Rethinking System Diagrams: from Arranging Components to Organizing Action, Thought, and Possibility

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Abstract

The use of system diagrams has encouraged information designers to tacitly consider the holistic context. However, because the traditional understanding about the nature of systems has been highly focused on the arrangement of components within a static model, users' experience is considered little. The goal of this research is to provide a theoretical framework to broaden designers' conception of the system diagram and enable them to design system diagrams that would prove most effective for different situations, needs, and design problems. Therefore, the key of system diagrams is to understand the relationship of how the system is organized, according to the intent of the designer, the purpose of the user action, and the function of the group. In order to further investigate this notion of a system diagram, we present four kinds of system diagrams where relationships emerge, depending on the following organizing principles: 1) law that holds together individual components, 2) rule that guides decision making, 3) function that supports users' action possibility, 4) condition that facilitates participation in cultural ideals. In addition, we examine numerous system diagrams that have been created in the Domestic Mail Manual Transformation Project by the Carnegie Mellon School of Design and the United States Postal Service. This is a design case study that not only illustrates the role of system diagrams throughout the design process but also identifies four cases of system diagrams according to different goals: structure diagram, pathway diagram, affordance diagram, and vision diagram.

Keywords

System diagram; information visualization; interaction design; design principle; case study

The role of information design has become increasingly important in our society, as people desire to regain their sense of control within an environment of information overload and growing idea complexity. However, many information design products take the approach of limiting people's choice of action rather than supporting decision making with open possibilities for action. For example, when there is an unexpected delay in a bus service, it is not easy to identify the problem and find another bus route if the users are only provided with scattered information. Without having a clear understanding of how the bus service system works holistically, users may not be able to take alternative actions if there is any breakdown in the sequential information initially given to them.

Among numerous approaches to resolve this problem, the use of system diagrams is the only one that allows information designers to tacitly consider the holistic context. There is a need for not only understanding the system itself, but also a need for studying system diagram as means of effectively communicating the system, which is abstract in nature. While the use of system diagram is still a key component in communicating and understanding the holistic structure of an information system, designers often have difficulty in discussing systems as an aspect of their work, even in contemporary discussions of design. Because the traditional understanding about the nature of systems has been highly focused on the arrangement of components within a static model, often the user's experience ends up fragmented and degraded.

The goal of this research is to provide a theoretical framework to broaden designers' conception of system diagrams and enable them to design system diagrams that would prove most effective for different situations, need, and design problems. In this paper, we will study the nature of the system diagram by presenting four kinds of system diagrams, analyzing different examples of system diagrams, and discussing how each mode of thinking is utilized in different needs and goals in the design process.

Organizing Principles of System Diagram

Encyclopedia of Science, Technology, and Ethics defines a system as "a set of distinctive relationships among a group of components that interact with one another and their environment through the exchange of energy, matter, and/or information" (Strijbos & Mitcham, 2005, p.1880). Although system thinking is regarded as dating back to the 1950s, it has been always prevalent in human history. But the big change today, states Richard Buchanan (2001b), is that the focus is no longer on material systems but on the aspect of the human who experiences the system. He further points out that:

> One of the most significant developments of system thinking is the recognition that human beings can never see or experience a system, yet we know that our lives are strongly influenced by systems and environments of our own making and by those that nature provides. By definition, a system is the totality of all that is contained, has been contained, and may yet be contained within it. We can never see or experience this totality. We can only experience our personal pathway through a system. (Buchanan, 2001b, p.12).

Then the question is—how can we possibly design a system diagram, if a system is the wholeness of the totality, and human beings can't experience the whole? In fact, the role of a system diagram is not a mere representation of particular phenomenon or fact. According to Charles S. Peirce, "diagram not only represents the related correlates, but also, and much more definitely represents the relations between them, as so many objects of the Icon" (Peirce, 1906, p.316). In this respect, system diagrams are about relationship.

Here we should not simplify a relationship as mere connectivity between numerous components, but rather take it as an idea or a thought that integrates different parts into a whole, that is, the organizing principle of the system. According to Buchanan, human beings can't see or experience the totality of the system and, therefore "in our effort to navigate the systems and environments that affect our lives, we create symbols or representations that attempt to express the idea or thought that is the organizing principle" (Buchanan, 2001b, p.12).

As the focus of system has shifted from things to human beings, a system diagram should be regarded as a visualization of the organizing principle of the system, which alters system into a *place* that opens up users' action possibilities and supports effective use of the system. In turn, the key of system diagram is more than to *represent* relationship among things. The key is to *understand* the relationship of how the system is organized, according to the intent of designer, the purpose of user action, and the function of group. In order to further investigate this notion of system diagram, we present four kinds of system diagrams where relationships emerge depending on the following organizing principles (figure 1): 1) law that holds together individual components, 2) rule that guides decision making, 3) function that supports users' action possibility, 4) condition that facilitates participation in cultural ideals. (Buchanan, 2008)

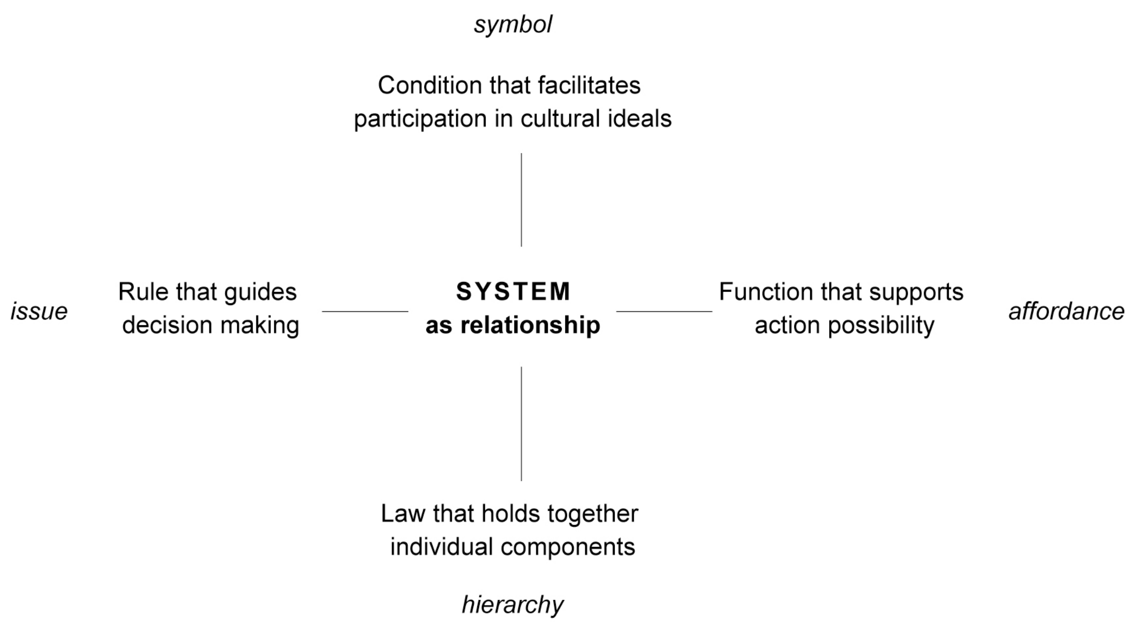

Figure 1. Organizing principles of system diagrams

System as law that holds together individual components

First of all, Herbert Simon's discussion on system gives insight to understanding system as an aggregation of individual components. Simon explains a complex system as "one made up of a large number of parts that have many interactions" (Simon, 1969, p183). As he seeks to find the essential quality of what is this interaction that constitutes the architecture of complex systems, ranging from artificial/natural adaptive systems, social systems to symbolic systems, he finds that the complex system is composed of subsystems and the subsystems are again made of their own subsystems. He sees this hierarchy to be the distinctive relationship among the parts that organize them into a system. As he states that "hierarchic systems have some common properties independent of their specific content. Hierarchy is one of the central schemes that the architect of complexity uses" (Simon, 1969, p184), hierarchy can be explained as a kind of law that serves as objective force that is universally applicable.

Network diagram is one of the representative system diagram that starts from this principle of hierarchical relationship among individual elements. Figure 2 is an example of social network analysis. Similar to a molecule made of electrons, individual people in the network diagram below would be mere elements without the hierarchical relationship visualized by the lines, the distances among people, and the overall positions of people. The repeated hierarchy of who gives order to whom and who belongs to whose command becomes the core organizing principle that holds those individuals together into a system and serves the purpose of analysis.

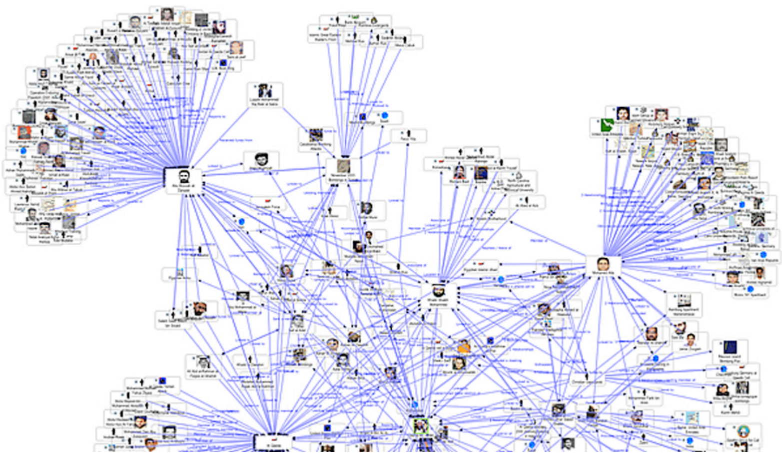

Figure 2. Network (http://www.fmsasg.com/) [1]

The system diagrams in figure 3 share the same element of the celestial bodies from the Solar system. However, the hierarchical law that serves as organizing principle is different in these two diagrams, which yield two different forms. The diagram on the left focuses on the hierarchy of size rather than exact representation of the distance. In comparison, the diagram on the right based on the hierarchy of distance omits the irrelevant hierarchy of size.

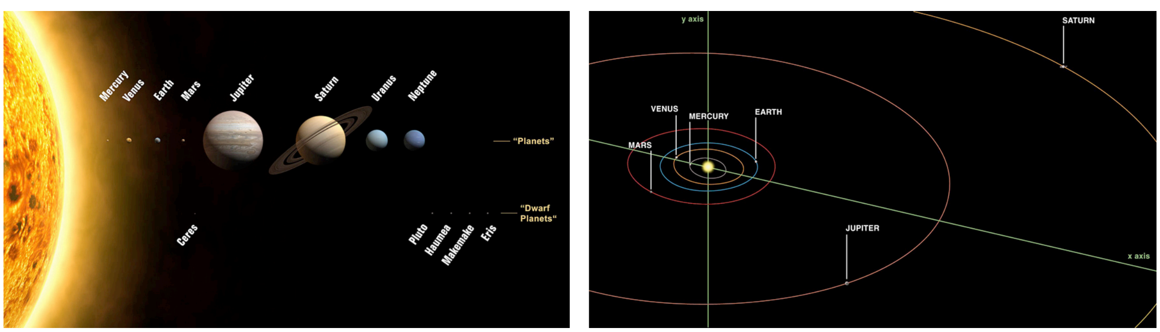

Figure 3. Solar system (http://en.wikipedia.org [2] and http://nasaimage.org [3])

System as rule that guides decision making

The next approach is based on the understanding of system as a set of rules that guide an agent's decision making. In contrast to the first approach that focuses on hierarchy among individual components, the emphasis of this approach is put on the role of the agent in the system, in particular, choices that individual agents can make. This is closely related to the discussion of information system by Kunz and Rittel when they define a system as "constructs of rules and procedures which are meant to serve the desired end" (Kunz & Rittel, 1984, p.57). It is important to note that they bring rules and procedures to their discussion of system. Instead of regarding a system as a piece of hardware that consists of individual components, they are instead interested in the human aspect of system, the agency that operates the system. In this respect, what organizes the second kind of system is rules that are arbitrarily chosen and changeable, not universal laws or truth.

In addition to this concept of agency, it is also important to discuss system as "an argumentative process" that is based on "a model of problem solving by cooperatives." This is articulated in Kunz and Rittel's discussion of an Issue-Based Information System (1970) where *issues* are identified as elements of system along with other elements, such as topics, positions, argument, etc. According to the authors, issues are "brought up and disputed because different positions are assumed" (Kunz & Rittel, 1970, p.2). Therefore, this kind of system leads individuals to continuously make decisions on the issues that are encountered by their reasoning process so that they reach the decision considered the most reasonable among all possible opinions.

One of the most common examples is a flowchart (figure 4). A flowchart is a diagrammatic representation of step-by-step procedures, and each step is connected to the next based on the cascade of issues that arrives at a ultimate solution to a problem. In this respect, flowcharts have been used as a method for problem solving, because they break down the whole process into manageable steps, where issues become focal points that determine the sequence of individual decision-making. Figure 5 is another example of system diagrams that visualizes the lifecycle of EMI Music products and operations. What makes this distinct from other kinds is the use of related environmental issues as color-coded arrows in order to organize key environmental areas, such as manufacturing facilities or music publishing suppliers.

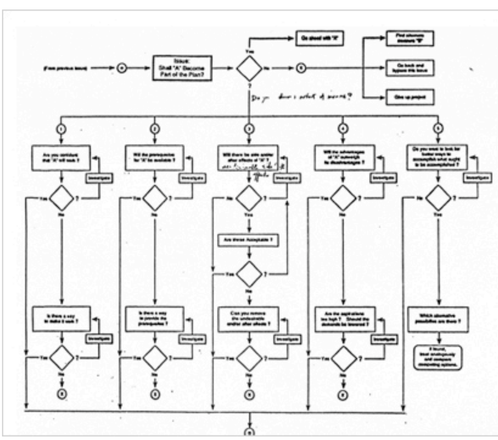
Figure 4. Flowchart [4]

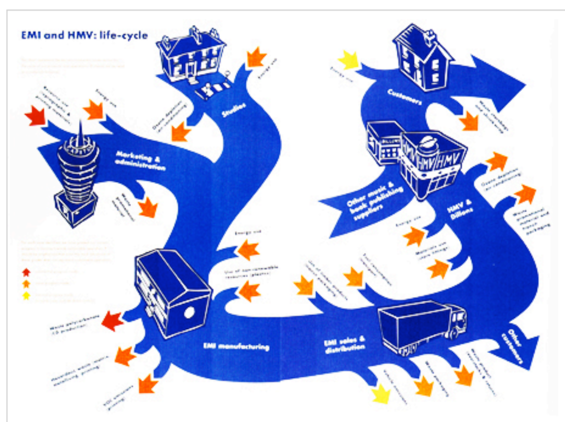

Figure 5. Music product life-cycle [5]

System as function that supports action possibility

The third view is to understand a system as an organic group. This view emphasizes a whole rather than parts, where the characteristic of the whole is lost if mechanically cut into parts. James J. Gibson proposes that human visual perception is not merely a channel but a system that requires all the parts to work together, with explanation that "vision is a whole perceptual system, not a channel of sense. One sees the environment not with the eyes but with the eyes-in-the-head-on-the-body-resting-on-the-ground" (Gibson, 1979, p.205). He further explains that a system has organs, compared to a sense with mere receptors. For Gibson, function is the key relationship that makes an organ a necessary part of the whole, as he states that "the perceptual capacities of the organism do not lie in discrete anatomical parts of the body but lie in systems with nested *functions*" (Gibson, 1979, p.205).

System and relationship in this third approach are especially meaningful within the context of experience design. Experience is our interaction with environment, and environment can be interpreted as a kind of system that supports our action possibility. However, it is not the case that any surrounding can serve as environment for an organism. Following Gibson, the environment and the animal are inseparable because the animal modifies the environment and the environement shapes the action of the animal. Therefore the environment *affords* the animal, in the sense that the environment as the system provides the function of good or bad. Based on this relationship of function, Gibson presents his theory of *affordance*, which can be explained as a necessary relationship of the ever-changing interaction between a living anmial and the environment.

An example of system diagram from this approach could be an airport sign system (figure 6). We may not easily recognize individual signs as affordance until our situation calls for the need to understand the function of each sign and how they work together in holistic relationship, in order to achieve our goal using this sign system. When the action-takers find out the relationship, they realize how the signs and maps in the environment work together just as navigating within a huge system diagram. This is the moment when meaningless pieces of signs are related to other signs together, and a surrounding is altered to an environment that provides systematic supports for action possibilities that are open to their different needs and goals.

Figure 6. Cologne-Bonn airport signage system [6] and map [7]

System as condition that facilitates participation in cultural ideals

The fourth kind of principle comes from the transcendent ideas that gives a unity to individual parts. In this approach to system diagrams, individual elements are still a recognizable, yet harmonious interaction among disparate parts of system and become an integrated whole to serve "a higher ethical, spiritual, cultural or aesthetic vision" (Buchanan, 2001a, p.82). In contrast to the three approaches described above, the distinctiveness of this approach is the emphasis on this transcendent whole. The fourth approach regards system as a condition that facilitates participation in these ideals, such as culture, truth, vision, or beauty, depending on the context and the purpose of system diagrams.

At this point, Kenji Ekuan's discussion of the aesthetics of the Japanese lunchbox (1998) can be useful to articulate this further. For Ekuan, the Japanese lunchbox is not merely a physical assortment of different kinds of food. All the ingredients are artistically arranged so that the visual layout pleases the eyes of the person who takes off the lid. However, the real beauty of lunchbox does not come from the skillful arrangement of elements, but from the harmonious integration of all distinct elements. Although individual ingredients are still recognized in this system, what is more important here is the appreciation of the cultural ideal that gives a unity to parts that otherwise remain separate. In this respect, the Japanese lunchbox serves as a symbol that embodies the cultural and spiritual ideal of Japanese culture. Its form and structure become the expression of the ideas of beauty as function or unification in diversity that is deeply embedded in Japanese culture.

Figure 7 is an example that illustrates this approach – a Tokyo subway map designed by Richard Wurman for the *Tokyo Access* guide (1984). In this map, what is first noticed is the symbol of yin yang along with the Imperial Palace marked as a red circle. When he created this subway map to emphasize the connections of two lines with reference to a familiar landmark, he deliberately altered the form of actual subway lines (left) to the yin yang symbol (right) so as to make it easier to understand and remember. In this example, the use of symbol is effective not merely because it simplifies the form of lines into an easily recognizable symbol. What is more important is that it symbolizes an idea of Japanese culture in its form, which organizes individual functional components (subway stations) into a unified whole (Japanese culture). In this repect, this can be an example of system diagrams that serves an intended function as well as expresses an idea of culture through its form that transcends individual human experiences.

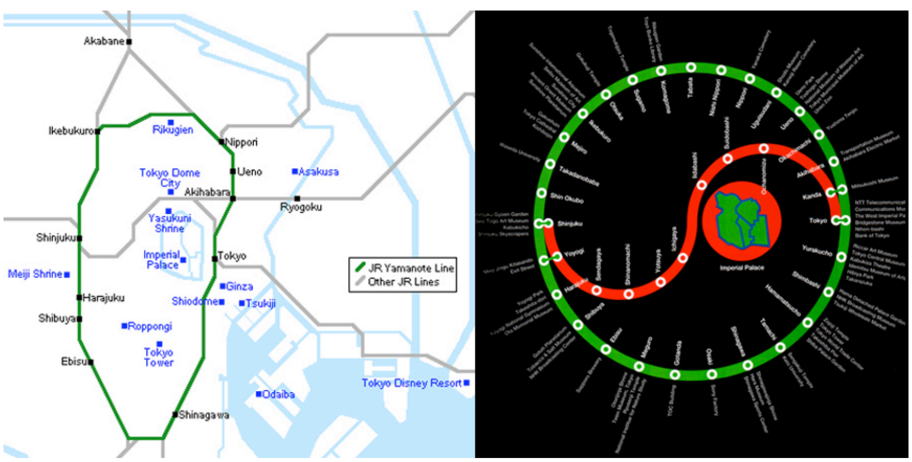

Figure 7. Tokyo subway map [8] and Tokyo transportation system [9]

Case Study: The USPS Domestic Mail Manual Transformation Project

So far we have investigated different kinds of relationships that are found in various system diagram examples. Understanding the relationships of individual components is the key to identify the organizing principle of a system. Then, is it possible to identify these relationships in the context of a design process? If so, what is the primary focus of each relationship in the activity of designing? When designing, system diagrams can be used in various stages of the process in order to serve different purposes of designers using system diagrams. System diagrams can serve as a roadmap at the very beginning of the design process or function as a means of communication with internal stakeholders or with clients during the process. They can also become a final product to inform customers. Although we may point out the distinct characteristic of system diagram examples in different phases of the design process, they can be distinguished one from another depending on the context and the purpose. This also changes the relationship as well as affects its formal representation.

From now on, we will examine how different kinds of relationships emerge in various system diagrams that have been created in a specific design research project. The Domestic Mail Manual (DMM) Transformation Project[1]was an interaction design project that moved beyond the traditional information design approach towards redesign. Similarly to the Australian Tax System design project (Preston, 2004; Body, 2008), the DMM Transformation project focused on designing the information system with a long-term goal of encouraging organizational change in the United States of Postal Service.

The DMM is a 1000-plus-page manual that contains all the mailing standards in the US. It serves as the operational core of a federal agency that employs 800,000 postal workers and supports an industry of more than nine million people. However, this manual did not provide employees and customers the tools to understand mailing options and guidance for making informed decisions because of the complexity, difficulty of use, and inaccessibility of the structure. Therefore, designing the information architecture became the most important concern, especially because the scope of the project did not include changing the actual wording of regulations. Since there was a big discrepancy between the existing topic-based structure and the way users make decisions, "understanding the relationships of the information contained in the DMM was the key to creating a structure that properly reflected the connections and dependencies within the document." (CMU and the USPS, 2005)

For this reason, human-centered design approach became the fundamental principle that guided multiple goals according to different design stages. During the restructuring of the architecture, numerous system diagrams were created to serve various goals. In what follows, we will illustrate four cases of system diagrams according to different goals, to show how the four kinds of relationships we discussed in the previous section are used in an actual design project.

Structure Diagram

One of the fundamental goals of this project was to design a new system architecture that improves efficiency of use. There was also a need to devise a resilient system that could evolve over time. In the initial stage of the project, designers continuously analyzed, tested, and restructured the contents with different versions while working closely with content experts at the USPS to ensure that the details of the structure were

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[1] The DMM Transformation Project (2001-2005) was a research project in the Carnegie Mellon School of Design that was funded by the US Postal Service from 2001 to 2005. (Richard Buchanan, project director; Angela Meyer, project manager)

accurate. Different system diagrams were generated in this process to analyze existing structure (figure 8) and to represent changing architectures. Therefore, we needed a system diagram that focuses on simple and universal hierarchy that would serve as a basic reference point for the ongoing conversation.

After the redesign of the architecture, the team collaborated in fitting the actual content into the new structure. We introduced Adobe Framemaker application because of our concern of how to support the sustainable management of a document with such a complex cross-reference. As time goes by, there would inevitably be a need to change the document as the regulations in the content would be updated. Our solution was to create a working system for the ongoing editing and publication, including software, content, code, and maintenance guidelines, that allows the USPS to continue to develop the DMM. Figure 9 is a diagram of the publishing workflow of the DMM, which was prepared as part of the maintenance guideline. The major relationship depends on the analytical representation of how computer files are co-referenced. When compared to figure 10, which focuses on the architectural analysis, the content does not differ much but the represented relationship does since the need and purpose change. Figure 10 focuses on shape-class-topic hierarchy, whereas figure 9 focuses more on the hierarchy of regulation numbers.

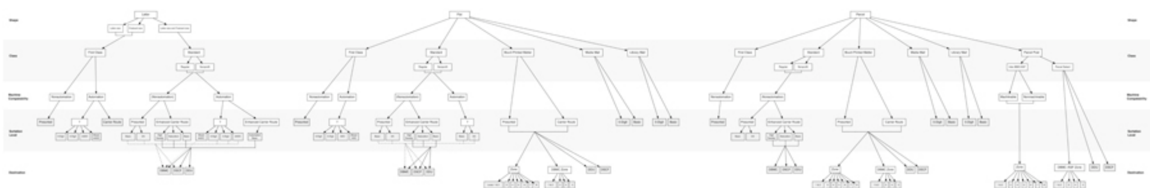
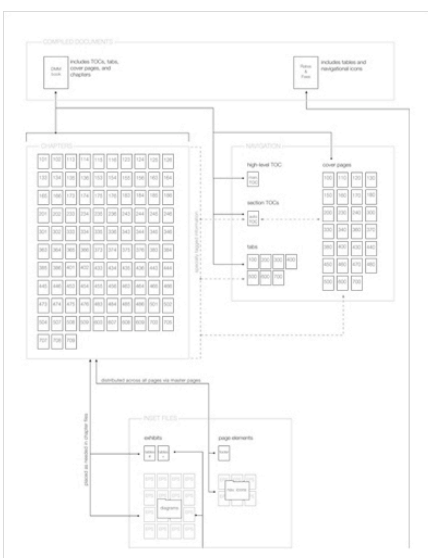


Figure 8. Rate structure analysis



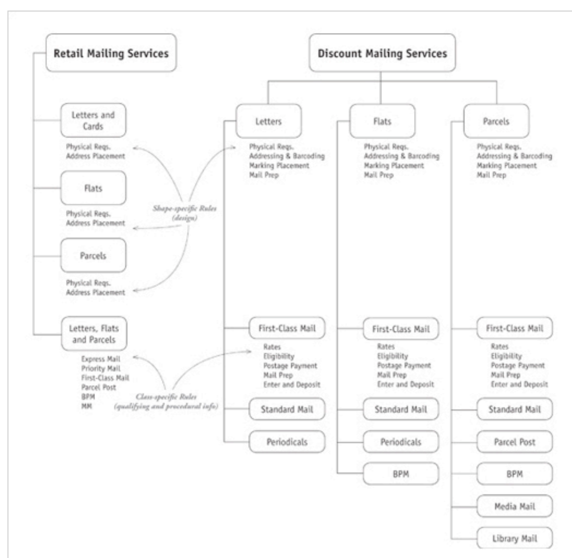


Figure 9. Framemaker file structure

Figure 10. Architectural analysis

Pathway Diagram

Another important goal of the project was "to develop user pathways to help customers find the information that they need in the DMM" (CMU and the USPS, 2005). In order to achieve this goal to guide users to make informed decision, figure 11 was built based on the idea of intuitive user pathways. Here, individual pathways are structured following the logic of decision-making based on cascade of questions that a user would logically ask when trying to decide *whether* and *how* to use the postal service, for instance, "the *issue* of shape" answering the question, "what are you mailing?"

In figure 11, what stands out the most is the connections made by lines with multiple cross-sections that lead to a certain destination, just like subway maps. Selection of this particular form was appropriate not only to emphasize the aspect of pathways but also to serve the intended function of this particular system diagram in the following two ways. First, pathway diagram makes procedure notion apparent so that the connections between modules are recognized as navigable pathways. When transitioning from the phase of redesigning the new information architecture to the phase of fitting the content into the new structure and its detailed adjustment, we needed a new system diagram different from the ones developed in the previous phase. This led us to create a new system diagram for this phase that could promote shared understanding of the team upon the new structure proposed. Second, this diagram was used to manage process and tasks. When we were deconstructing the existing structure of the DMM to fit the content into the new one, this diagram was used to visualize and check the progress as we finished each modules.

This relationship becomes clear when comparing figure 11 to one of the previous iterations for the same purpose (figure 12). In fact, there were some advantages in figure 12 in that the amount of each module and the regulation numbers could be more visible. However, that was not the primary relationship that figure 12 needed to visualize because the idea of navigable pathways that guide decision making process was not apparent. Furthermore, representing each module as book shapes seems to emphasize the materiality of documents rather than the connections between the modules. In a sense, the organizing principle in the figure 12 is closer to static hierarchical organization for structure diagrams.

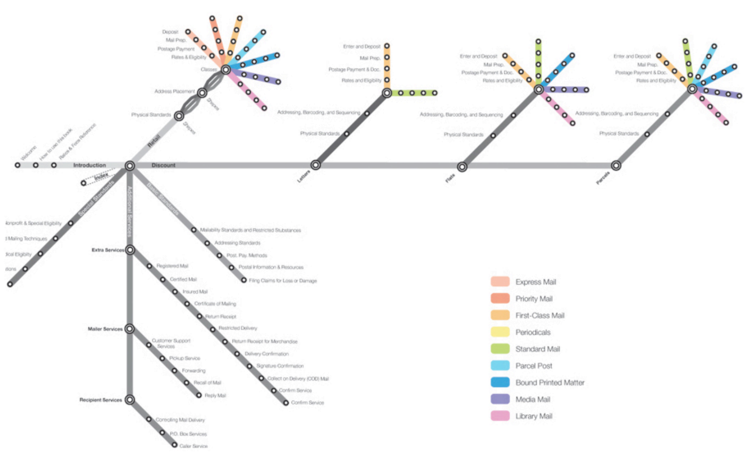


Figure 11. Pathway diagram

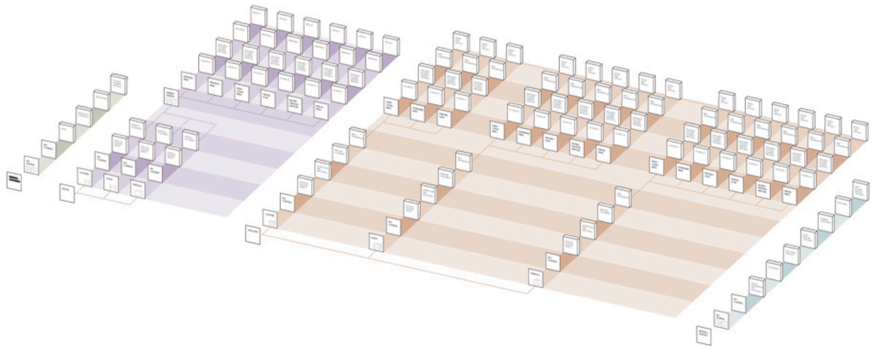


Figure 12. Proposed architecture

Affordance Diagram

Another goal of this project was to create a document that is intuitively meaningful to the user, focusing on an information system that presents the standards from a practical user perspective, that serves pragmatic needs, and is concrete. After we completed the restructuring of the architecture and inserted the content, we realized the need to prepare introductory material for the users. This introductory material was more than just a preface or a table of contents in that the purpose was not just to help the user find certain information. First, as the old DMM has been transformed to the new DMM, there was a need to offer a quick and easy explanation that helped users to understand the difference, and to let them know how to use the new DMM. Second, this introduction material also needed to serve as a promotional piece that encouraged USPS employees to embrace the new document and to educate themsleves.

Figure 13 is the core system diagram that illustrates the document structure of the new DMM. Here, *affordance* is the key organizing principle of this diagram based on the user-centered approach that accommodates users' needs as well as the creation of satisfying user experience by providing intuitive access and a seamless transition. This is articulated in the DMM process book as the following: "A good document architecture does more than just provide categories and arrangements for content. It is designed to create *affordances* for good user experience and is closely informed by users' real needs and expectations" (CMU and the USPS, 2005).

Figure 13 is an example where this relationship of affordance is reflected in various ways. First, it is found in the way the new DMM is physically represented in this diagram. In contrast to other shematic system diagrams, this one imitates the physical aspect of the new DMM, such as the color-coded divider tabs for each section or the binder for the entire volume (figure 14). The idea of a modular approach is also reflected in a similar way to best meet user's needs by modifyng the document. Second, the use of perspective implicitly reinforces this relationship of affordance, in particular by presenting the shape of the new DMM in the moment when opened for use, reflecting users' point of view. In order to use the new DMM, the first step is to assemble the whole documents into a binder for personalzation. This system diagram affords the user's action possibilities for how to assemble this document, not by directly instructing but by indirectly providing one of the major entry points for navigation of the documents. This organizing principle becomes evident when comparing figure 14 to another iteration. Figure 15 may be a more realistic representation of the volumes to some degree, because it shows the hierarchy of thickness of each module. However, this detailed description is not important in the context of user action.

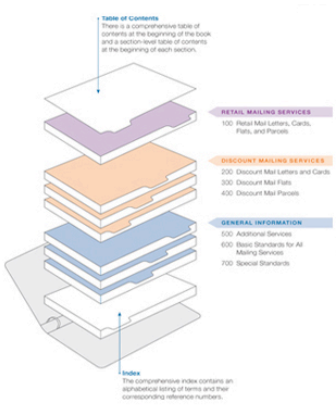


Fig 13. Oganization diagram   Figure 14. New DMM's color-coded divider tabs

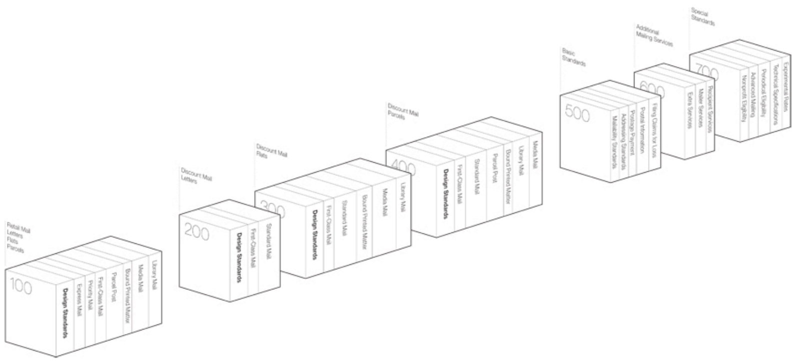


Figure 15. Module system

Vision Diagram

There were specific reasons in our project to encourage the shared vision. First of all, this was an academic project where students were in the continuous process of learning, and the role of the faculty was to stimulate the spirit of inquiry throughout the evolution of the product to create an environment where changing team members can adjust to unfamiliar design problems. The work itself was also complex and fragmented because there were multiple components being developed by different members, and the interweaving of task items required a holistic approach. A clear vision was needed in this process to allow the project to evolve as a whole.

The DMM process book (2005) provides the vision statement as: "the project will design a Domestic Mail Manual that speaks directly to users and tries to meet their needs in the clearest and most efficient ways." This vision of human-centered design remained as the fundamental value and culture in practice that drove the development of process, incorporated diverse people within the USPS system, and facilitated participation in the culture of change. In other words, human-centerdness was not only about the interaction between user and the document. Rather, it was about the culture of the organization that includes internal users, postal employees, and even those responsible for establishing and enforcing regulations. Therefore we needed to share it with the client as well as team members. Moreover, not only was this vision of human-centeredness an ambiguous idea but also was a novel concept at that time, even to the designers who joined the team. For this reason, system diagrams played a critical role in embodying this abstract idea in a visible form to promote its acceptance.

Figure 16 and 17 are examples of system diagrams created for this purpose. Both were made in the early phase of the project and were posted on the wall as roadmaps to maintain our vision. With rich use of symbols which effectively show the perspective and action of users, these diagrams tell the story of mailing as a whole. In comparison, figure 18, which served as the inspirational figure of the project throughout the process, was developed in a later phase when the need to share vision with the client arose. After proposing the initial architecture, we needed to prove that the new shape-base structure would be usable by providing the clients with the first glimpse of what the new DMM would be. The comprehensive nature of figure 18 helped to bring their attention to the high-level organizing principle of "user-intuitive shape" without unnecessary details. At the same time, this diagram sucessfully ensured the client that every piece of information has a logical place within the system, by focusing on the relationship of holistic integrity.

Figure 16. Shape-based framework

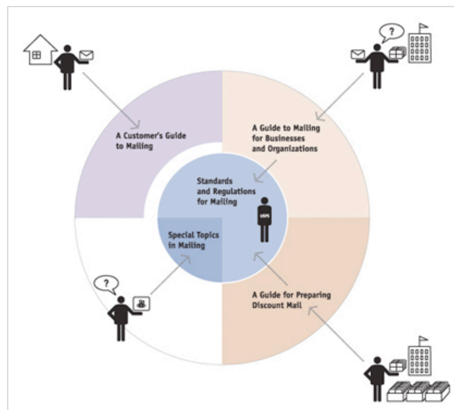


Figure 17. User segmentation and access

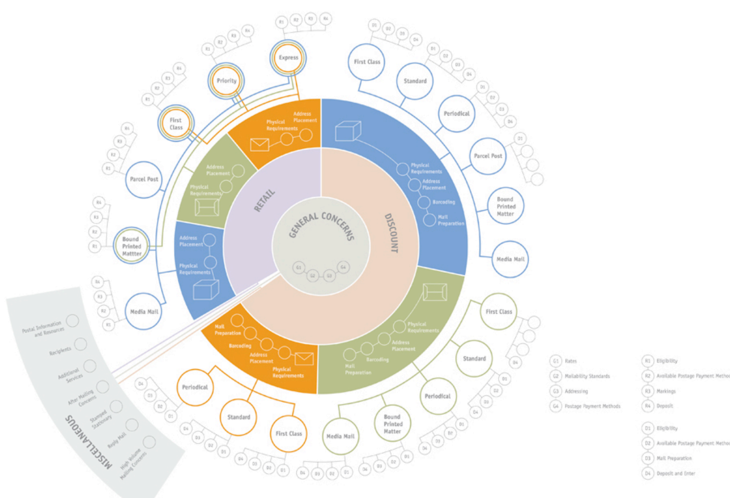


Figure 18. Architectural overview

Conclusion

We have identified four modes of thinking to differentiate relationships with the intention of clarifying the organizing principle of system diagrams. But the purpose of this distinction is by no means to argue which one of the relationship described above is better than the other. All are valuable for advancing the discussion of system diagrams in design and related disciplines. Better understanding of the essence of system diagram will also lead to a shifting perspective from regarding it as a mere data-rich statistical graphic to conceiving it as a place for invention or discovery, depending on various situations.

The situation of use for system diagrams is shifting. The emergence of complex information system, human-centered design, and participatory culture point to a further situational change for how system diagrams will be used, like our case study example. Users are also in need to understand the organizing principle of the complex information system in order to take action. As the problem of design becomes more complex, designers are also facing increased need to work in collaboration with experts from other fields, to bring in clients or users to participate in the design process, and to mediate these different stakeholders' collaborative work. There is a growing need for a system diagram that can work as a reliable reference tool and a shared structure to support group work in such a situation where multiple stakeholders are engaged.

What is needed in this situation is high-level thinking that will help designers foster different modes of thought to utilize designers' reasoning, while at the same time serve as a reference point that guides the direction for designers' reflective arguments. This research will contribute to design education and practice by broadening designers' understanding of the nature of systems, classifying system diagrams used in the design process according to its purpose, and by exploring its potential use for supporting users' action and shared group vision.

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