designers and design projects. These mental structures however, whether planned or the result of the design process or a mixture of both, have in them a hierarchically ordered diagram of the design problem criteria and the order in which those criteria were satisfied, and became context for other decisions. That diagram is associated with a collection of solutions for those criteria that were implemented in the final design problem solution. Some of the decisions in that hierarchical criteria matrix were well defined consciously ordered design criteria and many of them were ill-defined problems that slowly found definition, solutions, and their place in the decision making order through the design process.

Accepting that in a design process many design decisions are impacted by design decisions made earlier in that same process, if the hierarchy of the criteria were shifted, a new design solution may occur. In this paper, a simple explorative study was conducted to investigate the impact of the order of incorporation of design requirement solutions on design outcomes.

2. BACKGROUND

It does not appear historically as though many designers have spent much time documenting their design process, neither as a general way of working or for a specific project. Rarely have they attempted to document the design criteria, their hierarchical organization of those criteria, their methods of solving the problems created by each of those criteria and their combinations, or the design precedents that they used as that process unfolded. By design precedents I am referring to physical documentations of previous designs that are studied to provide inspiration and/or design solutions as well as mental precedent collections that have been developed through experience (analytical awareness, study, profession, life, etc.). However, there have been instances in which hierarchical diagrams or matrices of design criteria for a specific design problem were developed by architects and architecture students to be fed into software developed for computer-generated designs. While the computer-generated designs were rarely regarded as very exciting, the development of these matrices was credited by the architects and architecture students with helping them understand design methodology and their individual design processes (Milne1975).

It is a similarity at some point within a large design criteria/ process matrix like the one mentioned above that makes one design problem solution a proper reference or precedent for a new design problem. An issue though is that finding these fine grained combinations of criteria-based precedents proves difficult when considering the information that is presented, or more importantly not presented, in many design documentation collections as well as the manner in which that information is ordered and structured.

Designers and design researchers have produced innumerable collections of design precedents, traditionally collected as published books but more recently showing up as digital collections distributed on a CD or DVD, sometimes with an interactive software package, and finally now on the Internet. These collections of design precedents are routinely used as design tools to supply both practitioners and students with design information. They generally consist of collections of work based on a certain designer, construction material, historical time-frame, or style, to name just a few of the most common ways of organizing designs. Less common however, seem to be collections of design precedents that are organized in regard to a specific design problem or programmatic requirement. Obviously there are plenty of precedent collections of specific design functions (billboards, cars, houses, etc.), design problems for sure. But what about the multitude of more fine-grained design requirements that need to be answered in order to solve the general programmatic requirement of a billboard, a car, or a house? These more fine-grained problems may consist of requirements such as a desired eye movement pattern on a billboard, a particular engine configuration for an automobile, or room adjacency requirements in architecture. While it is understood that design experience may provide experienced designers with a set of mental precedents with which to proceed, it does not do much for the novice designer or design student.

Fortunately, digital collections of design precedents with database driven criteria-based searches has allowed for the indexing of one precedent with many different tags based on the different qualities it may possess and different scenarios in which it is relevant. But, in order to tag the precedent in its most informative manner, these collections of designs would need to be accompanied by an in-depth analysis, and/or description, of the decision making that produced the design and the effectiveness of the design. Which decisions were primary, secondary, tertiary, etc., and why? Put another way, why were the design criteria and requirements hierarchically organized by the designer in that specific order? In the event that two requirements were competing with one another, which requirement became more important? How did this order impact the final design outcome? This is one of the types of information that researchers have been attempting to uncover through design protocol analysis. Again, an experienced designer may be able to make an educated guess about the design issue that created a certain solution but the novice designer will have a much harder time with this task.

The question that these ideas hinge upon however is this: Does the order of incorporation of design requirement solutions impact which design outcome, out of a set of possible outcomes, is more likely to occur?

3. METHODOLOGY

3.1 DATA COLLECTION

Two groups of freshman design students were asked to design and sketch a residential floorplan consisting of 5 rooms. They were then given a design requirement and asked to redesign or alter their existing floorplan based on that information. They were instructed to sketch this new plan on a subsequent sheet of paper. This process was repeated through a series of 4 design requirements, always building upon the previous requirement's final solution and resulting in a new plan that satisfied all of the requirements presented to that point. During this design process one group of students was presented the design requirements in a given order and the other group was given the exact same design requirements in a different order. The design requirements were developed to reflect types of information that may be required to satisfy a typical architectural design problem (Table 1). Neither order was chosen for any specific reason in order to not knowingly privilege any specific design criteria hierarchy over another. However, even in this simple experiment, certain hierarchies established themselves out of necessity. For example, the Spatial Adjacency criteria which determined which spaces had to be accessible to which other spaces needed to be provided after the Room Type criteria was established in order for it to make sense. Perhaps they could have been grouped together but each design phase contained only one type of design information (this was done in an attempt to remove any confusion on the student's part regarding what information they were supposed to acquire from the design criteria/precedent.) The resultant design development sketches and solution sketches were then collected and analyzed.

Group 1	**Group 2**
5 Room Residential Floorplan	5 Room Residential Floorplan
Room Types *(Entry, Bathroom, Bedroom, Living Room, Kitchen)*	**Perimeter Form** *(Must be Square)*
Spatial Adjacency *(Entry to Kitchen and Bath, Kitchen to Entry and Living Room, Living Room to Kitchen and Bedroom, Bedroom to Living Room and Bathroom, Bathroom to Bedroom and Entry)*	**Room Types** *(Entry, Bathroom, Bedroom, Living Room, Kitchen)*
Perimeter Form *(Must be Square)*	**Spatial Adjacency** *(Entry to Kitchen and Bath, Kitchen to Entry and Living Room, Living Room to Kitchen and Bedroom, Bedroom to Living Room and Bathroom, Bathroom to Bedroom and Entry)*
Front/Rear *(Bedroom and Living Room at rear of floorplan)*	**Front/Rear** *(Bedroom and Living Room at rear of floorplan)*

Table 1 – Design Requirement Hierarchy

3.2 DATA ANALYSIS

Each sketch protocol was coded according to the design action taken by the designer at each step in order to satisfy the new requirement while maintaining satisfaction of the previous requirements. Design actions were classified as to whether or not the new plan based on the new criteria resembled the old plan (Classified as a "Version") or appeared to be a new plan altogether (Classified as "New Plan"). When the evolution of a plan involved only one observable action, such as a simple plan rotation or mirror, that specific task was noted. Figures 1-5 document a typical series of solution sketches from Group 1and Table 2 shows a coding of the actions taken by the designer to satisfy each requirement as well as some other process information that was collected. In more detail, Figure 1 is the initial sketch that satisfied the first requirement, which was to sketch a plan for a 5 room residence. In this particular drawing, the 5 rooms represented in the plan were a Living Room and a Bedroom across the top of the plan with a, Kitchen, Bathroom, and Spare Bedroom stretching across the bottom. Upon introduction of the "Room Types" criteria (Figure 2) the perimeter form remained relatively unchanged while a few adjustments were made to the room types as well as room locations. Since the room location changes were not necessitated by the criteria, it can only be assumed that the designer believed this to be a "better" plan, according to some self imposed internal criteria. In the coding of the process, these plan changes are referred to as a "Version", Version 2 in this instance. Figure 3 shows the changes made to the plan upon the introduction of the Spatial Adjacencies criteria and was documented as Version 3. In this version, once again the perimeter form remained intact while more adjustments were made to room locations and the positioning of circulation elements (doors, openings, etc) within the plan. Perimeter Form was the next criteria introduced and the requirement stated that the plan must be square. To achieve this goal, the designer extended the living room to fill in the gap below the bedroom from Figure 3 and adjusted the overall dimensions of the other rooms to fit it into the required square form (Figure 4). Again, because of the obvious relation to the previous sketch, this drawing was coded as a version, Version 4. Lastly, the requirement that stated that

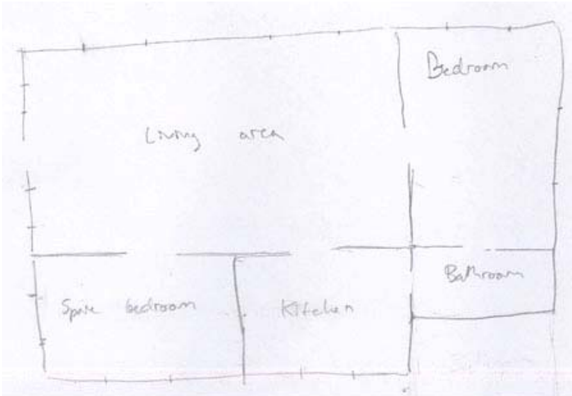


Figure 1

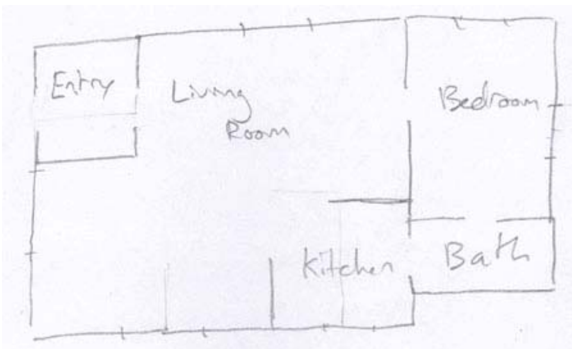


Figure 2

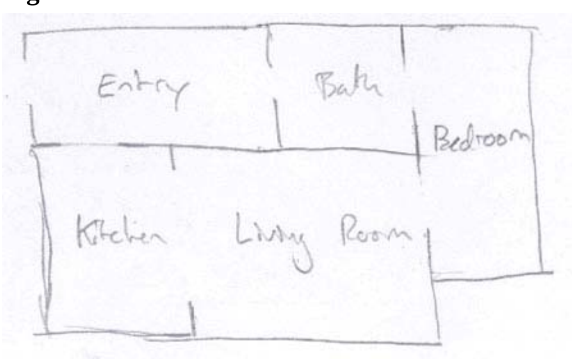


Figure 3

the Living Room and the Bedroom had to be at the rear of the plan was introduced. In this sketch (Figure 5), coded as Version 5, the Bedroom and the Kitchen remain in the

same location while the Living Room traded spaces with the Entry and Kitchen.

Additionally, the final floor plans that satisfied all of the design requirement were analyzed and indexed according to their basic geometry or parti, of which there were only three different solutions (Fig. 6-8). There are six different solutions if you count the mirrored versions of the original three as distinct from one another. As you can see, Figure 5 above matches the parti indicated in Figures 6-8.

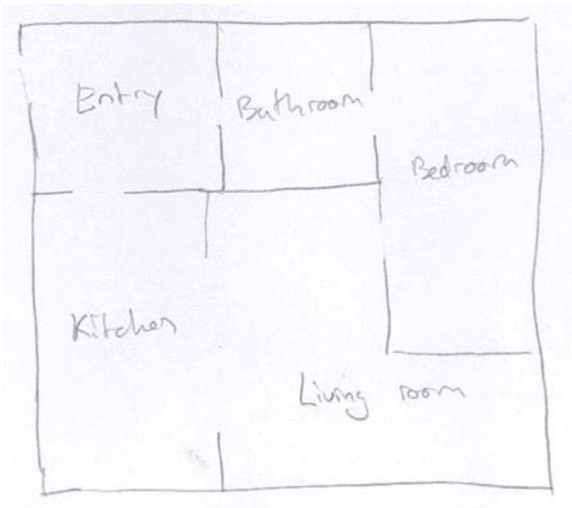


Figure 4

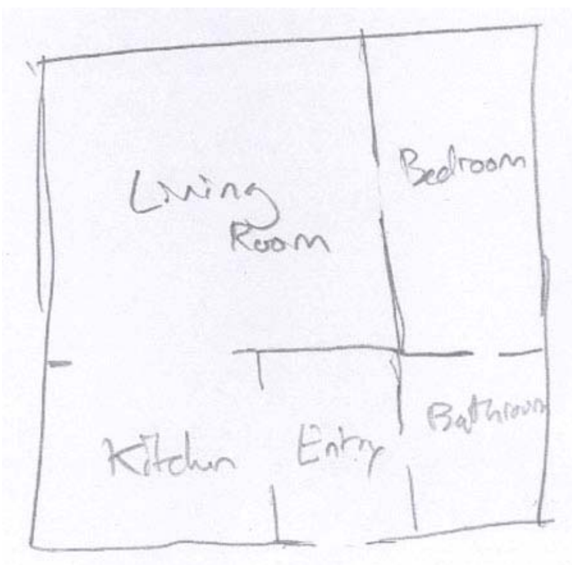
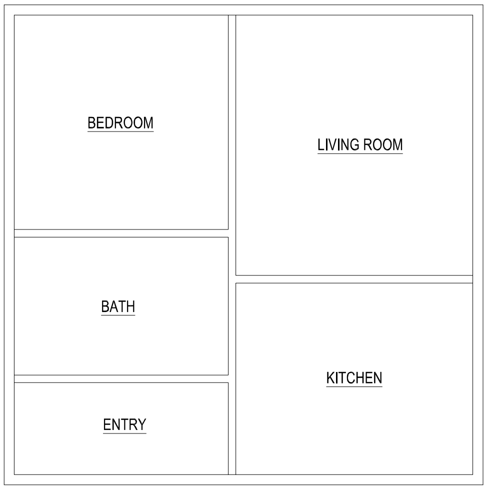
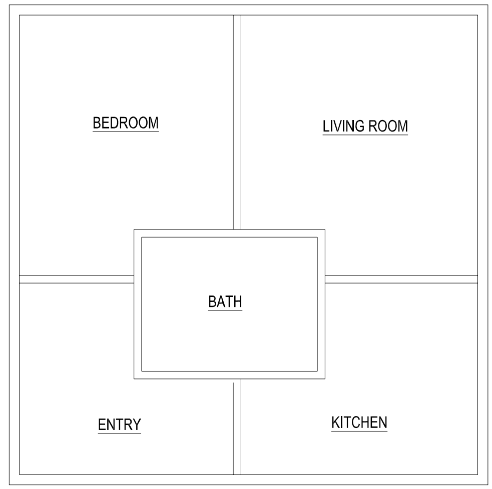


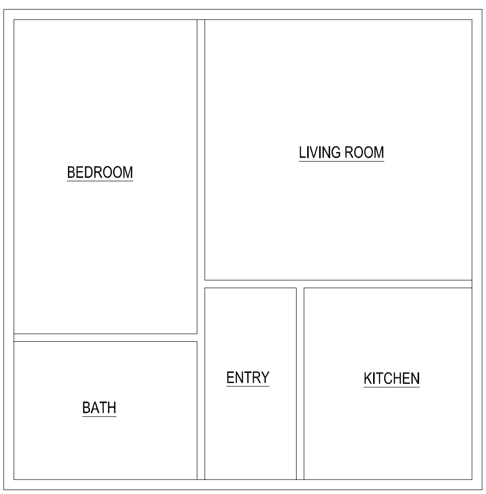
Figure 5

N	1-11
Diagram or Plan	Plan
Rooms in First Dwg	2 Bed, Bath, Kitchen, Living
# of Spaces	5
Room Types	Version 2 (Figure 2)
Spatial Adjacency	Version 3 (Figure 3)
Must be Square	Version 4 (Figure 4)
Front/Back	Version 5 (Figure 5)
Parti Type	3 (Figure 8)

Table 2







4. RESULTS

In the first group, 7 out of 14 (50%) sketch protocols were resolved using parti 3 (Figure 8). In the second group, 4 out of 6 (66.6%) sketch protocols were resolved using parti 1 (Figure 5). While the sample is admittedly small, we were intrigued enough to ask the question "how"? How did the different implementation order of design criteria privilege or hinder certain design outcomes from a known set of outcomes? The sketch protocols were analyzed again to see if we could find a reason, other than chance, that the two groups differed so markedly. As you can see, the difference between the three partis that were presented as problem solutions centers around the relationship between the entry and bathroom. All other spaces stay relatively static while the entry and bathroom find different methods of accommodating one another and encroaching on neighboring spaces. Upon further analysis, almost all of the first group that sketched a final design solution resembling figure 8 achieved resolution of the entry/bath relationship by the 2nd criteria, spatial adjacency. Most of group 2nd that sketched a final design solution resembling figure 5 did not realize their final entry/bath relationship until after the third criteria, also spatial adjacency. While these samples are way too small to attach any meaning to them, it is not difficult to understand why the entry/bath relationship was not established in either group until after a very confined spatial adjacency criteria was introduced.

The question then becomes, what happened before that step to make it such that the same new criteria pushed one group toward one parti diagram and another group toward a different parti diagram? In both cases the previous criteria that had been satisfied was that of Room Types. It was not apparent why or how this criterion would or could have influenced the final design solution outcomes in such a way. In Group 1, the only step before the Room Types criteria was introduced was the initial 5 Room Residential Plan sketch. In those Group 1 sketches for the initial 5 room residential plan, many of them were developed with an entry placed somewhere near the middle of the front side, either as a specified entry space, or as a door placed on a wall leading into the living room. With only one step, that of Room Types, between the initial sketch and the Spatial Adjacencies criteria, it is not difficult to imagine that the central entry could have been maintained , thus resembling parti diagram 3 (Figure 8).

Upon further analysis of Group 2, it is much less clear what may have contributed to the potential privileging of one parti diagram over another. That group proceeded through two criteria-based plan transformations before the Room Types to Spatial Adjacency transformation took place. They moved from the 5 -Room Residential Plan to Perimeter Form and then from Perimeter form to Room Types. As the number of criteria-based transformations of the plan increased before the Spatial Adjacency critieria was introduced, thus tightening the final parti together, there seems to be an increase in plan variation. This increase in plan variation, when combined with our small sample, did not allow for any meaningful observations from the sketch protocols.

5. DISCUSSION

This research suggests that the order of incorporation of design requirement solutions impacts which design outcome, out of a set of possible outcomes, is more likely to occur.

This makes intuitive sense as a designer. As designers, we have all probably been in the unfortunate situation in a design problem when we realize that we have waited too long to consider a certain design requirement and it proves to be in conflict with the current resolution of the design problem. Depending on how long ago in the design process the conflicting decision or decisions were made, a considerable amount of redesign or rethinking of the design criteria hierarchy may be required. In some instances such a conflict can result in the designer being "stuck" (Sachs, 1999). This research suggests that reordering the hierarchy and implementation of design requirements and their solutions may lead to previously unconsidered design opportunities and aid in the relief of "stuckness". Additionally, if the designer wanted to deviate from the given programmatic criteria to investigate other possibilities as a method of exploration, that process seems to consist of an adjustment to the design criteria hierarchy. The designer inserts a new design criteria into an existing, whether documented and/or considered or not, framework.

Studied over time and across designers, many design criteria hierarchies or matrices have a few basic similarities. At the very least there are structural similarities linked to the loosely defined but generally accepted design phases such as pre-design, schematic design, design development, construction drawings production, and construction administration. However, based on the hierarchical index of the design criteria as necessitated by the design problem and its context (the designer is also considered context for the design problem), there is no telling in which of those or any other categories any of the innumerable number of design questions that make up the final design product may land. In fact, many of the design decisions will be thought and rethought several times at many different phases of the design process as criteria with more than one possible answer slowly become limited in solutions by subsequent design decisions and their impact on previously thought out criteria.

How do current design tools support this type of design information structuring? What design process information and solution information do those tools present? How do they present that information? What design processes or informative scaffolds do these tools promote by their own inherent information structure? Which ones do they hinder? Let's look briefly at a few types of design precedent collections.

5.1 BOOKS:

Typically, bound collections of design work seem to offer the least amount of design information for the design precedents included. Because of the way they are structured, the work is often only tagged in one way (ie. designer, material, function, style, etc.) Admittedly, there are many instances in which some of these are grouped together such as a collection of concrete homes by a specific designer, but rarely does the content of these books become involved with discussions regarding how or why that design developed the way it did or how well it performed as a design solution? Additionally, many pieces of design have appeared in many different books on many different topics within design. That design product could be tagged with all of those topics. Unfortunately, the limitations of the book have not allowed for this level of cross-referencing of design precedents.

However, focus pieces on specific designs could go a lot further toward providing more complete and analytical information that would be useful in many phases of design, about a given project. Obviously this type of book takes a lot more time in development than collections that consist of a series of photographs and drawings. This type of information can be gathered using a multitude of data gathering techniques ranging from ethnographically based analysis techniques to statistically rigorous plan analysis techniques, to in depth documentation of project data. This type of information in conjunction with the photos and drawings will help a designer know the extent to which a given precedent is appropriate for their needs.

5.2 DATABASE AND SOFTWARE ARTIFACTS:

The development of database driven precedent collections and design tools and the search functionality of these tools has gone a long way toward getting past some of the limitations of book based precedent collections. Similarly, many catalogue based collections of design products, such as Sweets Catalogues, became available on CD and were searchable through the file index. While the information that such a catalogue contained did not necessarily increase over its book based predecessor, it made very apparent its potential for fixing some of what was limiting about book-based information.

To that end, we began seeing design precedent collections that incorporated more information about the design precedents. In one such tool, called ARCHIE, design information about U.S. Courthouses was organized according to design descriptions (text, graphics, drawings, etc), problems (incorrect outcomes), design responses (general responses to design intentions) and stories (a brief description of how problems and solutions played out for a specific building) (Zimring, Bafna, Do, 1996). This information was retrievable through a multitude of search capabilities and allowed for designers to search for very general design information as well as in depth design issues (Zimring, Bafna, Do, 1996).

Additionally, while not a precedent-based tool, relatively inexpensive home design software packages for the non-professional designer have become readily available. Since this software is more intended for the homeowner or other non-designers that do not have experience at this task, what design process or even design solutions does the software promote through its programming and interface? AutoCadd, more commonly used by experienced designers that are familiar with the design process, allows the designer to work in a very unrestricted environment. This type of environment may not work well for the novice designer.

5.3 INTERNET:

Currently, we are seeing the development of internet based, dynamically structured, database driven, case/precedent based design tools. Researchers at the Georgia Institute of Technology have recently created one precedent-based design tool called Courtsweb, featuring U.S. Federal Courthouses, and are currently developing a similar tool called Healthcare Design Web, which will feature best-practice design examples from the healthcare community While still relatively in their infancy, the potential for such tools is quite large. The navigation of such a web page could incorporate an information structure development interface, which allows for the development of different matrices based on a individual projects design requirements as well as an individual designers specific strategies and biases. This matrix development interface would allow for “on the fly” adjustments to the database driven precedent set and set order, based on alterations to the matrix structure. These alterations may be necessitated by design requirements introduced over the course of the design project rather than having been presented at the beginning of the process or an interest on the part of the designer in exposing heretofore unexplored possibilities.

6. CONCLUSION

This exploratory study suggests that the order of incorporation of design requirement solutions impacts the outcome of the final design product. It impacts it in such a manner that certain design solutions out of a set of potential solutions may be more likely to occur than other solutions. Obviously this study is limited due to its small sample size. A follow up study with a larger sample needs to be conducted to verify these findings. Further more, this larger sample may allow for a more complete investigation into why or how a specific design criteria hierarchy privileges a certain design product outcome.

This outcome poses some interesting research opportunities in regard to design methods and design tools. As more database driven, web-based design tools are developed, used, and studied, the patterns of use of those tools by designers and the order in which they view information provided by these tools can be tracked. Such tracking has the potential to reveal patterns of design criteria hierarchy that are more common than others. This could lead to new navigation and information structuring strategies of these design tools.

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