

A WEB-BASED USER-ORIENTED TOOL FOR UNIVERSAL KITCHEN DESIGN

by

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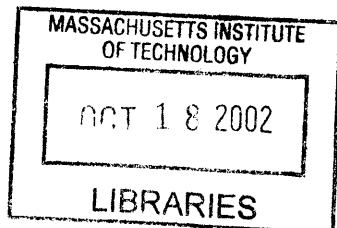
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ROTCH!

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Requirements for the Degree of Master of Science in
Architecture Studies

ABSTRACT

Economic constraints to the professional design practice limit customized solutions to the very wealthy, and thus most of the kitchens in current development housing projects are still generic. With aging baby boomers and an increasing number of survivors of disability, diversified user needs require professional housing design to accommodate all different individuals, which challenges current design standards. Based on universal design principles, a user-oriented tool for universal home design provides more than a few homebuyers with a chance to take advantage of professional design. Kitchen layout design is taken as the starting point of the home design, since the kitchen has the most complex functional requirements and the most difficult barriers of any room in the house. The tool takes user needs as the design motivation and professional best design practice as the database. For the majority of lay people, this tool makes it possible for them to orient their own kitchen design through a guided searching of proper design strategies according to the user needs and preferences. It highlights the needs of particular users at different ages and physical conditions according to the universal design principles. A direct typological conversion is implemented to link user needs with design strategies.

This paper is also the documentation of the universal home design tool project in the House_n Consortium at MIT. The paper takes the project as the main example for stating the possibility and feasibility of the new design methodology.

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A Web-based User-oriented Tool for Universal Kitchen Design

1 Goals

1.1 Problems of generic kitchen design in development housing projects

A properly designed kitchen is essential for maintaining independence of living, as it has the most complex functional requirements of any room in the house and presents the most difficult barriers for those with frailties. In the current development housing projects, economic constraints to professional design practice limit customized solutions to the very wealthy, and thus most kitchens are still generic.

1.1.1 Economical constraints to the professional design in the development housing projects

Professional design in housing projects is limited only to the very wealthy. Figure 1-1 shows an estimate of professional design working in all cost-range housing typologies. Except for extremely high-cost housing designed by architects and the typical development housing, most of the cost range represents housing without professional design. For the vast majority of new housing projects, due to the high cost to listen to the homebuyers' opinion, which is unrealistic in development housing, architects can only make generic design to accommodate the average buyers: typically middle-aged adults in good health. However, only a small percentage of users fit for this profile. Most users especially those who may be functionally limited by age or disabilities can hardly meet the "average" standards. Hence, most homebuyers except the very wealthy seldom have a chance to directly take advantage of professional designers.

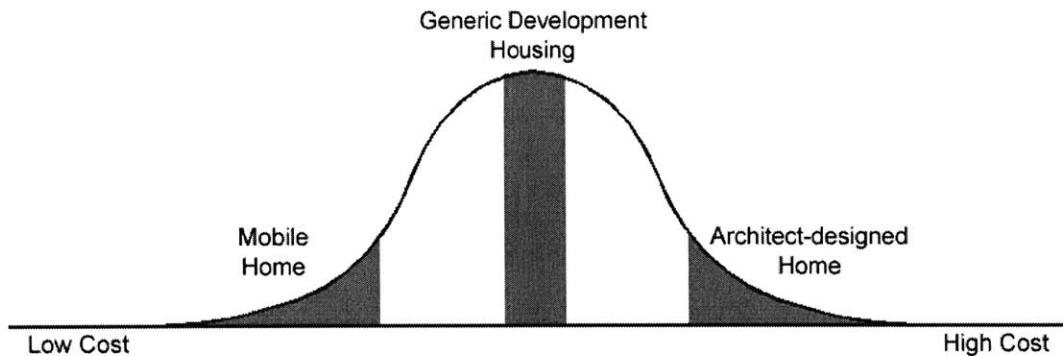


Figure 1-1. Professional design in all cost-range housing projects

1.1.2 Diversified user needs to challenge current design standards

With aging, baby boomers and an increasing number of survivors of disability, user needs are rapidly diversified. Seniors, young babies, and the handicapped receive more and more social attention. While many building codes, such as ADA (Americans with Disabilities Act), especially emphasize the design for the handicapped, housing solution that can accommodate everyone, namely universal design that will be introduced in depth later, has not been paid enough attention by the majority of architects due to several reasons:

- (1) As mentioned above, the current development housing system only allows architects to design housing that accommodates the average user group. Although this kind of new housing can meet ADA and other building codes, it is not the design that fully addresses the needs of seniors, young babies and people with certain physical limitations.
- (2) Most architects have little detailed knowledge about universal design. Although this concept was coined twenty years ago, there has been little systemized education about universal design both in architectural education and development housing projects.

- (3) Currently the majority of housing codes emphasizing design for the handicapped are scattered. Also the best universal design practices and strategies are isolated from the context of home design. It is difficult for architects to collect all the information in order to systematically start the design that accommodates to every individual's needs.

1.1.3 Increasing user needs to demand the media between homebuyers and builders

Thomke and Hippel at the Harvard Business School indicated that although many developers understood the importance of homebuyers' needs for the housing projects, the difficulty that prevented them from carefully listening to customers' opinions is that this is often a costly and inexact process. Moreover, even when customers knew precisely what they wanted, they often could not transfer that information to manufacturers clearly or completely. Since face-to-face interviews are unrealistic in most development housing projects, particular user needs or ideas have been neglected.

Because generic kitchens cannot fulfill most homebuyers' needs, certain user-oriented design tools is coming to be the communicative media between homebuyers, builders and manufacturers.

1.2 Prospect on the existing user-oriented kitchen design tools

Actually, many kitchen manufacturers now equip users with web-based tools to develop their own kitchen. There are mainly two sorts of such tools: design guides or questionnaires and automatic design tools.

1.2.1 Design guides and questionnaires

Design guides and questionnaires are used to educate lay people how to prepare kitchen design. They are mostly static product introductions or design expertise. The best are straightforward and easy for lay people to understand the relevant knowledge, but difficult to integrate this information. Strictly speaking, these guides or questionnaires are not design tools because they lack an interactive input and output environment.

Below are several examples of design guides and questionnaires:



Figure 1-2. Excerpt from <http://www.kitchens.com>

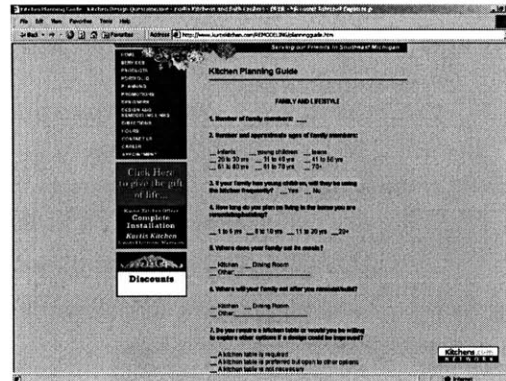


Figure 1-3. Excerpt from <http://www.kurtiskitchen.com>



Figure 1-4. Excerpt from <http://www.kitchenssw.com>

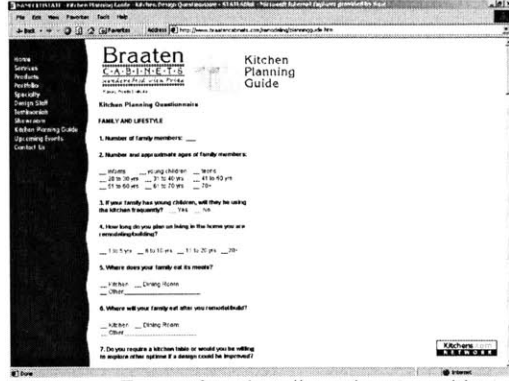


Figure 1-5. Excerpt from <http://www.braatencabinets.com/>

1.2.2 Automatic design tools

Kitchen manufacturers have been presenting more and more automatic design tools, which deploy new technologies like computer graphics and rapid prototyping. With these tools, users can drag kitchen parts such as appliances, drop them together, and obtain a computer-generated design result. Certain design results interest lay people and help them to understand kitchen design in an interactive way. However, these tools usually do not place the design in the context of activities or adjacent spaces. Few take into account the user needs and design strategies. This kind of design process, therefore, is still “tool-oriented” instead of “user-oriented”. Limited to the dragging and dropping of elements, they are not effective in helping lay people make informed design decisions.

Below are some examples of automatic kitchen layout design tools in the current market:

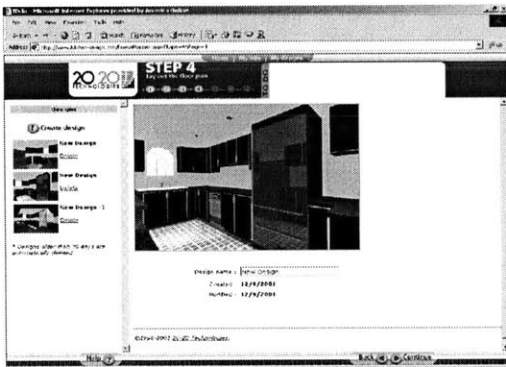


Figure 1-6. Excerpt from <http://www.kitchen-design.com>

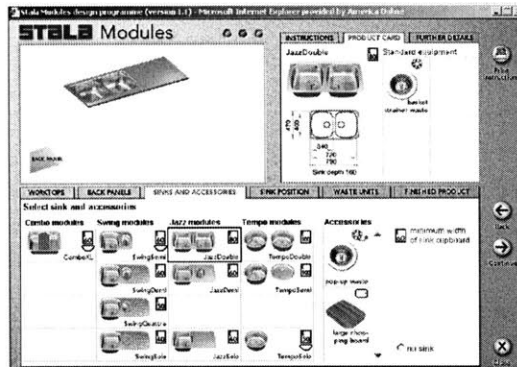


Figure 1-7. Excerpt from <http://www.stala.fi>

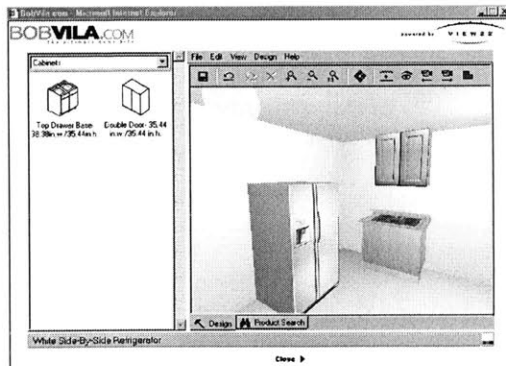


Figure 1-8. Excerpt from <http://www.bobvilla.com>

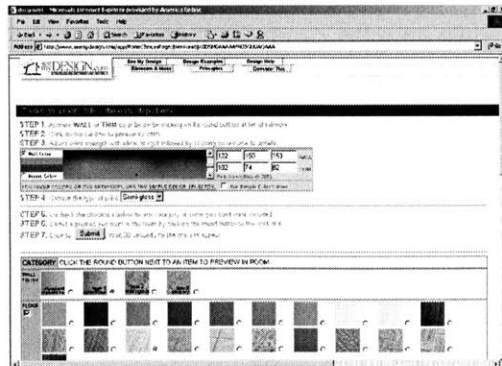


Figure 1-9. Excerpt from <http://www.seemydesign.com>

1.3 Goals of the user-oriented tool for universal kitchen design

The user-oriented tool proposed in this paper is expected to reach the following goals:

1.3.1 To develop a tool for lay people to implement universal kitchen design strategies

The new tool will be an implementation of the design strategies that meet both “general” requirements and the needs of particular users of different ages and physical conditions. It embeds universal design into the design process. It is also an effective means to collect universal kitchen design information including design standards and product introductions, with which it educates and informs homeowners about the benefits of universal design to their particular lives. Universal design will be introduced in depth later in this paper.

1.3.2 A web-based user-oriented design tool

The new tool will be an interface to help users assume a more active role, recognize their own expertise, express their particular needs, evaluate the design, and make independent decisions for the design results. The educational objective is therefore important in this approach. Moreover, this approach as a web-based automatic design tool, is towards more than just the very wealthy, and therefore should be free to all and especially user-friendly for lay people.

1.4 Introduction to the project

The project is prepared for the universal home design website of AARP. Kitchen layout design is taken as the starting point for the user-oriented universal home design tool, as it is difficult to live independently if people cannot prepare his/her own meals. Moreover, the kitchen has more barriers than any other room in the home, which makes it an ideal place for involving the users’ daily life experience, meeting functional requirements, satisfying user preferences, and applying universal design strategies.

This paper is focused on the conversion from user preferences to the design solutions where universal design strategies are embedded. Hence, the first phase of the project will be introduced in depth for supporting the main point of the paper while other phases will be simply introduced for maintaining a complete look of the project.

2 Universal design

2.1 Concept

2.1.1 Definition

According to research at the Center for Universal Design at the School of Design in North Carolina State University, “universal design is the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design.” The intent of universal design is to simplify life for everyone by making products, communications and the built environment more usable by as many people as possible at little or no extra cost. Universal design benefits people of all ages and abilities.

Universal home design provides housing solutions that can accommodate everyone including the handicapped as well as the normal, old as well as young, women as well as men, short people as well as tall, left-handed people as well as right-handed. It increases the usability of the home for people to independently live in their own home for as long as possible. A typical universal kitchen design strategy is to provide multiple heights of counter tops so that all family members, including those seated in wheelchairs, are able to help prepare meals.

2.1.2 Universal design and accessible design

According to Steinfeld, universal design is different than accessible design. Accessible design means products and buildings that are accessible and usable by people with disabilities. Universal design means products and buildings that are accessible and usable by everyone including people with disabilities. Although these different definitions appear to be simply semantic, they actually have significant differences in meaning. Accessible design has a tendency to lead to separate facilities for people with disabilities, for example, a ramp set off to the side of a stairway at an entrance or a wheelchair accessible toilet stall. Universal design, on the other hand, provides one solution that can accommodate people with disabilities as well as the rest of the population. Moreover, universal design means giving attention to the needs of older people as well as young, women as well as men, left handed persons as well as right handed persons. An entrance that is designed to be "universal" would not have stairs at all. Over the last several years there has been a growing interest in universal design as an alternative to accessible design.

2.2 Background

Over 20 years ago, the architect Ron Mac coined the term “Universal Design”. Universal design, as a developing design trend, has demographic, legislative and technological backgrounds. Steinfeld in his study indicated several reasons for the growing interest in universal design as a promising design trend over the last several years. Below introduces the research at the School of Design in NCSU that has kept track of the development history of universal design over the last century.

2.2.1 Increasing life spans

Over the last century, people have been living longer and healthier lives. The average lifespan has increased to 76 from 47 years at the beginning of the 20th century, largely due to healthier living, better medicine, vaccines, and sanitation that have virtually eliminated many killer infectious diseases (The Denver Post, 1998). Nearly 80% of the population now lives past the age of 65. Moreover, projections based on U.S. Census Bureau estimates indicate that the

number of persons aged 65 and over will grow to almost 40 million by the year 2010 (Jones and Sanford, 1996). By 2020, the Census Bureau estimates that 7 million to 8 million people will be over age 85 and 214,000 will be over age 100. By contrast, at the end of World War II, only 1 in 500 made it to age 100 (The Denver Post, 1998).

The increasing life spans draw more and more attention to the home designers and manufacturers. Older adults have been identified not as minorities but an important part of population, with more important roles in families. Thus, the design standards based on the "majority" of the population are thereby challenged by the changing demographics.

2.2.2 An increase in the number of survivors of disabilities

More people are now living with disabilities. Antibiotics and other medical advances enable people to survive accidents and illnesses which were previously fatal. At the end of 1994, 53.9 million people in the United States (20.6% of the population) had some level of disability, and 26.0 million (9.9%) had a severe disability. It is estimated that among the population 6 years and older, 8.6 million people had difficulty with one or more activities of daily living (ADLs) and 4.1 million needed personal assistance of some kind (McNeil, 1997).

2.2.3 Increasing purchasing power among the elderly and disabled populations

The demographic changes show that potential consumers of design who may be functionally limited by age or disability are increasing at a dramatic rate. As they become integrated into general community life, hold jobs and earn more money, they begin to exert influence on the design of mass marketed products. One of the most significant social trends has been the development of the "gray market." Consumers over 65 have the highest discretionary income in the U.S. It is estimated that the population over 50 years of age, which includes most middle age people as well as the aged, amounts to an \$800 billion market. This group controls 56% of all discretionary income. For example, they purchase 60% of all domestic cars and own 50% of all homes.

Moreover, the current generation of children, baby boomers entering middle age, older adults, people with disabilities, and individuals inconvenienced by circumstance, constitute a large market. The limitations imposed by products and environments designed and built without regard to the needs and rights of all groups of users are significant but often unrecognized. To accommodate individual differences among increasingly diverse clientele, universal design provides a blueprint for maximum inclusion of all people.

The increasing "globalization" of the marketplace, as the emerging economic trend, also results that the diversity of the consumer base is expanding to include differences in language, and culture, customs, experiences, and historical design precedents. All of these increase the need for design that is sensitive to individual abilities and preferences. Because reasonable cost is a fundamental issue in any design and production process, universal design has become a very marketable approach, since it addresses the diverse needs of a majority of consumers.

2.2.4 Recognition of inadequacies of assistive technologies

Rehabilitation engineering and assistive technology emerged in the middle of the 20th century. Efforts to improve prosthetics and orthotics intensified with the return of thousands of disabled veterans from World War II in the 1940s. During the 1950s, engineering research centers sponsored by the Veterans Administration and other federal organizations were established to address other technological problems of rehabilitation, including communication, mobility, and transportation. Rehabilitation engineering centers expanded during the 1960s and 1970s.

Rehabilitation engineering became a specialty that applied scientific principles and engineering methodologies to these problems. The label, "assistive technology," was applied to devices for

personal use created specifically to enhance the physical, sensory, and cognitive abilities of people with disabilities and to help them function more independently in environments oblivious to their needs.

Despite the increasing economic power of the older population and people with disabilities, there are many gaps in the market place. Many special products, i.e. assistive technology, are Band-Aid approaches to deficiencies in general consumer product design. The same can be said about accessibility features in public buildings or "adapted" housing. Research on consumer acceptance of assistive technology has demonstrated that people do not like the medical/technical appearance of these products. They are also too expensive, hard to find, unreliable and difficult to repair. Perhaps one of the most significant limitations is that consumers see them as stigmatizing; "special" products and environments promote a negative self-concept. Increasingly, the proponents of disability rights and design professionals have come to realize that the concept of accessible design has to be rethought.

The less developed countries share some of the same trends as the highly developed countries. They also are experiencing an increase in survivors of disabilities and, in some cases, increasing life spans. However, in these countries, assistive technology is much more costly and hard to find. In some countries it is simply outside the reach of most people in the population. These countries have a need to control public welfare costs as well; moreover, the stigma of disability can be much greater. For these reasons, universal design makes a great deal of sense as an alternative to accessible design because it can be more generally available at lower costs than assistive technology or specialized settings. With the advent of an independent living movement in the less developed countries, there is an opportunity to avoid the trap of special products and special places.

2.2.5 Conclusion

Public acknowledgment of elderly people and people with disabilities and progress toward universal design has developed in the last few decades. It is important to note that the term universal design does not imply that everything in this world be fully usable by everybody but refers more to a goal to be reached and an attitude rather than a strict absolute. It is also important to note that there is no clear line between the categories of young and elderly people as well as healthy and disabled people. Therefore, universal design fills up the gap having been arbitrarily defined between "majority" group and "minority" group by advocating the design with the maximum generosity and tolerance.

2.3 Categories

Universal design includes two categories: universal design guidelines, which are obligations of all the new design, and universal design products, which can be choices for users to make for a better environment.

2.3.1 Universal design guidelines

Universal design guidelines are to be compliant with ADA and other building codes. For instance, in any kitchen layout design, there should exist or potentially exist a space for a wheelchair to turn around, which is no smaller than a circle area 5-feet in diameter. In the application part of this paper, universal kitchen design guidelines will be especially addressed, based on which kitchen layout variations are generated and the relevant interfaced are accomplished.

Moreover, universal design guidelines also address the product usability for seniors and people with different physical limitations besides wheelchair users. For instance, seniors are usually shorter than when they were younger and their arms are less strong so that reaching a higher

position becomes a problem. Universal design is supposed to locate upper utensils such as upper wall cabinets at different or flexible heights to fit for all. The majority of these guidelines are based on the best practices of universal design.

2.3.2 Universal design strategies

Based on universal design guidelines, universal design strategies are mostly carried out with the best practices of professional designers. These strategies can be either bright design ideas or marketable products that improve the design. In the next two sections, principles of generating universal design strategies and the samples of universal kitchen design implementations are presented.

2.4 Principles of universal design implementations

According to the research in the Center for Universal Design at the School of Design in North Carolina State University, there are several principles to implement universal design. Universal kitchen design is used as the example to explain each principle.

2.4.1 Equitable use

The design is useful and marketable to people with diverse disabilities. It should provide the same means of use for all users and avoid segregating or stigmatizing any users. Provisions for privacy, security and safety should be equally available to all users.

In the universal kitchen design examples introduced in the next section, all the products are available in the current market. Universal design pays attention to a wide range of disabilities including visual impairments, hearing impairments, physical impairments, and cognitive impairments. In this paper, users with physical impairments, from people with arthritis to wheelchair users, are especially mentioned.

Equitable use of universal design provides users with easy access to the design by referring design directly to the products available in the market.

2.4.2 Flexibility in use

The design accommodates a wide range of individual preferences and abilities. For instance, should provide choice in methods of user, accommodate right-handed or left-handed access, facilitate the user's accuracy and precision, and provide adaptability to the user's pace.

In the universal kitchen design examples introduced in the next section, more than one product to meet the same goal is provided to make diversified choices. For instance, when serving people with limited ability to grip, there are several kinds of water faucets including a single-lever control that fits people with limited ability to grip, The EZ-Flo water control valve can be used for people with extremely low grip ability to turn on water without touching the faucet. Flexible uses enlarge the consideration scope for users in different physical conditions.

2.4.3 Simple and Intuitive use

Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level. It should eliminate unnecessary complexity, be consistent with user expectations and intuition, accommodate a wide range of literacy and language skills, arrange information consistent with its importance, and provide effective prompting and feedback during and after task completion.

Simple and intuitive use is important in a kitchen since all kitchen parts are used in everyday life and by every family member.

2.4.4 Perceptible information

The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities. It should provide different modes for redundant presentation of essential information, provide adequate contrast between essential information and surroundings, maximize legibility of essential information, differentiate elements in ways that can be described and provide compatibility with a variety of techniques or devices used by people with sensory limitations.

People with low vision and hearing abilities always expect high resolution and high contrast in perceptible information. For instance, contrasting-color front edges of the counter tops can help people with vision impairment to determine the exact location of the counter to minimize accidents.

2.4.5 Tolerance for errors

The design minimizes hazards and the adverse consequences of accidental or unintended actions. It should arrange elements to minimize hazards and errors, provide warnings of hazards and errors, provide fail-safe features, and discourage unconscious action in tasks that require vigilance.

2.4.6 Low physical effort

The design can be used efficiently and comfortably with a minimum of fatigue. It should allow user to maintain a neutral body position, apply reasonable operating forces, and minimize repetitive actions and sustained physical efforts.

A typical example is diverse drawers or other parts of lower cabinets that provide easy access to storage without difficult reaching too deep, high or low locations.

2.4.7 Size and space for approach and use

Flexible size and space is provided for approach, reach, manipulation, and use regardless of the user's body size, posture, or mobility. It should provide a clear line of sight to important elements for any seated or standing user, making the reach to all components comfortable for any seated or standing user. It should also accommodate variations in hand and grip size and provide adequate space for the use of assistive devices or personal assistance.

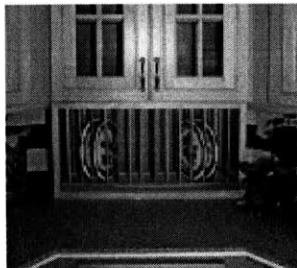
A typical example is to vary the height of counter tops to accommodate family members who usually stand or sit when preparing meals.

2.5 Examples of universal design products and strategies

2.5.1 Upper cabinets

Strategies:

- I. Lower the cabinets to the cook's level especially for those who are shorter, seated or have physical limitations of reaching.
- II. If more than one cook share the kitchen, consider installing the cabinets at varying heights to satisfy different physical needs.



An open, vertical rack to hold platters and serving plates without stacking.

(<http://www.aarp.org/universalhome/kitchen/>)



Place upper cabinets at the optimal reach-level for the family members instead of a standard level.

(<http://www.aarp.org/universalhome/kitchen/>)



Under the cabinet, pull down a spice organizer and tuck it underneath the upper cabinet when not in use.

(<http://www.organizes-it.com/cabinorg.htm>)



Pull-down shelves in a wall cabinet make frequently used items easily accessible to short and seated users.

(<http://www.oznet.ksu.edu/atid/Housing%20Links%20&%20Resources/UDF/images/>)



The wall cabinet can be motorized to allow access by a seated user. With a press of a button, approach for the cabinet provides a 20-inch range of adjustment. It can move cabinets down to meet a standard height counter, or one that is 34-inch high.

<http://www.oznet.ksu.edu/atid/Housing%20Links%20&%20Resources/UDF/images/>

Table 2-1. Universal design solutions about upper-cabinets

2.5.2 Lower Cabinets

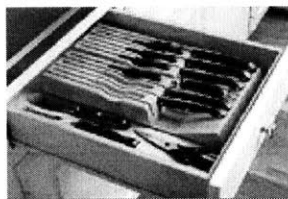
Strategies:

- I. Organize things with all kinds of drawer organizers.
- II. Install full-extension drawers that pull out further to easily reach the items in the back.
- III. Lazy Susan and door shelves allow easy access without difficult reaching
- IV. Pullout storage units allow easy access without long reaching.



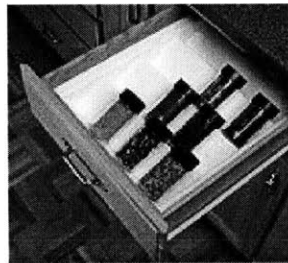
Cutlery tray.

(<http://www.organizes-it.com/drawerorg.htm>)



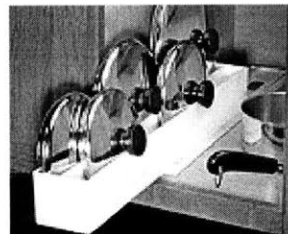
Knife tray.

(<http://www.organizes-it.com/drawerorg.htm>)



Flavor tray.

(<http://www.kitchen-organizers.com/>)



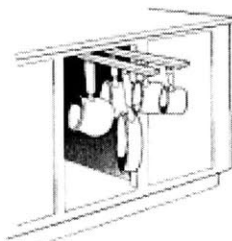
Lid Maid Cabinet Organizer.

(<http://www.organizes-it.com/cabinorg.htm>)



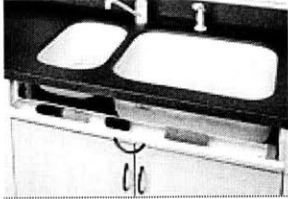
A vertical rack for cutting board, small trays, lids, pie plates and serving plates.

(http://www.hrdc-drhc.gc.ca/hrib/sdddds/odi/documents/help_yourself/chap2.shtml#Top)



Pullout sliding racks for small pots that hang, under lower cabinets can also hold heavy pots and pans.

(http://www.hrdc-drhc.gc.ca/hrib/sdddds/odi/documents/help_yourself/chap2.shtml#Top)



Tray for placing cleaning utilities next to the sink.

(<http://www.kitchen-organizers.com/>)



A pullout double waste container for trash separation and recycling on full-extension slides for convenient accessibility.

(<http://www.kitchen-organizers.com/>)



A pullout base organizer will provide excellent storage in base cabinets. Reversible for non-handed operation.

<http://www.kitchen-organizers.com/>



A pantry and utility cabinet lazy Susan and door shelves allow access without difficult reaching.

<http://www.oznet.ksu.edu/atid/Housing%20Links%20&%20Resources/UDF/images/>



Rollout shelves in base cabinets bring the item to the user without a long reach.

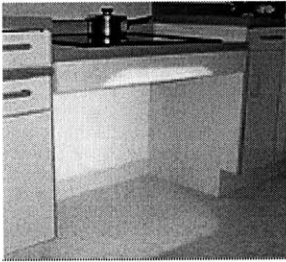
(<http://www.kitchen-organizers.com/>)

Table 2-2. Universal design solutions about lower-cabinets

2.5.3 Counter tops

Strategies:

- I. Vary the height of the counters so that the whole family can help with meal preparation.
- II. Choose countertops with rounded edges to reduce the risk of injury.
- III. Use heat resisted, easy cutting materials as partial counter.
- IV. Counter tops have contrasting-color edges and back splashes to assist low-vision users.
- V. Lighting under counters is helpful to low-vision users.



Counter tops have contrasting-color front edges and back splashes and lighting under the counter to assist low-vision users.

(<http://www.oznet.ksu.edu/atid/Housing%20Links%20&%20Resources/UDF/udf.htm#ushape>)



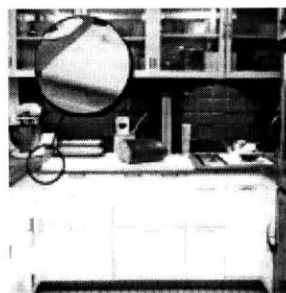
A built-in pullout shelf provides a lower work surface for a seated user.

(<http://www.oznet.ksu.edu/atid/Housing%20Links%20&%20Resources/UDF/images/shelf.jpg>)



Heat-resistant countertop next to the cooktop and the microwave can provide a safe place to rest hot dishes when they come out of the microwave. Wheelchair users can slide hot pots from the cooktop onto the heat-resistant countertop without having to lift them.

(The cook book)



Easy-cutting material for partial counter as cutting boards.

(The cook book)



A mix center installed on a crank-operated unit can be raised or lowered to the easiest work height.

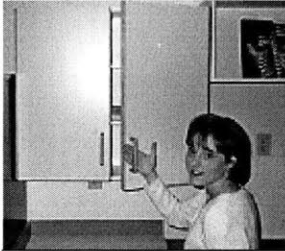
(<http://www.oznet.ksu.edu/atid/Housing%20Links%20&%20Resources/UDF/images/crank.jpg>)

Table 2-3. Universal design solutions about counter tops

2.5.4 Counter doors

Strategies:

- I. D-shaped cabinet door handles are easier than round knobs to grasp by persons with limited ability to grip.
- II. Doors with magnetic latches are easier to open simply by pushing and releasing the door and require very little hand strength or dexterity.



D-shaped cabinet door handles are easier than round knobs to grasp by persons with limited ability to grip.

(<http://www.oznet.ksu.edu/atid/Housing%20Links%20&%20Resources/UDF/udf.htm#ushape>)

Table 2-4. Universal design solutions about counter doors

2.5.5 Refrigerators

Strategies:

- I. The side-by-side refrigerator makes both freezer and refrigerator accessible to all users.
- II. An automatic ice dispenser eliminates the need for homeowners to carry trays of water to the freezer or struggle while removing ice from trays.



A freezer at an accessible height.

(<http://www.kitchensystems.com/handicapped.htm>)



An automatic ice dispenser.

(http://www.geappliances.com/specsheet/gea/generic_frameset.htm?/specsheet/gea/tft20jrbww/tft20jrbww.html)



The side-by-side refrigerator makes both freezer and refrigerator space accessible to all users.

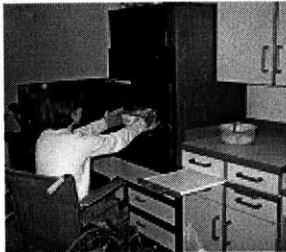
(<http://www.oznet.ksu.edu/atid/Housing%20Links%20&%20Resources/UDF/images/refrig.jpg>)

Table 2-5. Universal design solutions about refrigerators

2.5.6 Wall-mounted ovens and microwave ovens

Strategies:

- I. Microwave oven can be placed at child-usable height with landing space nearby.
- II. The wall oven should have a side-opening door that eliminates reaching over a hot door.
- III. The wall oven should be installed at a height accessible to a seated user and has a side-opening door.



A wall-mounted oven at an accessible height.

(<http://www.oznet.ksu.edu/atid/Housing%20Links%20&%20Resources/UDF/images/oven.jpg>)



A microwave oven at an accessible height.

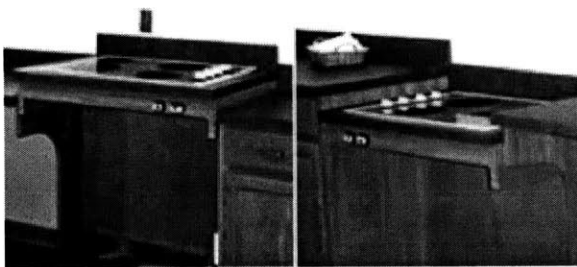
(<http://www.oznet.ksu.edu/atid/Housing%20Links%20&%20Resources/UDF/images/microwav.jpg>)

Table 2-6. Universal design solutions about wall-mounted ovens

2.5.7 Cooktops

Strategies:

- I. The newer cooktops feature recessed burners that lie below a smooth, glass top, which are safer to use and easier to clean.
- II. Front or side controls eliminate the need to reach across hot burners, reducing the risk of clothes catching on fire.
- III. Push-button controls are easier to use for people who have trouble grasping knobs.
- IV. A special residual heat indicator lights to remind the cook which cooking surface is hot, even after they turn off the burners.
- V. Contrasting-colors will help people with visual impairments distinguish between hot and cool areas.
- VI. A downdraft venting system eliminates the need for a vent hood. Downdraft venting systems have vents at the center or at the back of the cooktop.
- VII. A mirror mounted above the stove can help a wheelchair user see into cooking pots.



Cook tops can be motorized to accommodate all the family members or cooking activities. The 36-inch wide counter shown accommodates most 30-inch cooktops. For more workspace, a counter up to 48-inch wide can be provided.

(http://www.ad-as.com/kb/approach_cook.htm)

Table 2-7. Universal design solutions about refrigerators

Dishwashers

Strategies:

- I. Raise the dishwasher about 8 additional inches to make it easier to load and unload without a lot of bending or stooping and used by a wheelchair user.
- II. The dishwasher should be installed next to a chair-accessible space.
- III. Countertop dishwashers are especially fit for wheelchair users.



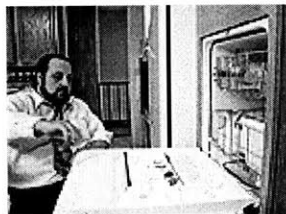
Raising the dishwasher about 8 additional inches from the floor will make it much easier to load and unload without a lot of bending or stooping when used by an individual in a wheelchair.

(<http://www.oznet.ksu.edu/atid/Housing%20Links%20&%20Resources/UDF/images/dishwash.jpg>)



The dishwasher should be installed next to a knee clearance space.

(<http://www.oznet.ksu.edu/atid/Housing%20Links%20&%20Resources/UDF/images/dish.jpg>)



The small countertop dishwasher can be mounted at an accessible height for wheelchair users.

(<http://www.hometime.com/projects/howto/access/pc2aces4.htm>)

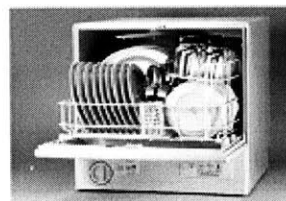
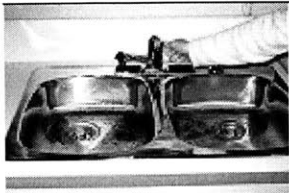


Table 2-8. Universal design solutions about dishwashers

2.5.8 Sinks

Strategies:

- I. Water faucets with single-lever controls are easily used by persons with limited ability to grip.
- II. Sinks should be set at a proper height for wheelchair users.
- III. Adequate knee space under the sink is needed for a seated cook.
- IV. A spray hose attachment for rinsing dishes or vegetables is needed.



Water faucets with single lever controls are easier to use by persons with limited ability to grip.

(<http://www.oznet.ksu.edu/atid/Housing%20Links%20&%20Resources/UDF/udf.htm#ushape>)



Adequate knee space under the sink is needed for a seated cook. Base cabinet doors can be used when knee space is not needed.

(<http://www.hometime.com/projects/howto/access/pc2aces5.htm>)

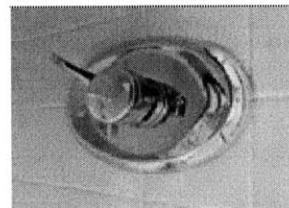


A spray hose attachment for washing dishes or vegetables. It can be long enough to reach the cooktop for filling pots, which is safer and more convenient than filling pots at the sink and carrying them to the stove.

(<http://www.aarp.org/universalhome/graphics/sinklg.jpg>)



A simple tool named EZ-Flo water control valve can be used by cooks to turn on the water without touching the faucet. Users can simply place hand or wrist under the faucet and by moving the rod off-center the water is released. Set their desired water temperature and leave it on. Releasing the rod will allow it to return to center, shutting the water off. Ideal for people who have problems tightening the flow handles. (http://www.dynamic-living.com/ez-flo_faucet_control.htm)



An anti-scald device can be used to regulate the temperature on the hot water heater to prevent scalding and burning when using the kitchen sink.

(<http://www.aarp.org/universalhome/graphics/sinklg.jpg>)



A sink installed in a motorized unit can be raised or lowered at a height from 28 to 36 inches. At its lower positions, the height is ideal for seated use or wheelchair heights. Raised to 36 inches, it matches the counter height of standard base cabinets.

(<http://www.oznet.ksu.edu/atid/Housing%20Links%20&%20Resources/UDF/images/sinkmot.jpg>)

Table 2-9. Universal design solutions about sinks

2.6 Conclusion: Universal design for the user-oriented tool

With universal design, it is possible and feasible for lay people to orient their own housing design. Universal design guidelines are the bottom lines of all new design, based on which universal design strategies can be implemented according to the user needs and preferences.

Each user need can be linked to certain design strategy. In this regard, kitchen design can be a process of combining proper design strategies according to the user needs and preferences and needs. Thus the new relationship between users and designers can be set up as show in Table 2-10.

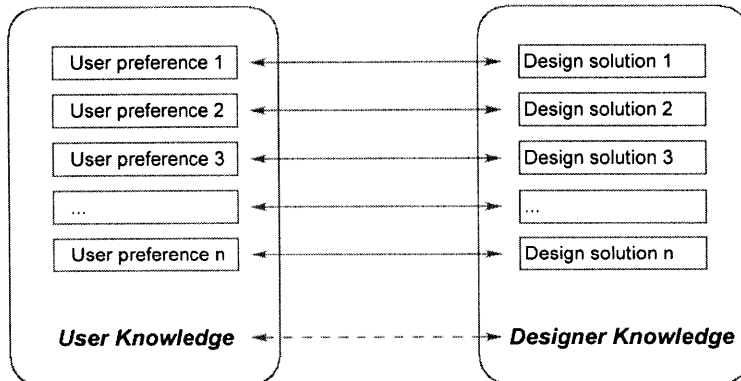


Table 2-10. Linking relationship inside universal design

In the following chapter, a user-oriented design methodology will be stated in detail so that this new relationship can work in the new tool.

3 User-oriented design methodology

3.1 Explicitly convert user knowledge to design language

As a tool kit that brings excellent design to more than the few, the user-oriented tool for universal kitchen design takes user needs and preferences as the design motivation and designers' professional knowledge as the database to consult. How to link user needs with design strategies is essential to the whole process.

3.1.1 Previous studies

Previous studies have addressed part of this conversion issue, although most of them referred to the designer-behavior based design process. Stiny in his work, *A note on the description of designs*, made a comment for the description of spatial design using shape grammars (Stiny and Mitchell, 1978): "Main details of the functional elements comprising designs in these languages are provided in the informal, verbal descriptions of the shape rules used to compose spatial elements (lines) in designs". He also gave the example of "villa plans" in the Palladian style and explained the descriptive way as "the occurrence of specific functional elements and their relationships in these plans corresponds to the application of specific shape rules in the grammar...thus, shape rules implicitly apply to create external and internal 'walls' defining large central 'halls' and smaller ancillary 'rooms'..." What is most interesting in this remark is the way in which design elements and their relationships are determined is implicit. In other words, suppose all the design rules themselves exist, the real implicit key point is when, why and how to apply these rules and which exact rule should be called.

This subtle, implicit way places an obstacle between the physical living world and the abstract design world. Designers are much better in getting through it than lay people, for they are experienced in dealing with the relationship between the two worlds in an informal way in their minds. For instance, a professional designer can instantly present several typical kitchen layouts with a central island to meet the functional requirement that 'the whole family can prepare meals face to face'. A simple way to express this thinking process can be:

The whole family can prepare meals face to face → A central island counter

The real decision-making process for the design should be certainly much more complicated than this simple line. What is addressed here is the explicit expression of the thinking process.

Stiny also initiated the way that a language of designs can be understood; in other words, the design thinking can be explicitly expressed:

"The way a language of designs is understood depends on two main factors:

- (1) The rules given to compose the spatial elements in these designs, and
- (2) The rules given to describe these designs in other terms pertaining to, for example, purpose, function, and use, meaning, type, or form."

Duarte in his work about a discursive grammar for Siza's Malagueira houses made a more explicit explanation. He divided the design process into two main phases:

- (1) From performance criteria to a design brief using description grammars
- (2) From the design brief to typology using shape grammars

According to Duarte, description grammar had a dual role. "First, it transforms the user data into the set of design requirements that form the design brief or housing program. The brief takes the form of a goal description. Second, it provides a way of evaluating the evolving

design by comparing its description with the goal description.” Both of the two previous studies emphasized that the rules given to spatial design and the rules given to the decision-making for the design are separate, since the former is graphical and formal while the latter is verbal and informal. Thus, the design process can be shown in the following diagram:

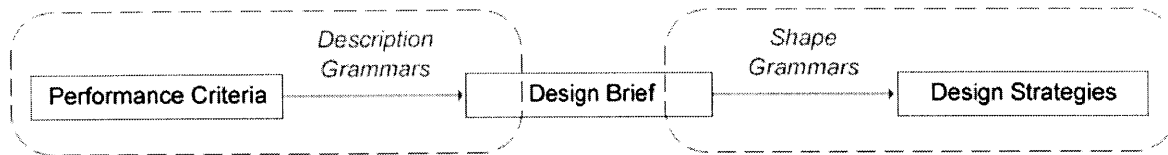


Table 3-1. Description grammar workflow by Duarte

3.1.2 An iterative conversion in user-oriented design

Duarte’s research is mainly towards designers’ methodology to accomplish the design. Although the user-oriented design should still be generated from performance criteria to design brief and from design brief to design strategies, non-professionals have difficulty completing these two steps for the following reasons:

- (1) It is difficult for lay people to make decisions about performance criteria or design results that are isolated. They may have difficulties thinking about the performance criteria without any design example. They may also feel confused to receive certain design without step-by-step comments about the generation process. Thus, it is better to well combine these two steps into one stage.
- (2) With the isolated criteria step and design step, it is difficult for lay people to evaluate the new design. Lay people like to comparing different design variations based on certain criteria. In this regard, instead of a one-time linear process as shown above, this user-oriented design process should be an iterative, transparent process.

Based on the above analysis, a new conversion method can be iterative as shown below:



Table 3-2. Recommended user-oriented workflow

3.1.3 Typology conversion from user preferences to design strategies

In order to directly convert user preferences to design strategies, without an intermediate design program, a typology conversion method is advanced.

Typology is a method to classify different objects into certain categories. It was originally a consequence of efforts to understand the use of space in the 1960s (Duarte, 1999). By categorizing different user profiles into typologies, all kinds of individuals can be labeled with certain attributes and ready for searching. By categorizing design variations, different design results can be also taken account into typologies. Through searching corresponding attributes labeled on top of both user typologies and design typologies, the conversion can be made following two requirements:

- (1) Both of the typologies are understandable to lay people.
- (2) Both of the typologies correspond to map to each other.

User typologies are generated by considering who are the family members, what are their main activities, where they usually make the activities, and how they are making the activities in the kitchen. Under each typology, there are several sub-typologies. For instance, under the “who” typology, there are several criteria to make the sub-typologies, which include male versus female, old versus young, healthy versus physically limited, main cook versus secondary cook and other criteria. Thus, user typologies can be indicated through categorizing the entire user needs, preferences, and expectations.

Note that the concern about the differences between different users does not conflict with the universal design that is supposed to make minimal difference between different individuals. The user typologies defined here will be used to make balances among various universal design elements, especially when user needs trigger several design strategies that inherently conflict.

Design typologies are generated through enumerating most of possible kitchen layouts. In terms of layout, the kitchen is an interesting place to study, since it has the most barriers and functional constraints as well. A large quantity of previous research delved into this area, which provides plenty of data about ergonomic dimensions, marketable appliance prototypes, and design styles. Most of this research proved that only a limited number of kitchen layouts could meet functional requirements, and thus it is possible to generate a limited number of basic kitchen types.

Design typologies can be arranged with a hierarchical tree shape “growing” from a high-level abstract to the low-level details. Below is an example of the hierarchy to generate a kitchen layout typology.

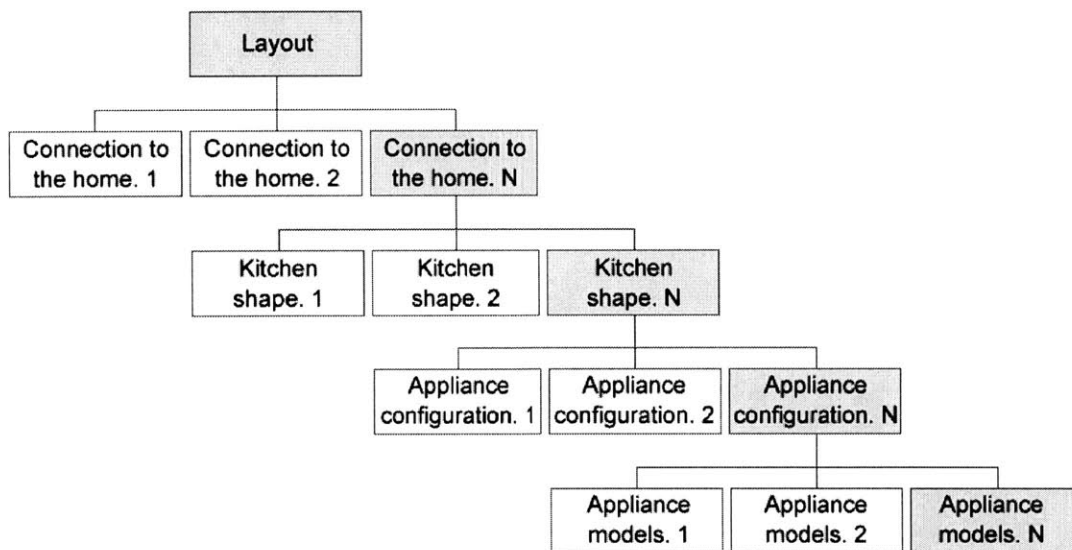


Table 3-3. Kitchen layout design hierarchies

Afterwards, the link between user typologies and design typologies is the essential, based on which users can navigate either from user typologies that trigger certain design typologies or from design typologies that reflect certain user typologies. Hence, the way to organize the sequence of these conversions is important.

3.2 A guided searching towards satisfactory design results

As stated in the section 3.1, there are mainly two concerns for the user-oriented tool:

- (1) How to set up the corresponding map between user typologies and design typologies;
- (2) How to search in the design typology tree.

Akin stated in the HeGeL project (Heuristic Generation of Layouts, 1991) that the previous studies in the area of artificial intelligence had suggested that most design problems acquire structures during the process of design development (Akin, 1991). Furthermore, they observed that designers employed heuristic techniques in searching for a solution to satisfy the design problems. Akin furthermore concluded that previous studies were mostly directed towards developing techniques that were as good as, if not better than, the performance of a human designer.

Below is the system outline for the HeGeL project. The task was to design an office layout given a list of personnel and furniture to be accommodated:

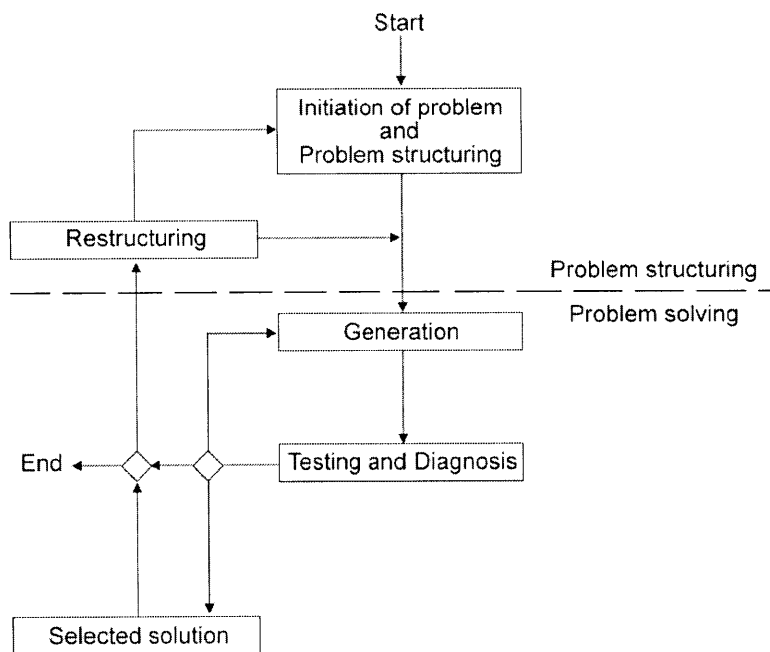


Table 3-4. HeGeL system workflow by Akin

This system outline is initiative in terms of the solution satisfying process. The key idea is to restructure problem settings to satisfy user preferences and thus to regenerate design. This ensures the stability of the system structure. This workflow reflects an important conceptual model of professional designers with two characteristics:

- (1) All of the requirements and preferences must be input before the initial design can be generated.
- (2) The initial design can be revised, until the initial problem setting is updated when the problem structure is updated.

In order to allow lay people to orient the design, a user-oriented design workflow should be based on two revised characteristics:

- (1) The initial design, as a best guess to the user typology, should be generated early in the design process because lay people need certain design to revise and compare.
- (2) When the initial problem setting is updated, the problem structure is unnecessary to update. Instead, the current design can be updated according to the change of the criteria.

These two characteristics actually place the initial design as the design template, based on which the tool can help the user to search a better, revised design layout. A guided searching is advanced here. It is the way to lead users to gradually revise the current design and then reach the satisfactory design result by following certain routes. Instead of letting users to choose design strategies without any direction, the design engine guides them to the pre-defined design strategy according to the data of needs and preferences that they input.

The advantage of this searching method is that it prevents lay people from being frustrated by taking wrong execution and receiving poor design results, as the guides ensure the quality of the new design layouts. Moreover, with the clear directions, users will be always aware of what they are doing and why they are doing so.

The disadvantage is that although the database that supports this guided searching can be more and more complete, it always lacks certain new design variations. There may be, at one point, a proper layout that best fits the user but is not contained in the database. A good designer-input engine can be compensation, with which designers or builders can add new design layouts into the database to reinforce it.

Two principles are crucial for a guided searching:

- (1) The input-output workflow should be transparent so that users can obtain the result once they input their requirements.
- (2) Frequent comparisons between instant design schemes are needed and thus the restructuring is the important tool for the process.

Based on the above analysis, a system outline is stated as below. The system generates an initial design result in terms of the initial user data. Whenever user data is changed during the process, the default design result, instead of being restructuring, jumps to a so-called “parallel” result with updated user data. Hence, an interactive user interface can be implemented to help users simultaneously design and evaluate the result.

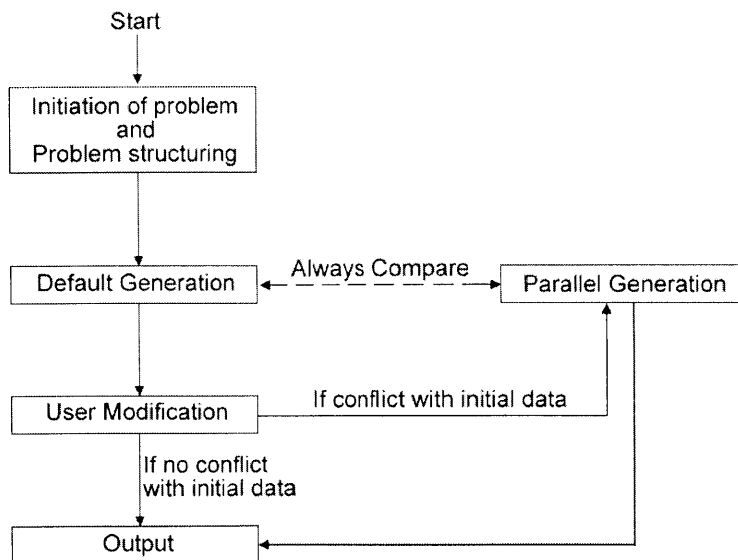


Table 3-5. Recommended system workflow

One point needs to be noted. When the user updates the needs so that the new user typology conflicts the current design typology, instead of traversing to the initial preference, the design engine transforms the current design to a “parallel” design that is most similar to the current design while updated with the new user data. The design engine actually pre-defines certain kinds of relationships among similar design layouts. “Parallel jumps” refer to the transformation between two similar designs in the same hierarchy.

“Parallel jumps” actually reflects a typical layperson’s conceptual model about the design: “one change of needs or preferences triggers only one change of design.” Obviously real design problems are not as simple as this. However, with a carefully pre-defined layout transformation flow, it is possible to explain each design decision to the user in this way so that users will not feel confused by many changes at one time. Moreover, it is a shorter way to update the design than restructure the whole problem setting. Below shows the way that parallel jumps work.

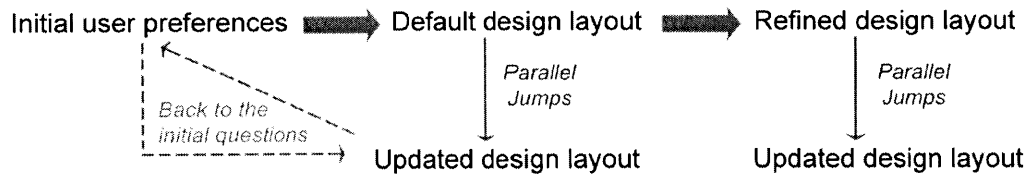


Table 3-6. Parallel jumps

In a word, there are several characteristics for the procedure:

- (1) The initial design should be a best guess to the user needs and preferences. The system will retrieve this layout to meet the largest number of the user needs without any priorities.
- (2) The initial design should be represented in the form with which design concepts are comprehensible and manipulatable.
- (3) If the user has a high priority of preferences, the system will retrieve the design that first fulfills the priority and asks the users what is the next prior preference until no more prior preferences are raised.
- (4) When the user data is updated, instead of updating the problem structure, the system updates the current design to a proper, most similar design.

Note that allowing users to compare their preferences while comparing the design results turns out to be an important way for user to evaluate the design. Many researchers from financial area have addressed the accurate measurement of user preferences. For instance, the conjoint analysis project at the Sloan school of Management, Massachusetts Institute of Technology has developed a mathematical model to measure user preferences with only a few questions, which was particularly effective for the web-based market. In this user-oriented design project, the user directly ranks preferences without facility with certain comparison engine. In the more complete, future version of this user-oriented tool, comparison engines may be added to facilitate users to make decisions.

In the Application Part, each guided searching step will be introduced in depth.

3.3 User-oriented design interface principles

W. B. Park wrote that user-centered design should make sure that “the user can figure out what to do and tell what is going on.” He concluded seven principles about how to transform difficult tasks into simple ones. Based on Park’s research and the best practice in the current project, the principles for user-oriented interface are addressed as the following:

3.3.1 Use knowledge that is naturally linked to the information

People usually learn better and feel more comfortable when the knowledge required for a task is available externally. Knowledge is useful only if there is a natural, easily interpreted relationship between that knowledge and the information it is intended to convey about possible solutions and outcomes. Therefore, in the user-centered design interface, users should not be asked to finish tasks that they are unfamiliar with.

In kitchen layout design, lay people typically feel that they do not have the skills to handle a professional design case. However, they are confident about what kind of kitchen table they like, what meal types they have and how many cooks usually work in the kitchen. Natural links between this user knowledge and layout manipulation, as the typology conversions stated earlier in this chapter, are crucial to the interface.

3.3.2 Develop proper conceptual models

This requires each operation be observable and all actions be consistent with the conceptual model. Park indicated three different aspects of conceptual models that should be distinguished: design model, user’s model and system image. The design model is the conceptualization that the designer has in mind. The user’s model is what the user develops to explain the operation of the system. Ideally these two models are equivalent. However, the user and designer communicate only through the system itself: its physical appearance, its operation, the way it responds and the instructions that accompany it. Thus the system image is critical: it must correctly convey the necessary information.

In the user-oriented design interface, the designer model refers to the task that users are expected to finish. A conceptual model chart based on Park’s research is shown as below. The system image should be in of forms of images, scenarios and other media that is easy way for lay people to understand.

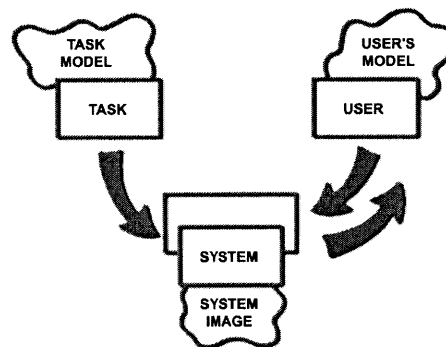


Table 3-7. User-oriented interface model by Park work

In this kitchen layout design tool, lay people’s access to professional design is one of the main goals. Thus the task model should be a professional design process that should not be intervened by user’s model. The challenge then refers to how to explain the whole professional design model to lay people.

In the application part, the research about the links between each two layouts along with a scenario explanation will be introduced in depth. Those natural transformations actually work as good balances between design variations and common life scenarios.

3.3.3 Simplify the structure of tasks

To simplify the structure of tasks, two points should be addressed: First, make sure each task is short and simple. This depends on the limitations of short-term and long-term memory or attention. Second, technological approaches can provide aids to reduce mental load, such as: make visible and natural what would otherwise be invisible, thus improving feedback and the ability to keep control, or keep the task in the same mental model.

3.3.4 Make things visible to bridge the gulfs of execution and evaluation

Let the users see clearly what they are doing and why they are doing so by instantly showing the results as they respond to each user input. Park indicated that the interface should only make visible information that directly related to users' tasks. Intensive computer design generation should be hidden or appear in an easily understood way.

In this kitchen layout design interface, execution and evaluation always work simultaneously and transparently. Each execution will reflect certain results and be ready for the evaluation. Thus the whole "design" process seems "transparent" to the user.

3.4 Conclusion: The web-based user-oriented tool for universal design

In both new construction and renovations, there are several key problems that the user-oriented tool proposed in this paper will help in the implementation of universal design strategies:

3.4.1 Education that raises awareness of universal design

Both homebuilders and homeowners have been reluctant to incorporate the features of universal design. They have often ignored the needs that may dramatically change over time as one ages or becomes injured. This is because consumers do not have the personalized information necessary to establish their own priorities and to make their own informed decisions about universal design elements relevant to their families' needs. Even while some homebuilders have incorporated a limited number of universal design features, many fear that increased costs will place them in a competitive disadvantage with builders who ignore universal design issues. Some builders have difficulty convincing homeowners of the value of universal design.

This tool, therefore, will be first a concerted education that empowers both homeowners and homebuilders by building awareness of universal design principles. By operating the tool and experiencing the design process, the users can learn about the benefits of the universal design to their particular lives and thus will be likely to demand from a builder more forcefully and with greater assurance those universal design features that are most important.

3.4.2 Integrated solution that contextualizes universal design principles

Existing universal design guidelines are communicated as a series of options and recommendations for an individual component of a design that is out of context and difficult to visualize by a layperson. By providing an integrated solution, the user-oriented tool can address this specific problem by generating a complete kitchen satisfying universal design principles.

3.4.3 Expanded access of experts' knowledge

There are few experts on universal design and their services are either unavailable in most localities or too expensive, because of demand for their time or distance considerations, for homebuilders to currently access. The user-oriented tool can directly address this problem in a democratic manner by providing both the homeowner and the builders with the rules for universal design built-in to the tool.

4 Application

4.1 Introduction

4.1.1 Context

Universal design concepts should be applied to all aspects of the home. To meet various expectations to the kitchen design, the question of “Why are you here?” will be asked before a new design process begins. These answers will categorize users into three groups:

- (1) Users who want to solve a particular problem about the kitchen.
- (2) Users who want to renovate existing kitchens.
- (3) Users who want to design new kitchens.

The tool introduced in this paper is supposed to meet the needs of third group. It can help those users who want to design new kitchens learn about the benefits that universal design work for their lives through an independently user-oriented process of a new kitchen layout design.

4.1.2 Four phases

The user-oriented design process consists of four phases:

- (1) Preference engine: elicit the user needs and values for the new kitchen
- (2) Design engine: generate design variations that are ready for user to tinker
- (3) Test engine: test selected design schemes according to user preferences and universal design principles
- (4) Output engine: output a user preference list and the qualified design results

Among the four steps, there preference engine and test engine are interweaved and work by turns, and thus provide users with the chance to instantly evaluate the design generated according to their requirements. The test engine is where qualified design schemes generated in the previous phases are synthetically evaluated with user preferences and universal design principles. The output engine is used to record all the actions that the user has had with the design process. It makes a conclusion about user preferences and qualified design schemes that can be forwarded to builders or contractors as a formal expression and forceful command from the users.

4.2 The computational framework

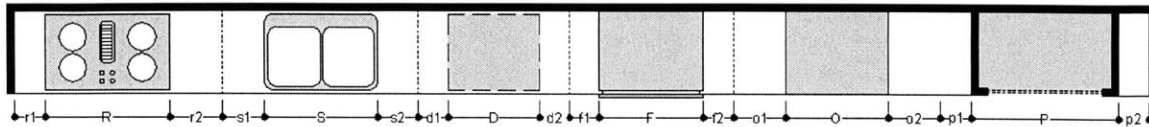
As stated in the last part, the design process proceeds from a default design strategy. The automatic generation of such a default design requires a framework that can categorize basic user data into certain computational data.

4.2.1 Framework

Based on the previous research, a framework that categorizes various kitchen layout typologies by the attributes of size and comfort level is set up as shown in the table. For instance, 3~4P[B] refers to a kitchen for a family of 3 or 4 members with the comfort level B, among which, the family size determines kitchen size while the comfort level determines kitchen layout level. The comfort levels are parameters that measure and synthesize user data in order to locate a particular design in the framework. The definition of the comfort levels is:

- [A] Obligatory level
- [B] Liberal level
- [C] Luxury level

It is difficult to define clear boundaries among these comfort levels. As the core idea of this user-oriented tool, each design strategy is a corresponding result for certain user life typology. The obligatory level represents the kitchen that meets the minimum functional requirements for a certain number of family members, while liberal and luxury levels represent better and best conditions, respectively.



Family Size	1	2	3-4	5-6	7-8
r1	12	12	12	18	24
R	21	30	30	30	36
r2	15	18	20	24	30
s1	15	18	20	24	30
r2+s1	24	30	36	42	48
S	16	25	33	33	38
s2	15	18	20	24	30
d1	12	12	12	18	24
D	18	18	18	24	24
d2	12	12	12	18	24
f1	12	12	18	18	24
F	24	28	36	36	36
f2	0	0	0	12	12
o1/o2	15	15	15	24	24
O	27	27	30	30	30x2
p1/p2	*0	*0	*12	*12	*12
P	*24	*24	*24	*30	*48

Table 4-1. Main framework and recommended dimensions for the critical frontage

- R Minimum frontage of stove
- r1 Minimum landing space for stove, far from sink
- r2 Minimum landing space for stove, near to sink
- S Minimum frontage of sink
- s1 Minimum landing space for sink on one side
- s2 Minimum landing space for sink on one side
- s2+r1 Minimum mixing place
- D Minimum frontage of dishwasher
- d1 Minimum landing space for dishwasher on one side
- d2 Minimum landing space for dishwasher on one side
- F Minimum frontage of refrigerator
- f1 Minimum landing space for refrigerator, near to sink
- f2 Minimum landing space for refrigerator, far sink
- O Minimum oven frontage
- o1 Minimum landing space for oven, on one side
- o2 Minimum landing space for oven, on one side
- P Minimum pantry frontage
- p1 Minimum landing space for pantry, on one side
- p2 Minimum landing space for pantry, on one side

Notes about the table:

- (1) * Indicates not required but can be added if the user specially indicates.
- (2) X2 indicates double wall ovens
- (3) F1 is for fully opening the fridge door, the space for **side-by-side fridge should be smaller than that for other types.
- (4) S does not include drain board width. To calculate it, add 16 as drain board on one side and add 30 as drain boards on both sides.

4.2.2 Calculation of the comfort levels

A critical issue in the framework is how to calculate the comfort level of a specific design case. A simple mathematical model is implemented. A “weight” parameter is applied to eating, meal and other user typologies. Basically, the weight is a value that represents the importance of each kind of typology among the overall comfort level.

Let Maximum comfort level = 100

Each overall comfort level is given a range as shown:

Comfort level [A] == (0, 49)

Comfort level [B] == (50, 74)

Comfort level [C] == (75, 100)

The overall comfort level is calculated by adding the weights of cooks' number, meal type, eating style and activity style, as shown below:

Maximum weight for cooks' number = 30

Maximum weight for eating style = 20

Maximum weight for meal type = 15

Maximum weight for activity style = 35

Note that the figure combined with each physical fact for how people feel comfortable with the kitchen only represents a best guess based on a large amount of previous kitchen design and studies. To design the kitchen that fits for the particular user, the interface helps the user figure out and ranks his/her preferences.

Below is a sample calculation of the each weight followed by the value of the overall comfort level.



Cooks' number weight (cN)

Maximum CN = 30

if 1 cook, cN = 10

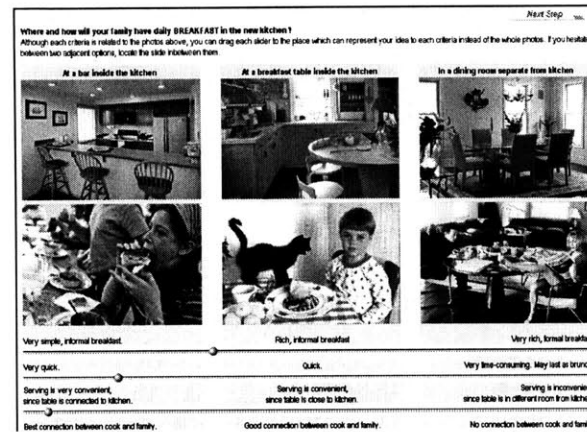
if 2 cooks, cN = 20

if 3 cooks, cN = 30

Hence

The data shown in the interface is

cN = 20



Eating style (eS)

Maximum ES = 20

If (dining room + kitchen table + bar), eS = 20

If (dining room + kitchen table), eS = 19

If (dining room + bar), eS = 5

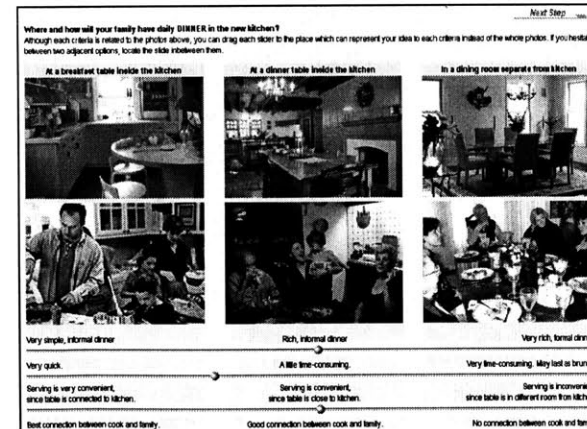
If (kitchen table + bar), eS = 14

If (dining room), eS = 10

If (kitchen table), eS = 9

To calculate the table type,

Let Total length of the slide bar = 20, so that each point on the bar can retrieve a value (1, 20)



The thresholds for table types are:

5 <= Kitchen bar < 10

10 < Kitchen table < 15

15 < Dining room <= 20

Also, let

A = Formal / informal = 25%

B = Time efficiency = 25%

C = Easy serving = 25%

D = Communication = 25%

Hence

Where and how will your family have HOLIDAY DINNER OR GUEST DINNER in the new kitchen? Next Step >>>

Although each criteria is related to the problem above, you can tag each slider to the place which can represent your idea to each criteria instead of the whole problem. If you decide between two adjacent options, locate the slider in-between them.

As a dinner table links the kitchen

Because the dinner table is close to the kitchen, everyone can help preparation and serve. Cooking and eating can be take place at the same time.

In a dining room separates from kitchen

Because the dinner table is not connected to the kitchen, there is no connection between the cooks and the family or guests.

Informal dinner

Time-consuming

Very formal dinner

Very time-consuming

Meals	Break-fast	Typical dinner	Holiday dinner
A	8	12	20
B	4	8	18
C	2	12	18
D	12	4	18
Total weight	7	9	17
Table type	Bar	Kitchen table	Dining room

Choose the frequency that your family has each type of meals. Next Step >>>

Frozen food to heat	Carry-out to reheat	Simple family meals	Simple vegetarian meals	Elaborate cuisines
<input checked="" type="checkbox"/> Typical weekdays <input type="checkbox"/> Typical weekends <input type="checkbox"/> Holidays / Guests <input type="checkbox"/> Seldom	<input type="checkbox"/> Typical weekdays <input type="checkbox"/> Typical weekends <input type="checkbox"/> Holidays / Guests <input checked="" type="checkbox"/> Seldom	<input checked="" type="checkbox"/> Typical weekdays <input type="checkbox"/> Typical weekends <input type="checkbox"/> Holidays / Guests <input type="checkbox"/> Seldom	<input type="checkbox"/> Typical weekdays <input type="checkbox"/> Typical weekends <input type="checkbox"/> Holidays / Guests <input type="checkbox"/> Seldom	<input type="checkbox"/> Typical weekdays <input type="checkbox"/> Typical weekends <input type="checkbox"/> Holidays / Guests <input type="checkbox"/> Seldom
<p>Frozen entrees are now among the top 10 most frequently served in-home suppers.</p> <p>Minimal number of dishes, so little time spent at the sink or dishwasher!</p> <p>Important appliances: freezer, microwave oven and sometimes cooktop.</p>	<p>Carry-out food are now more and more common among working couple families.</p> <p>Minimal number of dishes, so little time spent at the sink or dishwasher!</p> <p>Important appliances: freezer, microwave oven and sometimes cooktop.</p>	<p>Preparation can include marinating meats and vegetables, which takes place primarily on cutting boards and sink.</p> <p>Baking or grilling meals is an easy method to reduce list.</p> <p>Important appliances: refrigerator, cooking sink, dishwasher and traditional ovens.</p>	<p>Preparation can be simple and quick and may occur in discrete stages.</p> <p>Variety of storage areas are needed such as refrigerator, freezer, hanging handles and pantries.</p> <p>Important appliances: refrigerator, sink and cutting boards.</p>	<p>Variation on heavy meals or vegetarian meals, usually take places on holidays or for guest dinners.</p> <p>Preparation may last long time. Presentation is important which requires counter space.</p> <p>Important appliances: All kinds of kitchen appliances.</p>

Meal style weight (mS)

Maximum MS = 15
 Let
 Typical weekdays = 70%
 Typical weekends = 30%
 Holiday / guest = 20%
 Seldom = 0%

Let
 Frozen food to heat = 3
 Carry-out or leftovers to reheat = 3
 Simple meals = 8
 Vegetarian meals = 8
 Elaborate cuisine = 12
 Hence, the data about each user preference shown in the interface can be calculated as
 Typical weekdays: $8 \times 70\% = 5.6$
 Typical weekends: $8 \times 30\% = 2.4$
 Holiday/guest dinner: $12 \times 20\% = 2.4$
 Hence,
 mS = 10.4

What other activities do your family do in the kitchen? Next Step >>>

<input checked="" type="checkbox"/> Party Preparation	<input checked="" type="checkbox"/> Family Gathering	<input checked="" type="checkbox"/> Kids Homework	<input checked="" type="checkbox"/> Young Kids Playing
<input type="checkbox"/> A Short Nap	<input type="checkbox"/> Ironing	<input checked="" type="checkbox"/> Computer / Reading	<input checked="" type="checkbox"/> Watching TV

Activity style weight (aS)

Maximum AS = 35
 Let aS = maximum of the following, if any
 Family fathering = 35
 Party preparation = 30
 Watching TV = 25
 Kids playing = 25
 A short nap = 20
 Kids homework = 10
 Computer = 10

Table 4-2. Sample calculation of the comfort level

Based on the calculation above, the overall weight equals to

$CN + eS + mS + aS = 20 + 20 + 10.4 + 35 = 85.4$ which is categorized as a luxury comfort level.

4.2.3 Implementation of the comfort levels

Comfort levels, together with family size, mainly work on two parts:

- (1) Define the default design. For the same family size there may be different default designs in terms of different comfort levels. The definition of the default design will be introduced later.
- (2) Determine the parametric design. For the same family size there may be different in-between dimensions in terms of different comfort levels.

4.3 Data structure of the design engine

The design engine actually contains the complete database of the design variations for the family types. The preference engine, according to each variation's attributes, can locate the best guess according to the user typology. In this chapter, an enumeration in the order of kitchen shapes, appliance configurations of each shape, and the parametric rules for each configuration, covers most possible kitchen layouts and thus constitutes the entire data structure.

4.3.1 Kitchen shapes

The workflow of the design process by turns of preference engine and design engine, though transparent to operate by lay people, will follow a professional design custom that most current kitchen layout cases start from the basic kitchen shapes including:






I-shape	II-shape	L-shape	U-shape	G-shape
				

Table 4-3. Primitive kitchen shapes

All these shapes have up to 4 counters (counter 1, 2, 3 and 4) and four corners (corner A, B, C and D). Thus, each shape consists of certain corners and counters. For convenience, counters are defined according to the following rules:

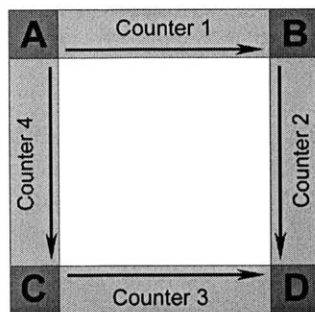


Table 4-4. Definition of counters

- (1) Each counter is a vector with certain depth and height. That is, each counter has orientation with respect to predefined shapes: counter 1 is the vector starting from A and stopping before B, counter 2 starting from B and stopping before D, counter 3 starting from C and stopping before D, and counter 4 starting from A and stopping before C.
- (2) Corner A is a fixed original starting point.
- (3) Each counter grows with the shape, from the starting point to the ending point.
- (4) The end of counter 3 can be trimmed as an entry into the counter.

Based on the above rules, every shape can be defined and grow in the following way:

- (1) I-shape is made up of corner A and counter 1, with the growing direction from A to B.

- (2) II-shape is made up of corner A, counter 1, corner C and counter 3, with the growing direction of $C \rightarrow D$.
- (3) L-shape is made up of corner A, counter 1 and counter C, with the growing directions of $A \rightarrow B$ and $A \rightarrow C$.
- (4) U-shape is made up of corner A, counter 1, corner B, counter 2 and counter 4, with the growing directions of $A \rightarrow C$, $A \rightarrow B$ and $B \rightarrow D$.
- (5) G-shape is made up of all the elements, with the growing directions of $A \rightarrow B$, $B \rightarrow D$, $A \rightarrow C$ and $C \rightarrow D$. Moreover, the end of counter 3 is trimmed for an entry.

Note that these primitive shapes will be transformed when a breakfast bar and/or a central island are added. Below is an expanded shape list following two rules:

- (1) An island can be directly added or be transformed from the front counter.
- (2) A breakfast bar can be added along with the counter or island that is in front.

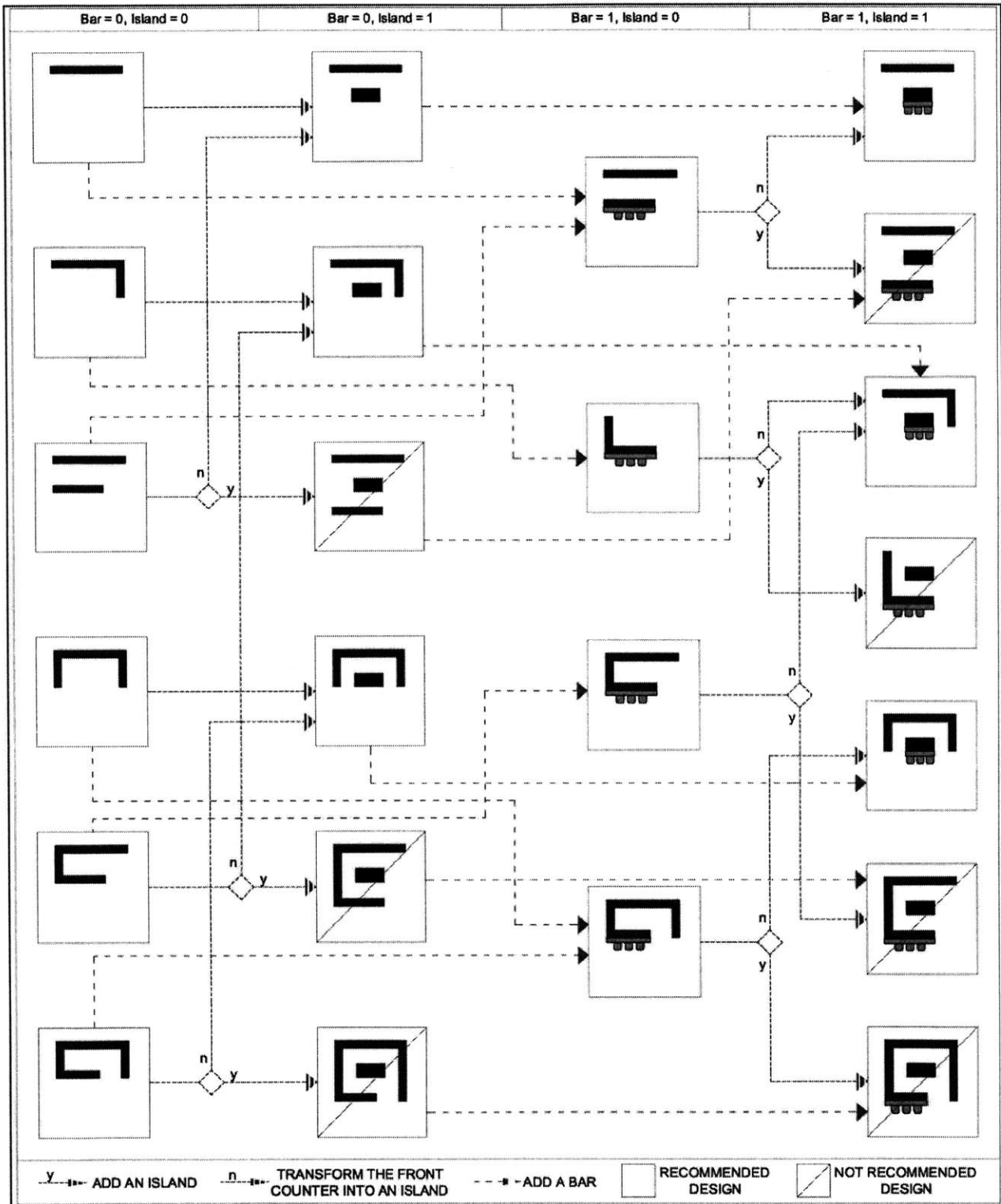


Table 4-5. Extended kitchen shapes

The first task of main structure is to raise a rational sequence of questions about user preferences in order to determine a proper kitchen shape. However, the shapes organized in the above way are too abstract for lay people to understand. The critical question turns out to be what is the meaningful level for lay people to capture the main idea of the design.

4.3.2 Configurations of kitchen shapes

If there are appliances located on a certain counter plan, the layout will be more understandable for lay people. Based on the kitchen shapes concluded above, there requires further research about how many configurations of main appliances can be reasonable placed based on each shape of the counter. There is a set of rules to define the appliance objects:

- (1) Appliance objects are aligned and continuous with the counter space.
- (2) Appliance objects always face away from the wall, into the center of the space.
- (3) Appliance objects have an ordering, though there can be predefined orderings and transitions of orderings, as associated with shape changes.
- (4) Each appliance object has its own working or clearance space. In other words, each appliance has an invisible outer boundary, which cannot be overlapped with each other.
- (5) Appliance objects can be adjacent to, parallel from, and catty-corner to other appliance objects.

Among the above rules, the fourth and fifth ones relate to the parametric rule that will be stated in depth later. In order to locate the appliances on the counter without considering the parametric issues, the ordering of the appliances is crucial. Based on the best practice of the kitchen layout cases, this ordering, as shown in table 4-6, is defined as

Cooktop → sink → dishwasher → refrigerator → wall-mounted oven → pantry.

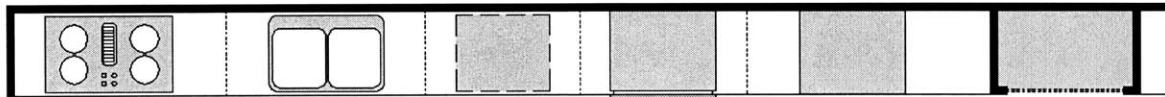


Table 4-6. Basic order of the main kitchen appliances

To simplify the problem, the four main appliances including cooktop, sink, dishwasher and refrigerator are chosen to make the primary arrangement list. A ring is used to locate the sequence of these four main appliances and label is taken as the breaking point, which refers to the breaking point of the counter. When there is only one label, it should be located between the cooktop and the refrigerator according to the rule, and then the I-wall shape kitchen, which is the only one variation, is created. Next, two, three and four labels are added and thus all kinds of kitchen arrangements are made. Table 4-7 shows the result of all the variations.




















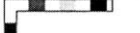










<p>■ Refrigerator ■ Dishwasher ■ Sink ■ Stove</p>						
1 Label			3 Labels (1-1-2)			
2 Labels			3 Labels (1-2-1)			
			3 Labels (2-1-1)			
			4 Labels			

Table 4-7. Graphical variations of the appliance configurations based on each shape

Note that all these arrangements are made only through a graphical composition. In other words, not all these kitchen layouts are good designs. To determine the qualification of each kitchen layout, some other criteria besides the basic ordering of the appliances should be followed:

- (1) Tall appliances, including refrigerator and wall-mounted oven, cannot be located between small appliances because a tall appliance may block passage between smaller appliances.
- (2) Tall appliances, including refrigerator and wall-mounted oven are better grouped.
- (3) Refrigerator should be at the end of shape that is close to the entry for putting up groceries.
- (4) Wall-mounted oven should be at either end of shape. That is, wall-mounted oven can be either next to the sink or next to the refrigerator.
- (5) Tall appliances, including refrigerator and wall-mounted oven, cannot be located on an island due to the visibility of entire kitchen.
- (6) If there is available counter space, the sink and cooktop should be distributed not to cramp one cook's movements and to avoid collisions for multiple cooks.
- (7) The sink and dishwasher should be adjacent to each other or in a close corner area if there is no enough space on one counter.
- (8) If the sink is on the island, the dishwasher is better on the island.
- (9) The dishwasher should not be between the sink and the cooktop on a continuous counter so that the cooks do not have to trip over the dishwasher, transitioning between the sink and cooktop. And for the same reason, if there is available space, the dishwasher should not be located inside the triangle of the stove, sink and refrigerator.
- (10) If there is a secondary sink, it should not be next to the primary sink.
- (11) The sink and the stove should occupy more than half of the overall counter length because they are the most important appliances.

Table 4-8 shows the process of qualifying each layout based on the above rules.

I-Shape							
							
II-Shape	     	✓	✗	✗	✗	✗	✗
	     	✗	✗	✗	✓	✗	✗
	   	✓	✓	✗	✗		
L-Shape	     	✓	✗	✗	✗	✓	✗
	     	✗	✗	✓	✗	✗	✓

U-Shape						
L-Shape + Island						
U-Shape + Island						
G-Shape						

Table 4-8. Best-practice determination of the appliance configurations

After checking out the qualification of each layout, below is the final list of all the qualified layouts. Table 4-9 shows the arrangements of the refrigerator, dishwasher, sink, and stove. Table 4-10 shows the conditions plus the wall-mounted oven. This is the final result of the appliance arrangements.

	■ Refrigerator ■ Dishwasher ■ Sink ■ Stove		
I-Shape			
I-Shape + Island			
II-Shape			
L-Shape			
U-Shape			
L-Shape + Island			
U-Shape + Island			
G-Shape			

Table 4-9. Qualified appliance configurations (without ovens)

	■ Refrigerator ■ Dishwasher ■ Sink ■ Stove ■ Oven		
I-Shape			
I-Shape + Island			
II-Shape			
L-Shape			
U-Shape			
L-Shape + Island			
U-Shape + Island			
G-Shape			

Table 4-10. Qualified appliance configurations (including ovens)

4.3.3 Parametric rules for appliance configurations

After the appliance arrangements are set up, the parametric relationships among all the appliances needs to be solved. Remember that there are two rules for the appliances stated in the last chapter:

- (1) Each appliance object has its own working or clearance space. In other words, each appliance has an invisible outer boundary, which cannot be overlapped with each other.
- (2) Appliance objects can be adjacent to, parallel from, and catty-corner to other appliance objects.

Parametric rules for the kitchen relate to several areas especially anthropometrics. Table 4-11 is a parametric analysis of the main appliances. A working zone or clearance space is required around every appliance. For wheelchair users, under-counter clearance is also required. It is obvious that the dimensions of the zones vary along with family size and comfort levels as indicated in Table 4-1. Based on this analysis, Tables 4-12 through 4-20 show a series of parametric relationship between each two appliances.

Legend				
	Normal Users			
	Top View	Section		
		Wheelchair Users		
		Top View	Section	
Sink				
Stove				
Refrigerator				
Ovens				
Dishwasher				
Full-height Pantry				

Table 4-11. Parametric rules –Part 1

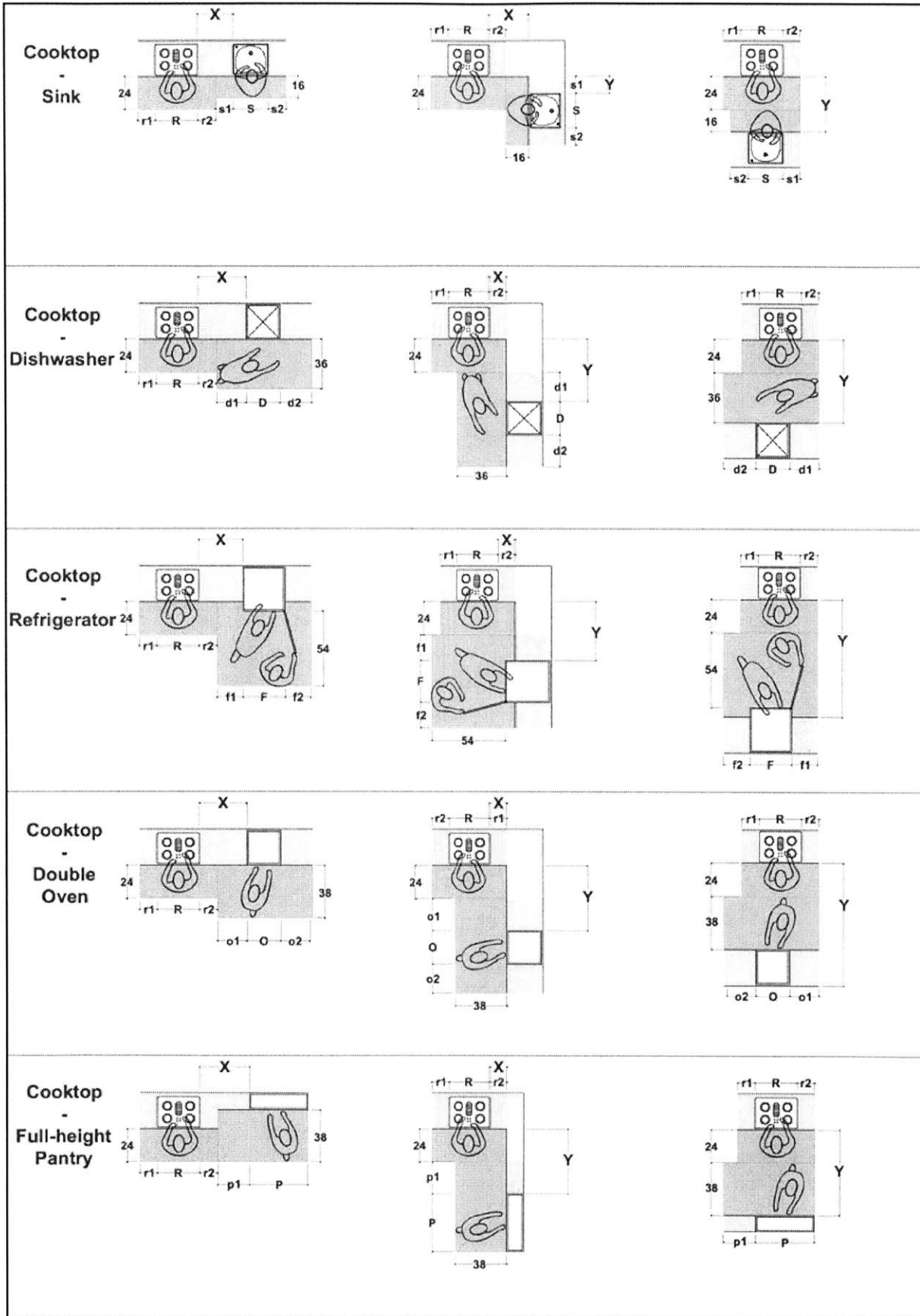


Table 4-12. Parametric rules –Part 2

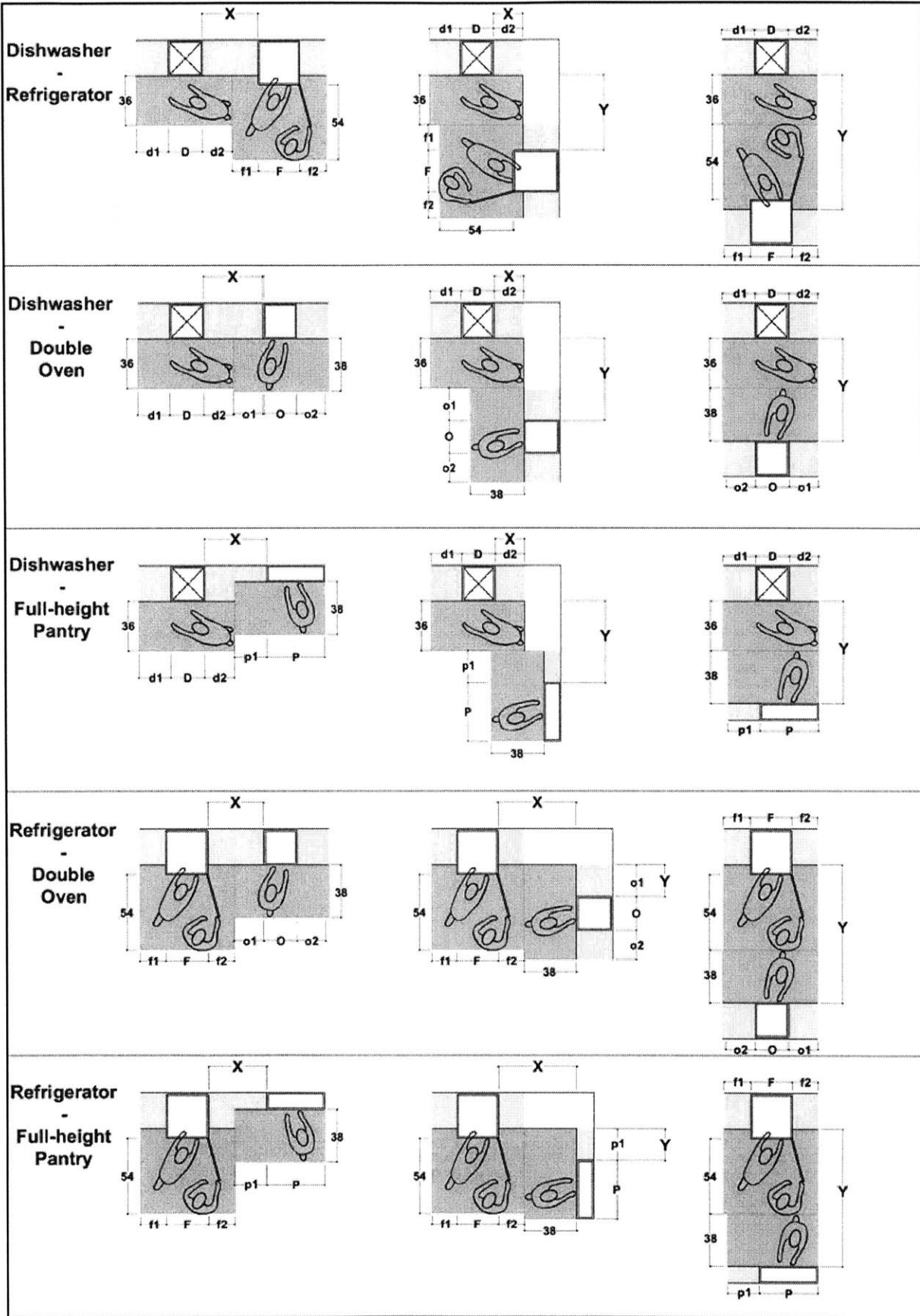


Table 4-13. Parametric rules –Part 3

	To Wall	To Window	To Open Counter Edges	To Wall
Cooktop				
Sink				
Dishwasher				
Refrigerator				
Double Wall Oven				
Full-height Pantry				

Table 4-14. Parametric rules –Part 4

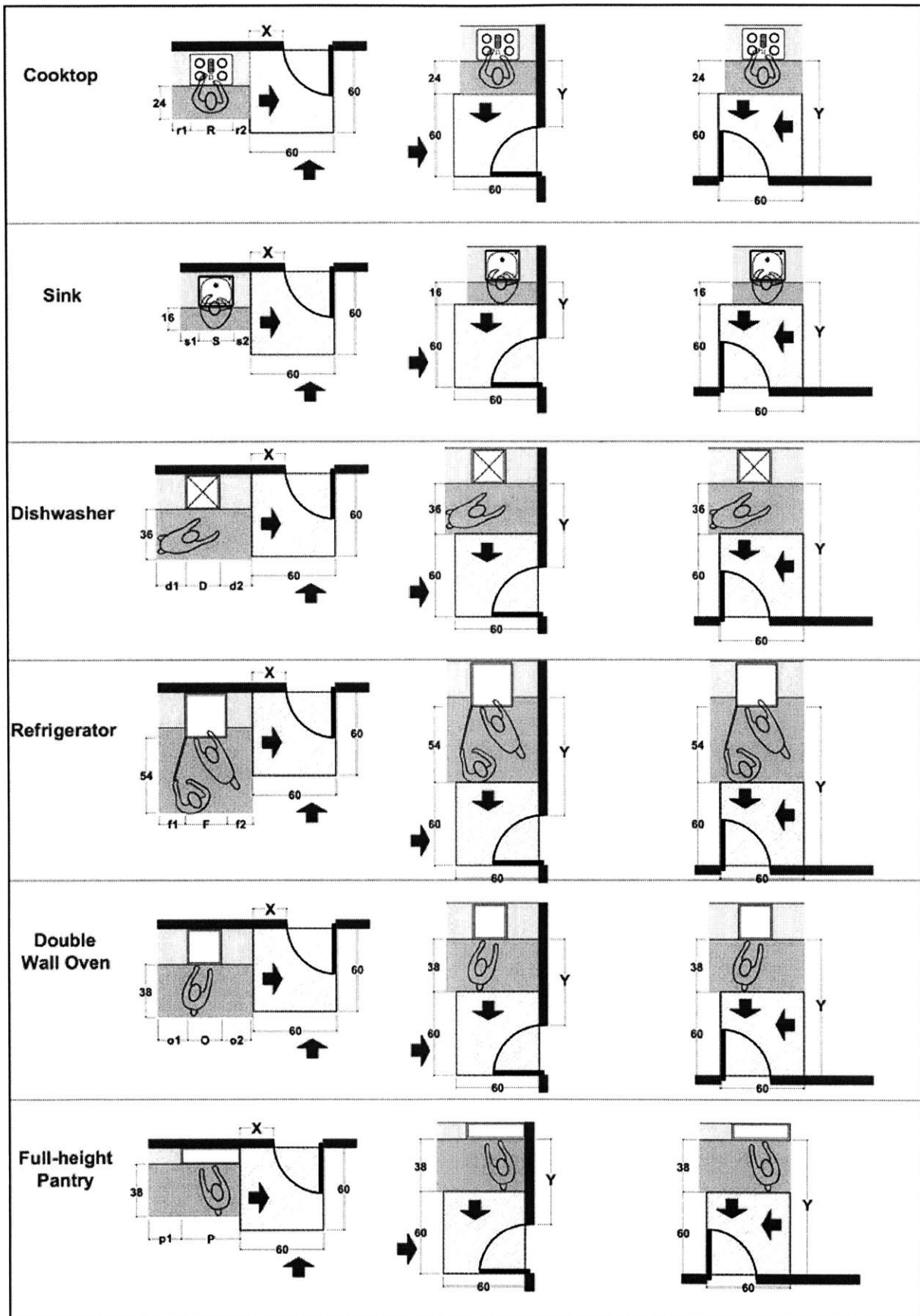


Table 4-15. Parametric rules –Part 5

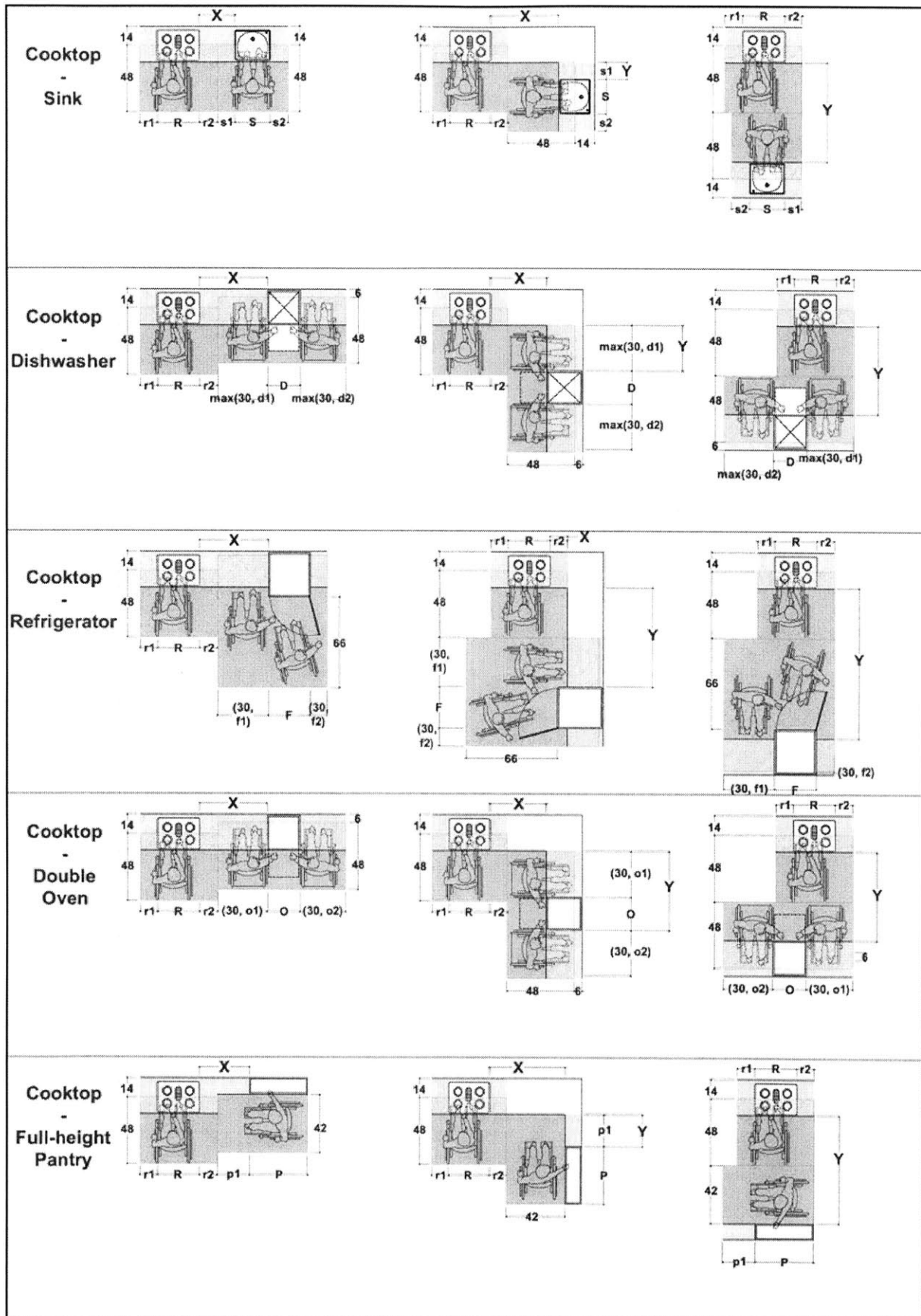


Table 4-16. Parametric rules –Part 6

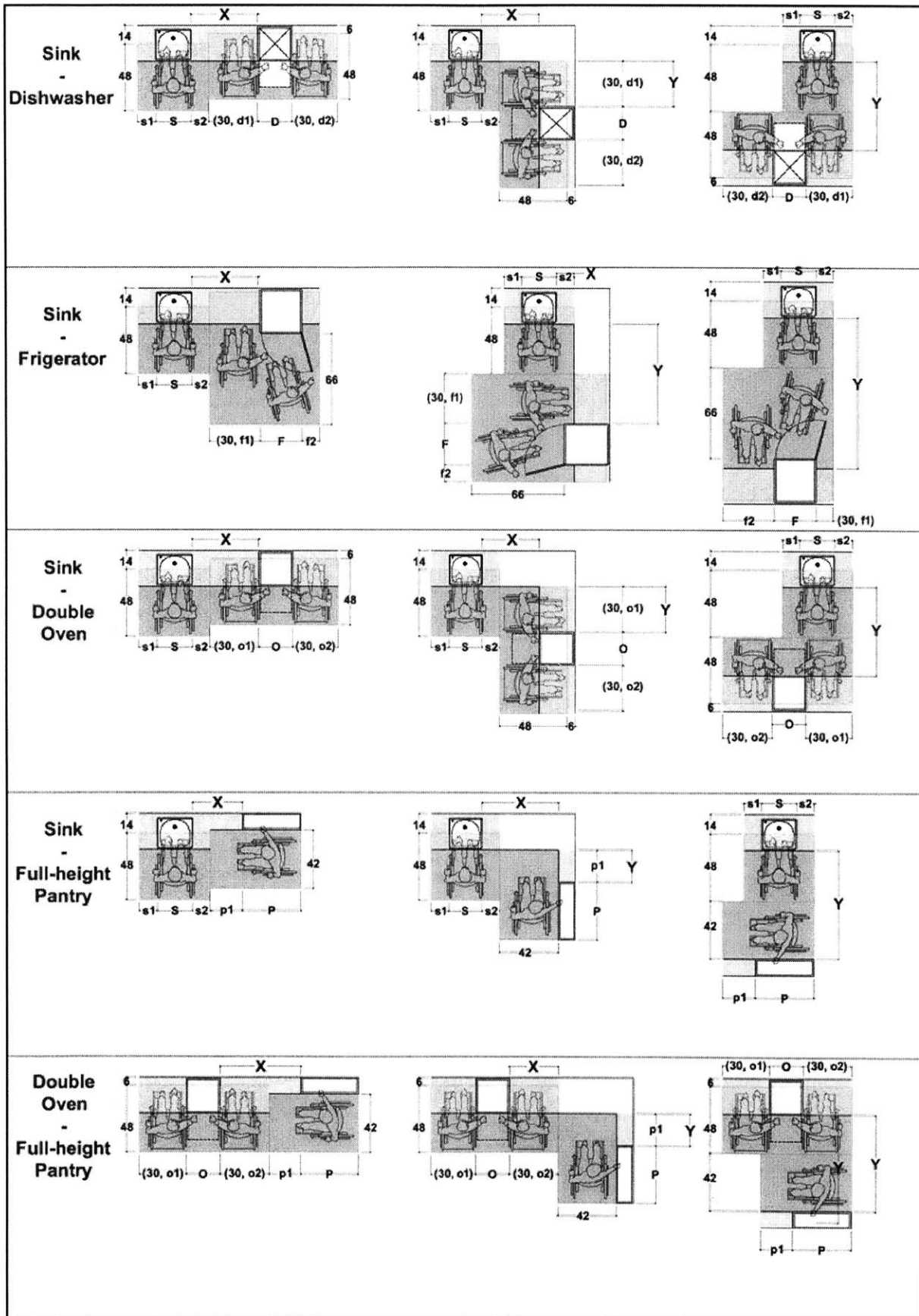


Table 4-17. Parametric rules –Part 7

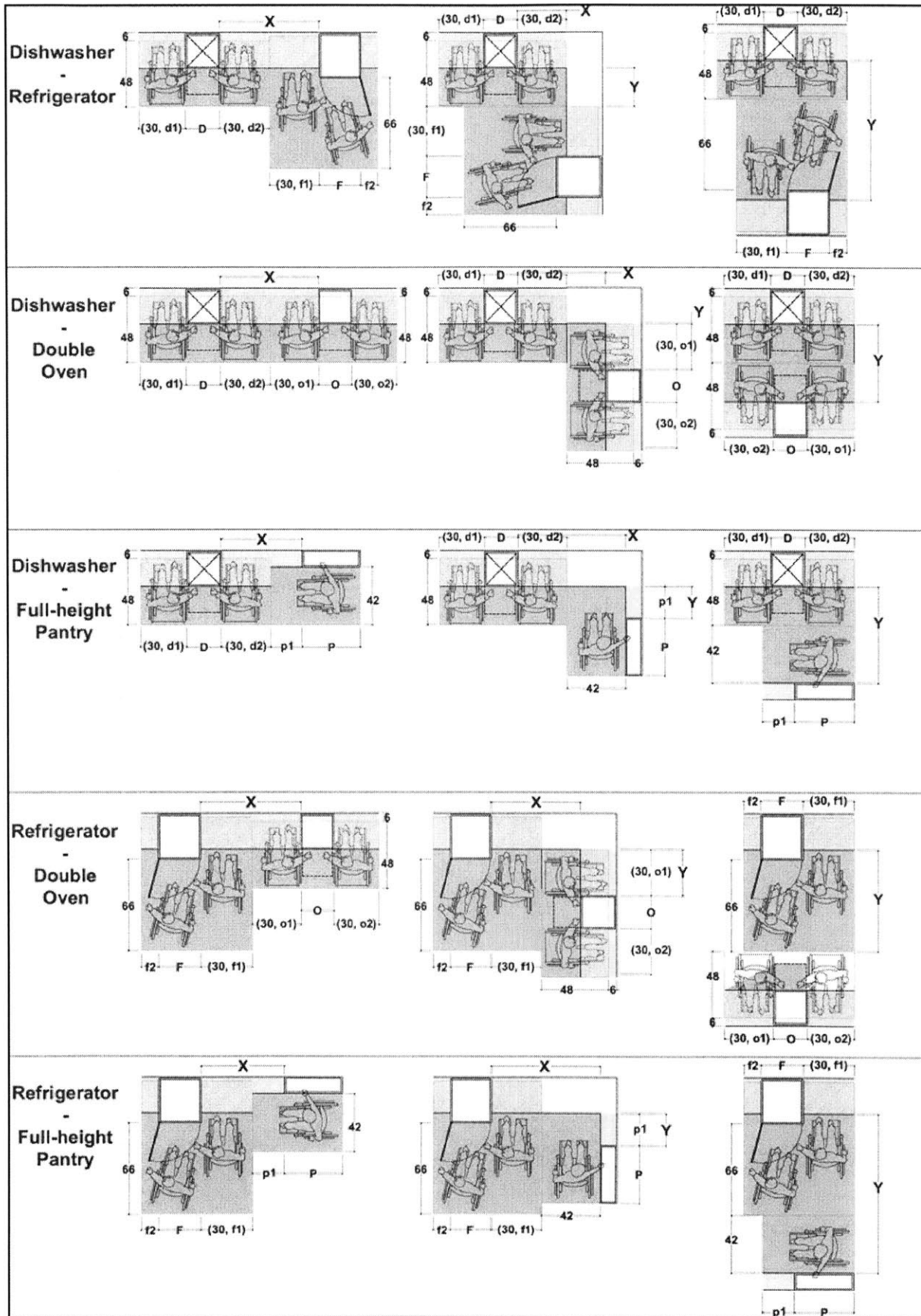


Table 4-18. Parametric rules –Part 8

	To Wall	To Window	To Open Counter Edges	To Wall
Cooktop				
Sink				
Dishwasher				
Refrigerator				
Double Wall Oven				
Full-height Pantry				

Table 4-19. Parametric rules –Part 9

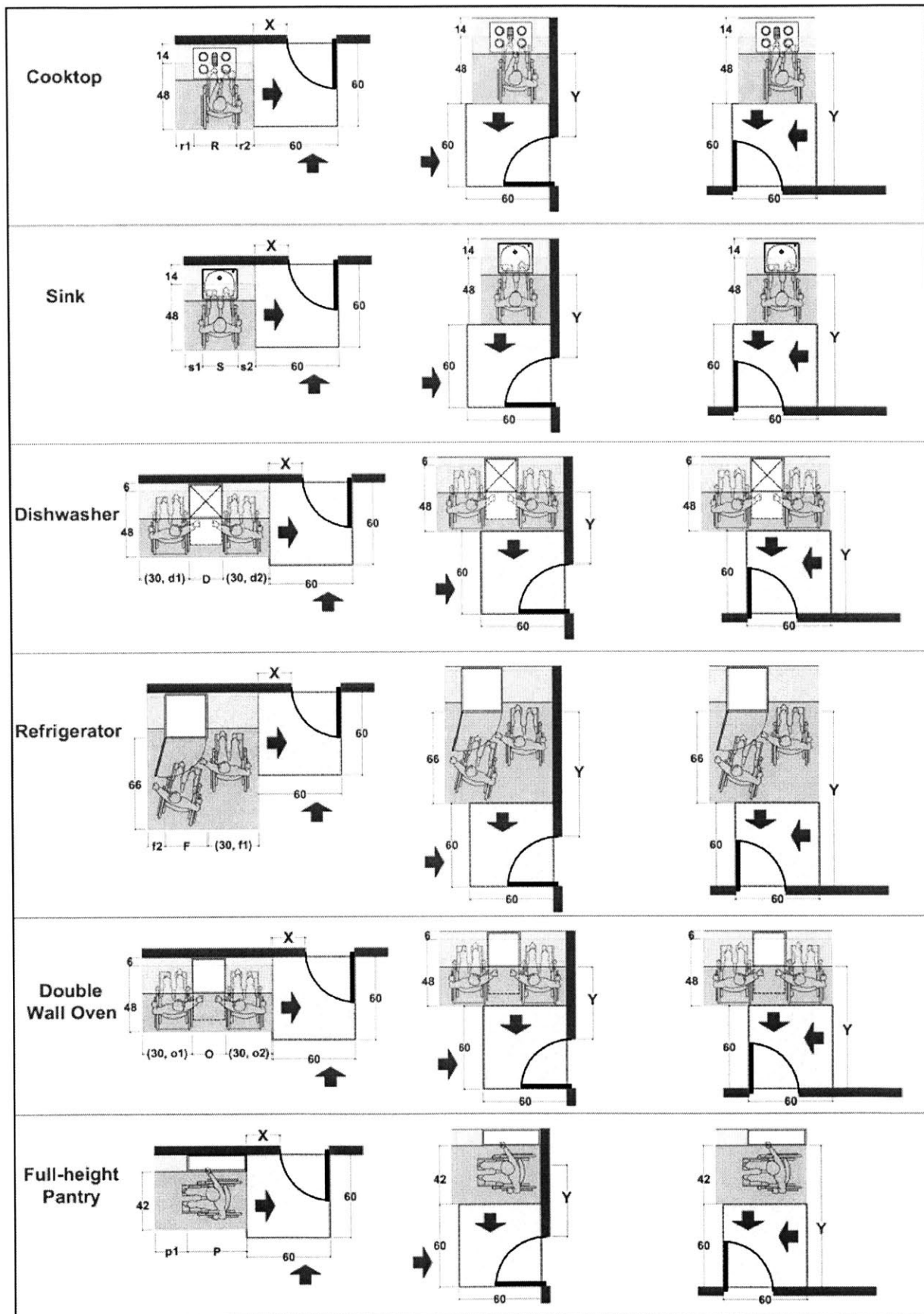


Table 4-20. Parametric rules –Part 10

The parametric data for each family size and the relevant comfort level can be calculated based on the above parametric analysis and the rules that the in-between dimensions equal to

- Comfort Level [A] Larger appliance dimension
- Comfort Level [B] Larger appliance dimension + ½ Smaller appliance dimension
- Comfort Level [C] Larger appliance dimension + Smaller appliance dimension

Table 4-21 is a sample information table for a family of six members with comfort level [C].

Inbetween Relationship		Adjacent to		Catty-corner to					Parallel from	
		X	X range	X	X range	Y	Y range	X+Y range	Y	Y range
Cooktop	Sink	48	48~60	24	12~42	24	12~42	36~84	48	40~60
Cooktop	Dishwasher	42	42~84	24	12~48	30	24~72	54~120	60	54~72
Cooktop	Refrigerator	42	42~84	18	18~48	36	36~72	54~120	60	54~72
Cooktop	Double oven	48	48~84	18	18~48	36	30~72	54~120	60	54~72
Cooktop	Pantry	36	30~72	18	18~48	24	24~72	42~120	48	48~72
Sink	Dishwasher	42	36~72	36	36~48	30	30~36	60~84	48	48~72
Sink	Refrigerator	42	42~72	18	18~48	30	30~72	48~120	60	60~72
Sink	Double oven	48	42~72	18	18~72	36	30~72	48~144	48	48~72
Sink	Pantry	36	36~	18	18~72	24	24~	42~	48	48~72
Double oven	Pantry	36	36~	36	36~	12	12~	48~	60	60~108
Dishwasher	Refrigerator	36	36~84	18	18~72	36	36~72	54~144	60	60~90
Dishwasher	Double oven	42	42~84	18	18~72	42	42~72	60~144	60	60~90
Dishwasher	Pantry	30	30~	24	24~72	42	42~	66~	60	60~
Refrigerator	Double oven	36	36~84	48	48~72	18	18~72	66~144	60	60~120
Refrigerator	Pantry	24	24~	36	36~72	12	12~	48~	60	60~120
Wall	Cooktop	18	18~							
Wall	Sink	24	24~							
Wall	Dishwasher	18	18~							
Wall	Refrigerator	12	12~							
Wall	Double oven	24	24~							
Wall	Pantry	12	12~							
Window	Cooktop	12	12~							
Window	Sink	~	~							
Window	Dishwasher	~	~							
Window	Refrigerator	12	12~							
Window	Double oven	12	12~							
Window	Pantry	12	12~							
Counter edge	Cooktop	24	24~							
Counter edge	Sink	24	24~							
Counter edge	Dishwasher	18	18~							
Counter edge	Refrigerator	18	18~							
Counter edge	Double oven	24	24~							
Counter edge	Pantry	12	12~							
Return counte	Cooktop	12	12~							
Return counte	Sink	18	18~							
Return counte	Dishwasher	12	12~							
Return counte	Refrigerator	12	12~							
Return counte	Double oven	18	18~							
Return counte	Pantry	12	12~							

Table 4-21. Sample database of the parametric rules (5~6P[C], Normal Users)

With the above table, each design layout shown in the last chapter can be parametrically defined. To avoid a conflict among different parametric relationships, the priority of different relationships should follow these ordered rules:

- (1) Parametric arrangement should be always started from “Corner A” and continued following the two directions, respectively:
 - Corner A → Counter 4 → Corner C → Counter 3 → Corner D
 - Corner A → Counter 1 → Corner B → Counter 2 → Corner D
- (2) For the relationships between a certain appliance and other appliances, the parametric rules are implemented always in the order of “Catty-corner to” → “Adjacent to” → “Parallel from”.
- (3) Without breaking the above rules, if any conflict takes place, the relationship between the cooktop and the sink is the first priority.

4.4 Typology conversion from preference engine to design engine

The typology conversion from preference engine to design engine is crucial to the entire problem. There are actually two goals:

- (1) Allow the preference engine to search the closest default design layout in design engine according to the initial user data.
- (2) Allow the design engine to navigate among the similar design layouts according to the updated user preference.

Note that all the conversions need to be natural transformations that are understandable for lay people. Therefore, there are several principles for organizing the transformations:

- (1) The default design layout should be closest to the initial user data. That is, for the same family size and different comfort levels, the default layout may be different.
- (2) Each design layout should be transformed to the most similar layout in responding to the updated user data: First, the two layouts should be only different with the changing user data. For instance, when the user updates the preference from “no island” to “with an island”, except an island added, all the other aspects of the design should be kept unchanged. Second, each time only minimum numbers of transformations, including translation, rotation and reflection may happen in order to transform one layout into another in responding to the updated user data.

4.4.1 Searching the default design according to the initial user data

Initial user data is the key to organize all the design layouts. Table 4-22 shows a list of initial questions to the user in order to determine the default design. These questions include:

- (1) How many people are there in your family?
- (2) How many cooks usually work in your kitchen?
- (3) What is the meal type of your family, such as frozen food, carryout, vegetarian, simple family meal, and elaborate meal?
- (4) Does your family eat in the kitchen? If yes,
 - a. What other activities do you do in the kitchen, such as party preparation, family gathering, kids doing homework, kids playing, short naps, ironing, reading, and watching TV?

- b. Do you need a central island?
 - c. Do you need a breakfast bar?
 - d. Do you like to work with the main appliances in the catty-corner?
- (5) Does your family eat in the kitchen? If no,
- a. Do you like to work with the main appliances in the catty-corner?

This question list actually works for two purposes:

- (1) Obtains user preferences.
- (2) Obtains the family type. That is, the family sizes and comfort levels can be calculated based on the information obtained from these questions. It is important to set up the basic framework at the very beginning.

Table 22 shows the pointers that point to the default design. For example, based on the following sample user preferences:

- (1) Family size = 6
- (2) Cooks' number = 2
- (3) Meal type = simple family meal and elaborate meal
- (6) Eat in the kitchen = yes,
 - a. Activities: party preparation, family gathering, kids doing homework, kids playing, and watching TV
 - b. Central island = yes
 - c. Breakfast bar = yes
 - d. Work with the main appliances in the catty-corner = no.

In Table 22, the design engine traces the tree-shaped diagram until it reaches the closest result. In this case, the first row of layouts meets the initial user needs. In the meantime, the design engine calculates and retrieves the family type of 5~6 [C], which makes a further categorization that the default design layout should be 1-1-1-U-0, 1-1-1-U-1 or 1-1-1-U-2. Table 4-23 furthermore shows that the starting point should be 1-1-1-U-0.

The five digits in each layout name actually represent the important attributes, respectively:

First digit: Eat in = 1/0

First digit: Island = 1/0

First digit: Bar = 1/0

First digit: Shape = 1/0

First digit: Appliance configuration = 1/0

Here, "1" represents "true" while "0" represents "false".

Thus, the name 1-1-1-U-0 actually represents the information including eating-in, with an island, with a bar, U-shape and appliance configuration 0. Note that configuration "0" always refers to the beginning point among the same type of configurations.

In fact, in order to allow users to reach the default layout based on how they can continue refining the design, these questions can be asked in an indirect, simpler way. In the next chapter, some user-friendly interface design methods will be recommended in terms of the indirect way to obtain user preferences.

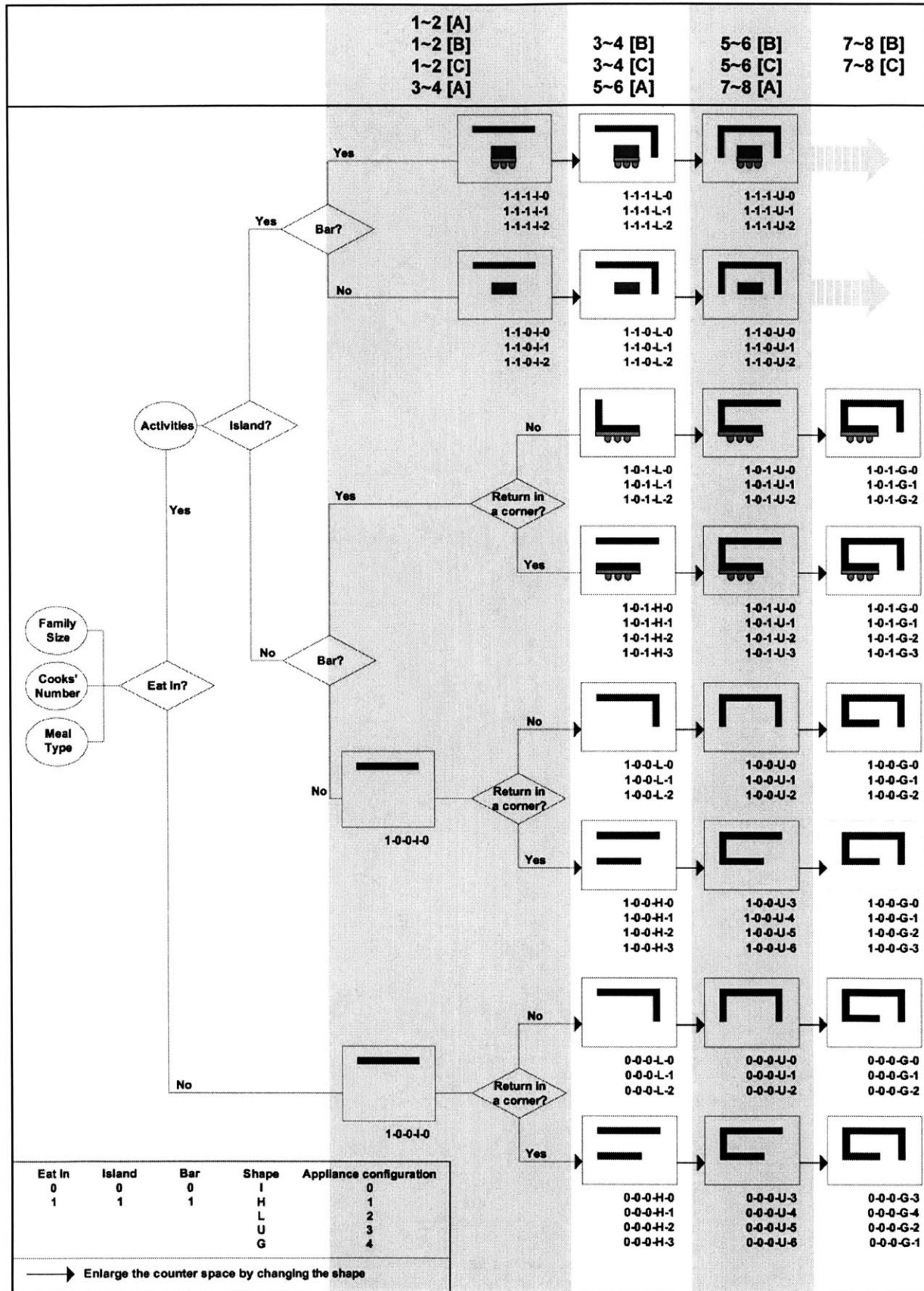


Table 4-22. Initial shape determination and shape/configuration transformations

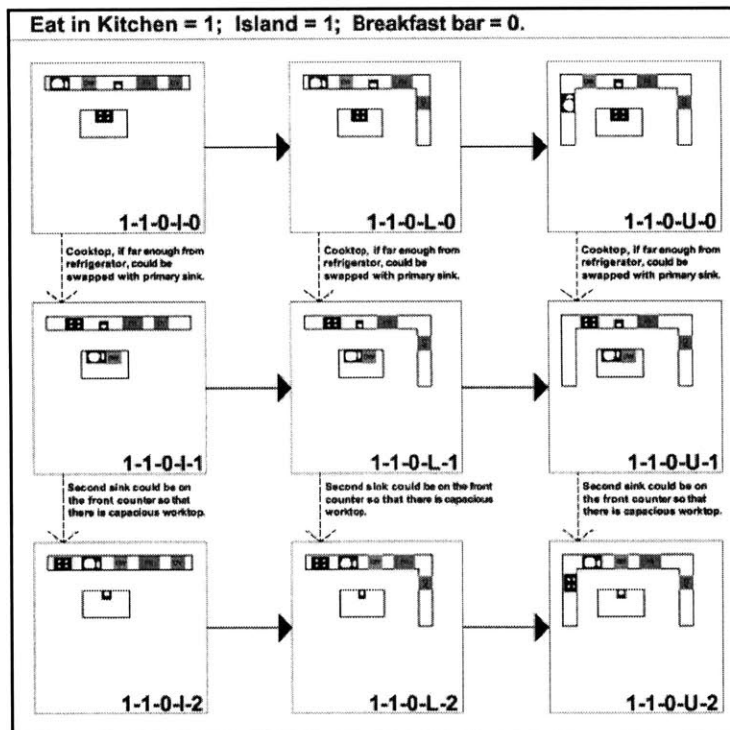
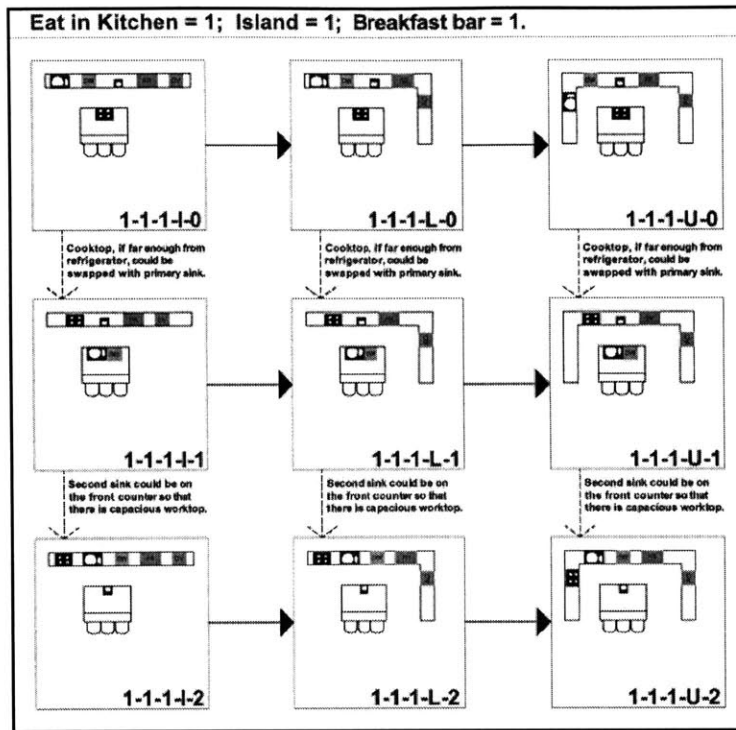


Table 4-23. Shape/configuration transformations except 1

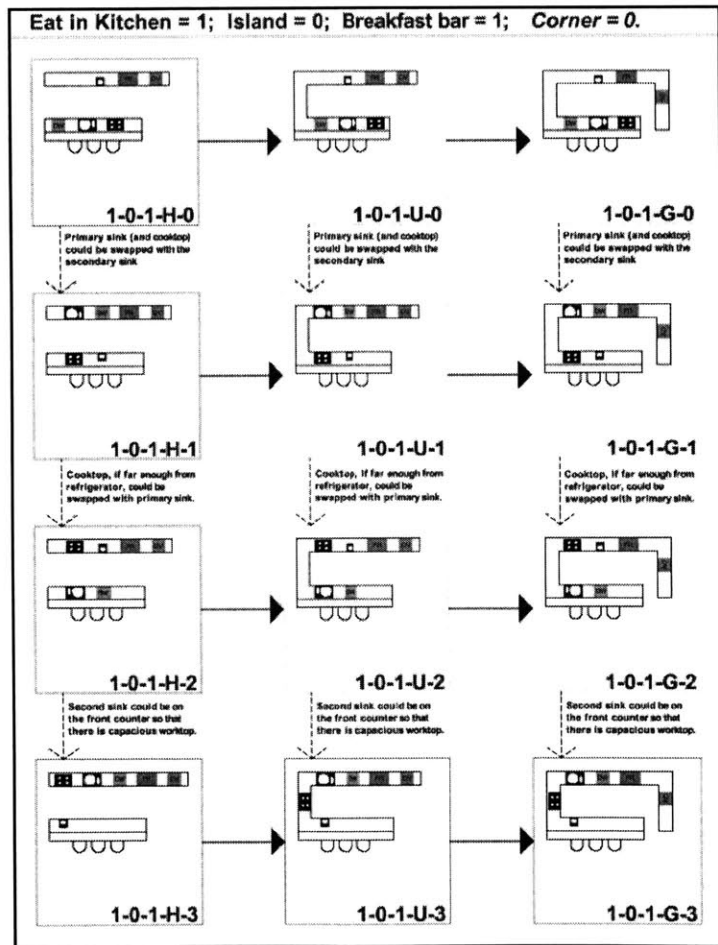
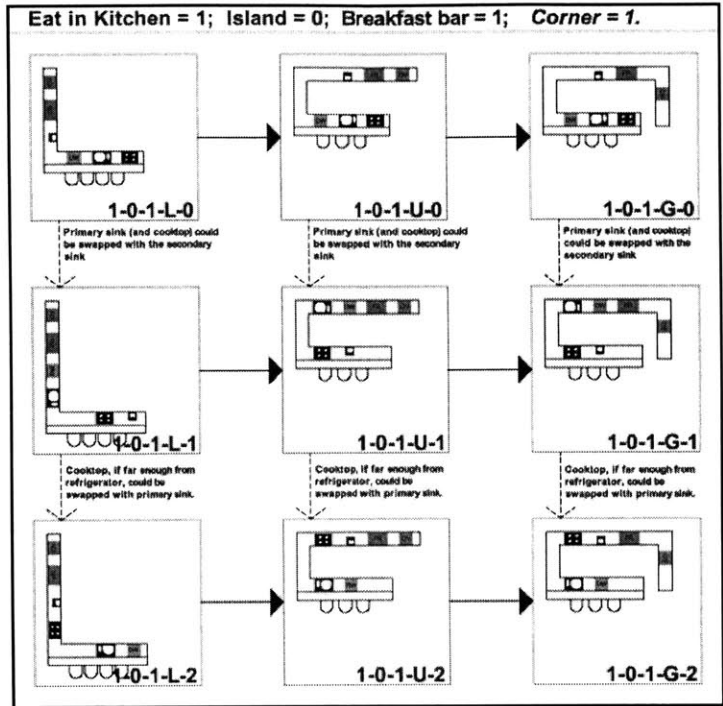


Table 4-24. Shape/configuration transformations excerpt 2

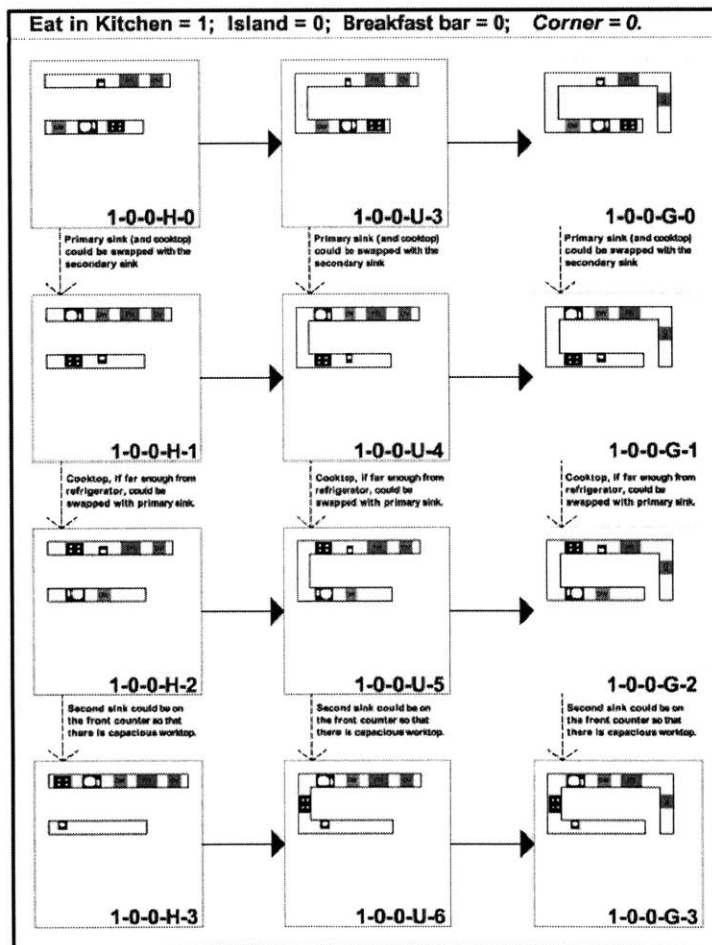
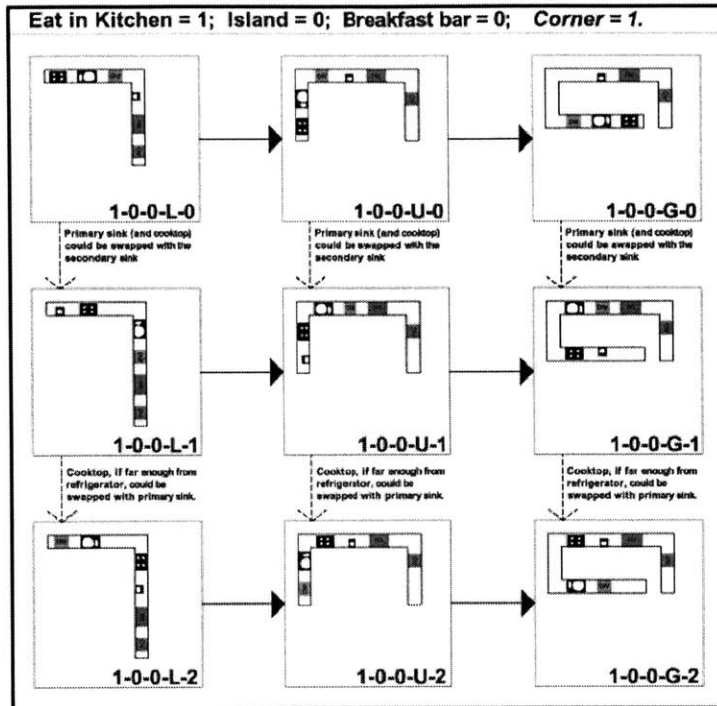


Table 4-25. Shape/configuration transformations excerpt 3

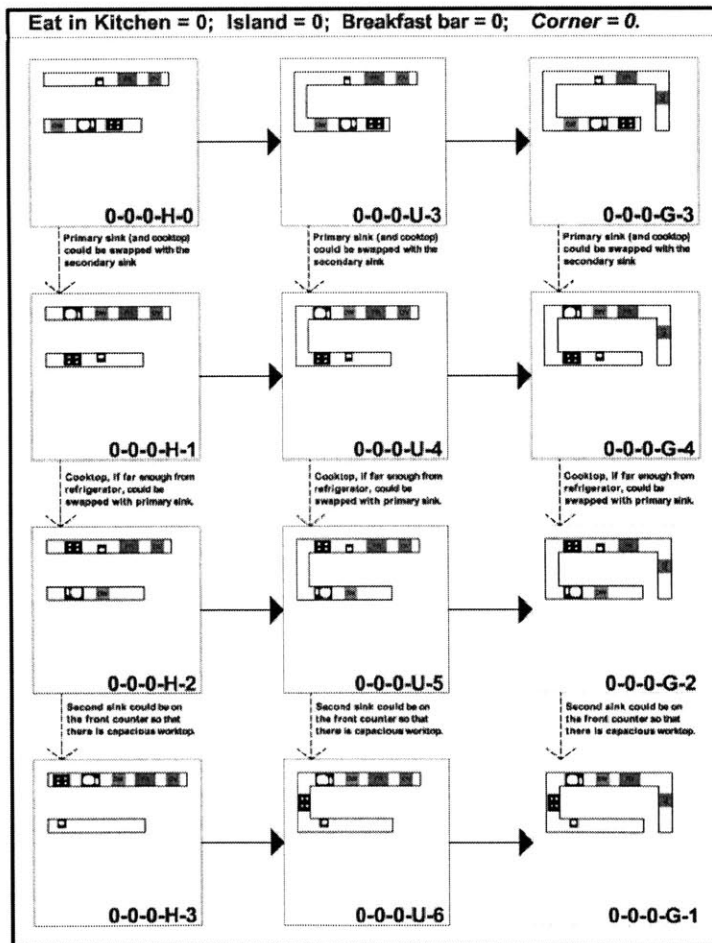
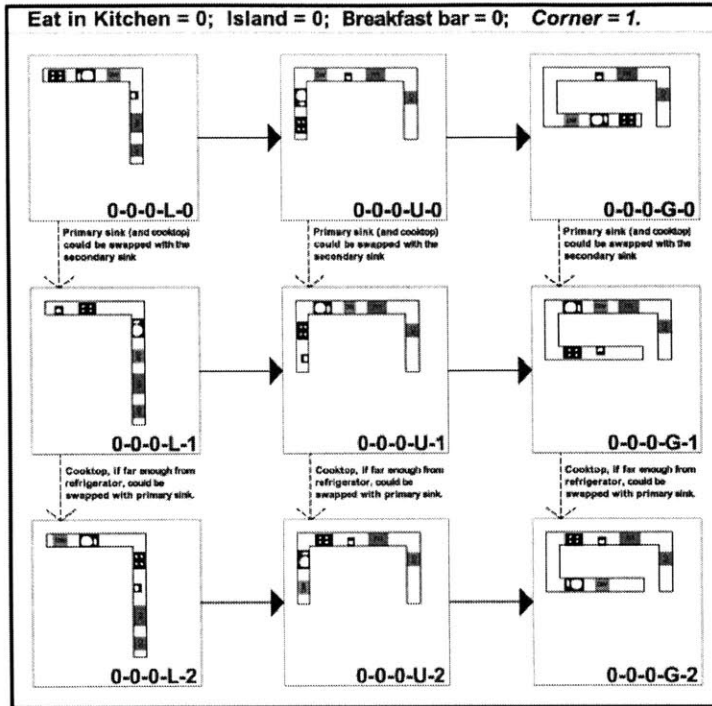


Table 4-26. Shape/configuration transformations excerpt 4

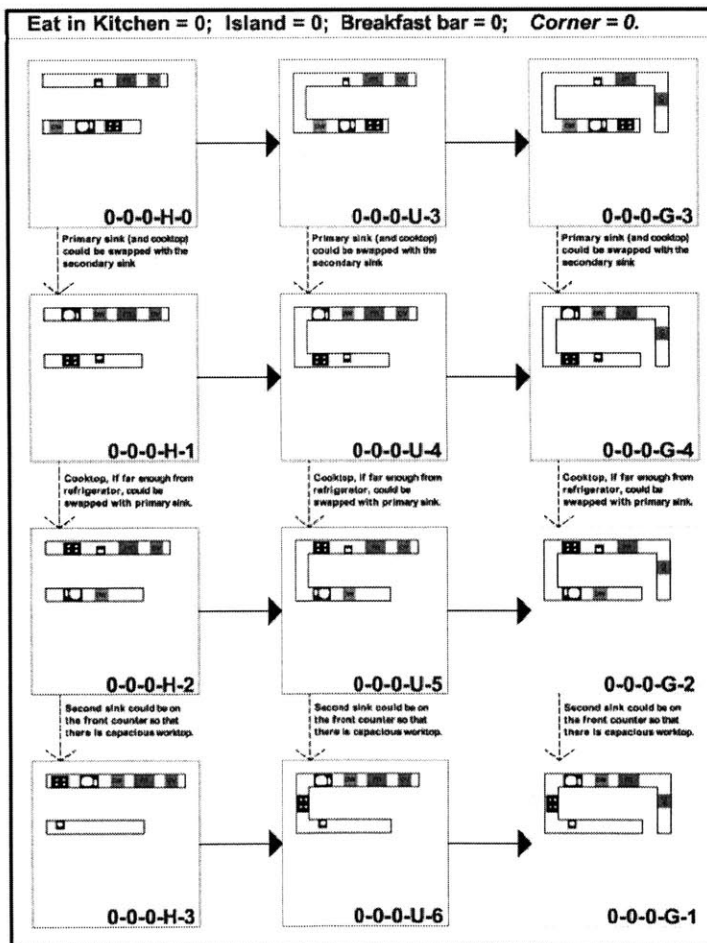
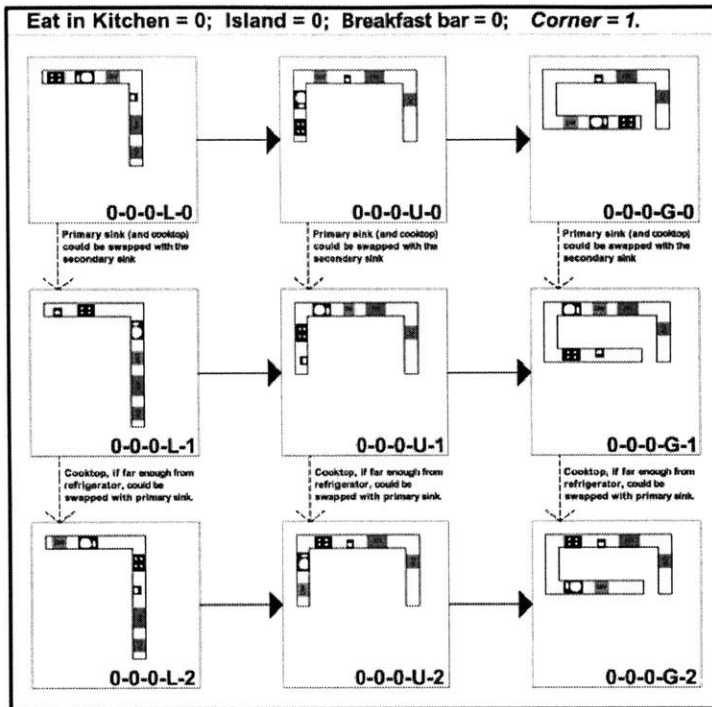


Table 4-27. Shape/configuration transformations excerpt 5

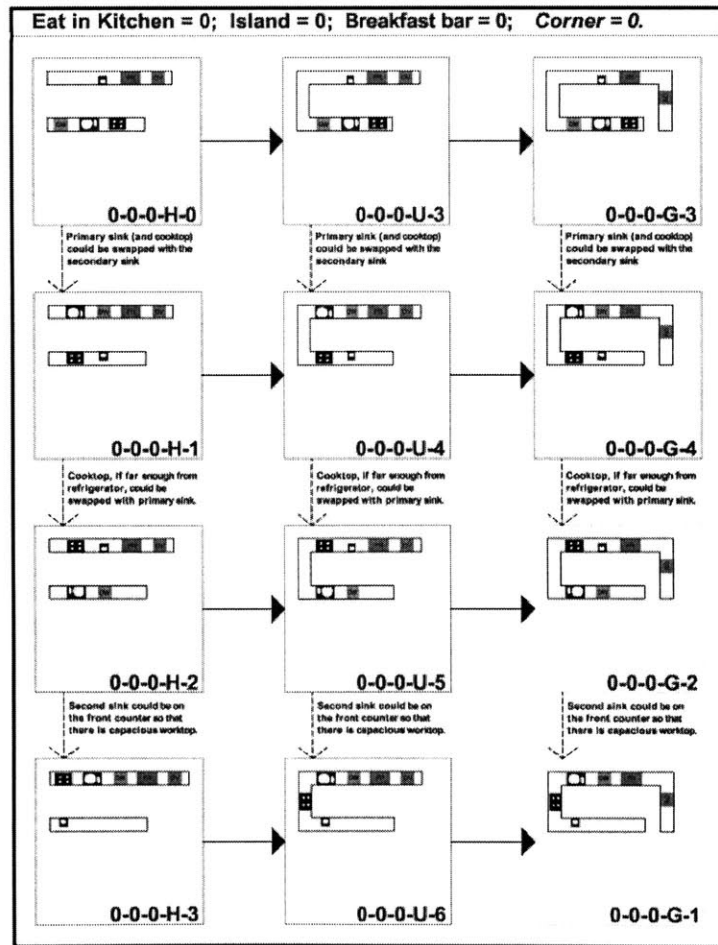
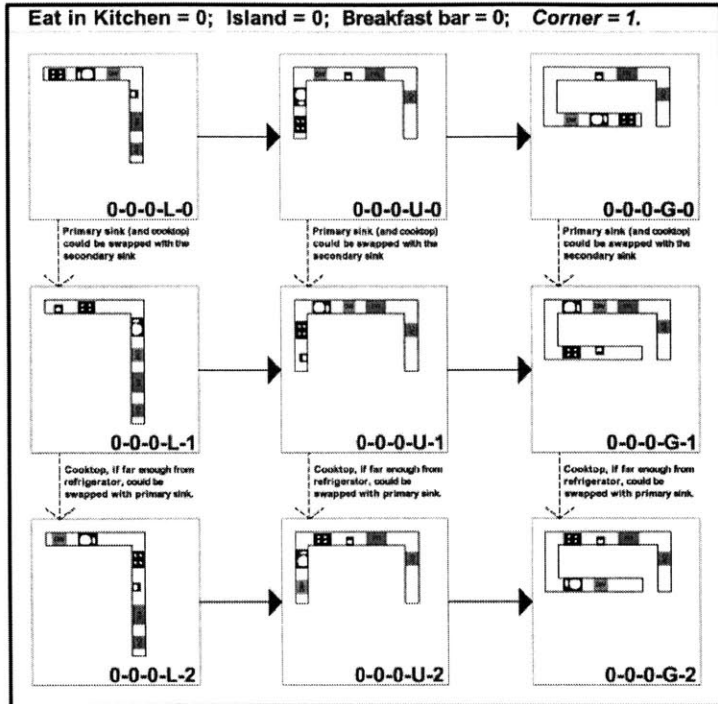


Table 4-28. Shape/configuration transformations excerpt 6

4.4.2 Refining the design according to the updated user data

Once the users reach the default design layout, they are able to make further refinement based upon it. There may be several conditions for the users to make some modification:

- (1) The user thinks that the current design is too small. In this case, the design engine needs to transform the current design into an adjacent design that reflects the same user preference with different size. Table 23 through Table 28 actually set up such a relationship with the blue arrow that means, "grow". For instance, below shows a growing process from design 1-1-1-I-0 through 1-1-1-U-0, which means:

With the same size of the kitchen façade, the usable area of the kitchen especially the usable area of the counter is enlarged. The reverse direction represents a shrinking process.

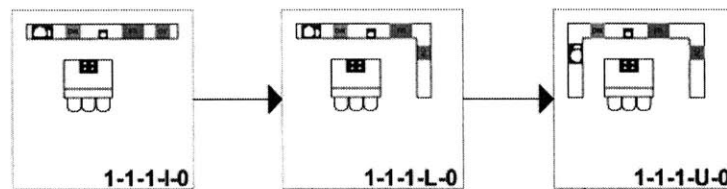


Table 4-29. Sample of the growing transformation

- (2) The user thinks that the current configuration is not convenient for him/her. In this case, a natural transformation of the appliance configuration is needed. Table 33 through Table 34 also set up such a relationship with the dashed arrow that means "configuration transformation". For instance, below shows a configuration transformation from design 1-1-1-I-0 through 1-1-1-I-2 with the explanations of usability.

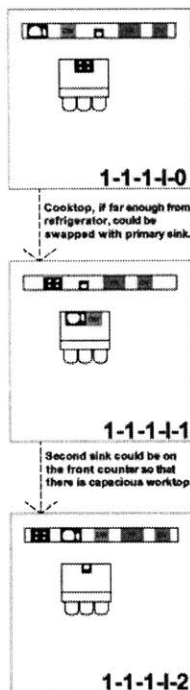


Table 4-29. Sample of the configuration transformation

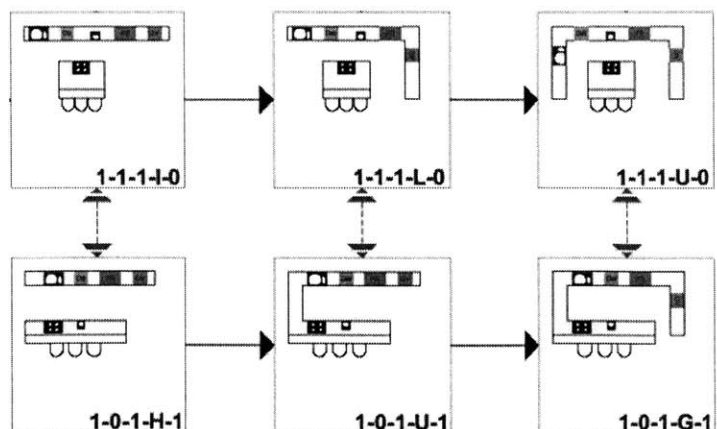


Table 4-30 Sample of island transformation

- (3) The user thinks that he/she does not need an island although he/she previously determined to have an island in responding to the initial preferences. In this case, a natural transformation between a layout with an island and the most similar layout without an island needs to be presented. In Figure 4-43 and Figure 4-44, the orange

arrows show the transformations about the island. Table 4-30 is an example: layout 1-1-1-I-0 can be transformed to layout 1-0-1-H-1 by transforming the island into a front counter; layout 1-1-1-L-0 can be transformed into layout 1-0-1-U-1 by rotating the surrounding counter and transforming the island into a front counter; layout 1-1-1-U-0 can be transformed into layout 1-0-1-G-1 by transforming the island into a front counter. During most of these transformations, the sequences of the appliances are unchanged.

- (4) The user thinks that he/she does not need a bar although he/she previously determined to have a bar in responding to the initial preferences. In this case, a natural transformation between a layout with a bar and the most similar layout without a bar needs to be presented. In Table 4-23, each layout with a bar corresponds to the layout without a bar at the same location as the other part of the table. The layouts in Table 4-24 are responding to the layouts in Table 4-25 at the same locations. Below is an example:

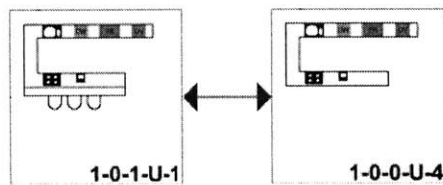


Table 4-31. Sample of the bar transformation

Theoretically, there is more user data that can be updated than those mentioned above. Along with the development of the tool, more and more layers of relationships can be added on top of the existing networks.

Note that “parallel jumps” introduced in Part 3 is the searching method to refine the current design. When the user updated the needs especially when the new user typology conflicts the current design typology, instead of traversing to the initial preference, the design engine transforms the current design to a “parallel” design that is most similar to the current design while updated with the new user data. The transformations introduced above are the examples of the relationships among similar design layouts that design engine pre-defines.

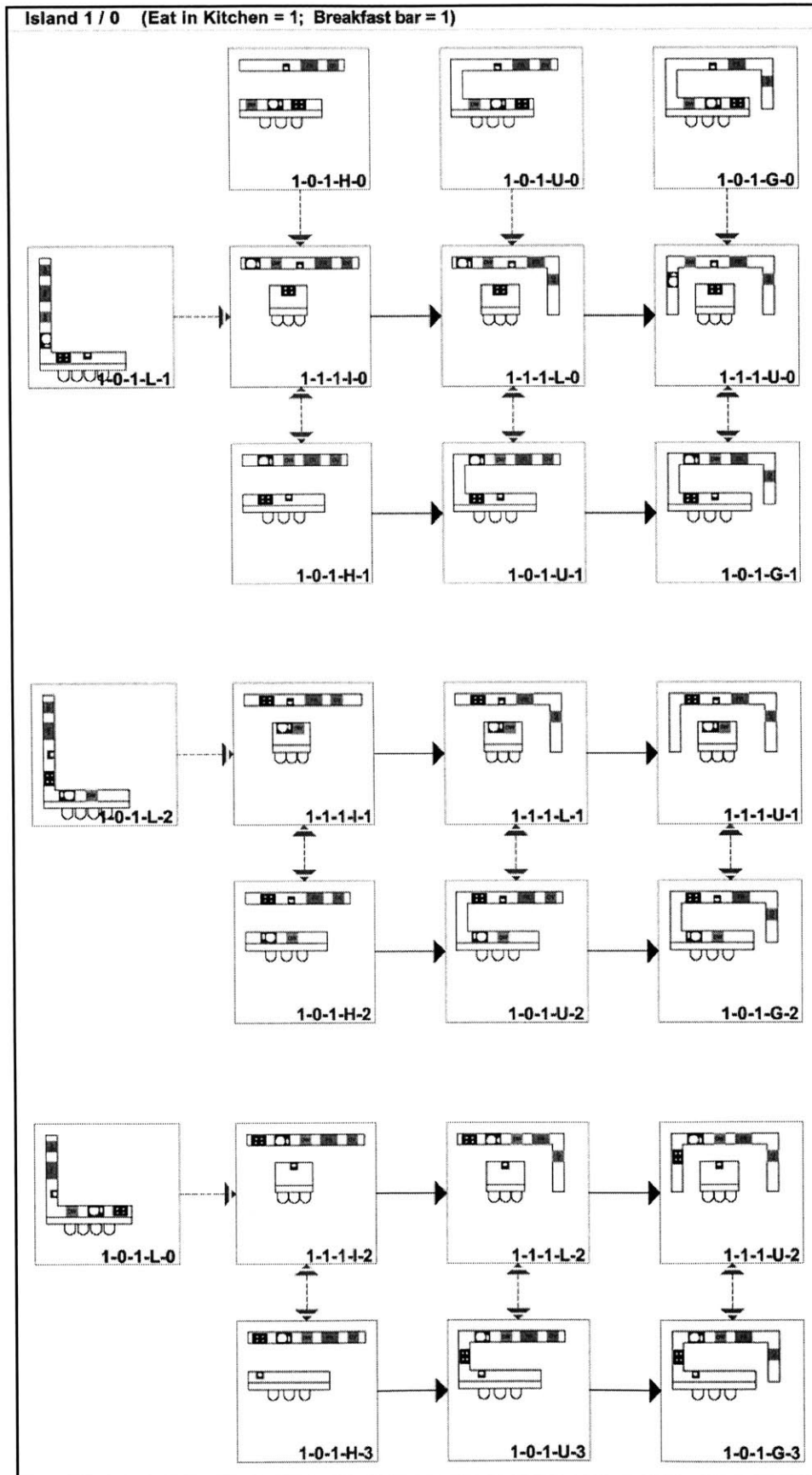


Table 4-32. Shape/configuration transformations except 7

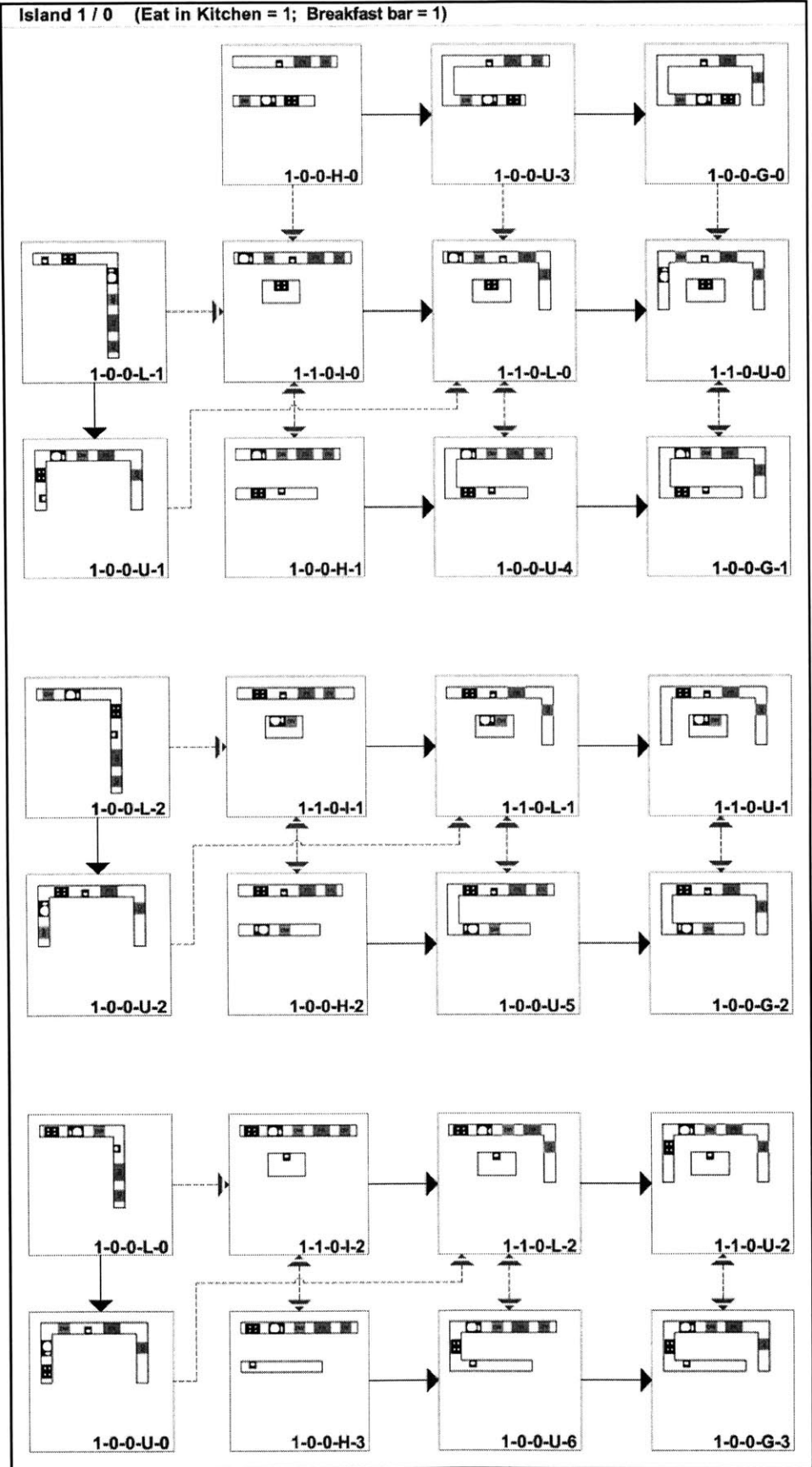


Table 4-33. Shape/configuration transformations excerpt 8

4.5 Implementation of the design engine in the context

In the above chapters, a complete workflow is set up so that users can search the proper default design and navigate in the connected design layouts. In this chapter, the abstract kitchen counter shapes can be equipped with actual kitchen appliances, implemented with universal design products and finalized in the context of family lives.

4.5.1 Choosing proper kitchen appliances

Most users, although lay people, have plenty of knowledge and preferences about kitchen appliances. Therefore, initial kitchen appliances should be chosen only for temporary. Users should be given enough freedom to choose any appliances, as they like. Initial kitchen appliances are chosen according to the family type including family size and the comfort level. Table 4-35 through Table 4-40 list most of the recommended initial kitchen appliances including sinks, cooktops, refrigerators, ovens and dishwashers. All the samples of the electrical appliance are from General Electric and all the samples of sinks are from Kohler.


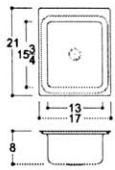
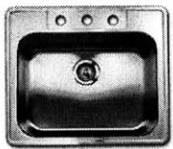
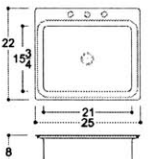
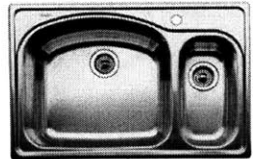
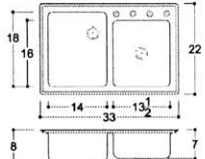
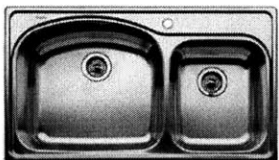
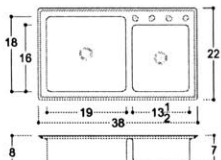
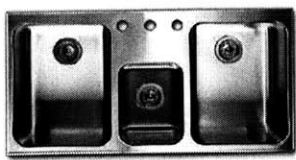
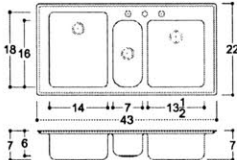
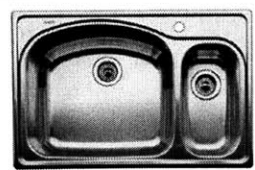

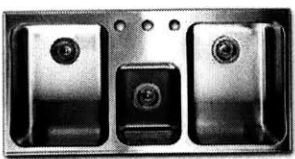

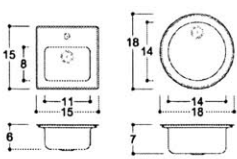
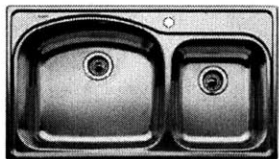

Level	Option 1				Model Drawing
1P[A] w = 16			W	17	
		D	21		
		H	8		
2P[A] w = 25			W	25	
		D	22		
		H	8		
3-6P[A] w = 33			W	33	
		D	22		
		H	10 & 8		
7-8P[A] w = 38			W	38	
		D	22		
		H	8 & 7		
7-8P[B] w = 43			W	43	
		D	22		
		H	7 & 6 & 7		
			W	33, 15	
			D	22, 15	
			H	10 & 8, 6	
7-8P[C] w = 53			W	43, 15	
			D	22, 15	
			H	7 & 6 & 7, 6	
			W	38, 18	
			D	22, 18	
			H	10 & 8, 7	

Table 4-34. Recommended Sinks


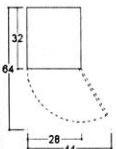
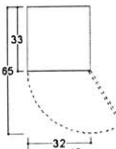
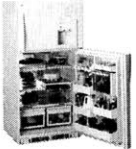
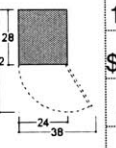
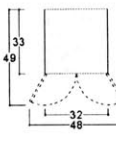
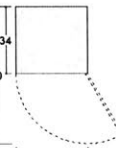
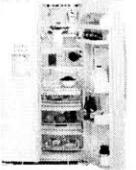
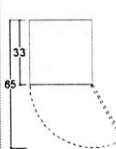
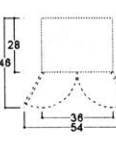
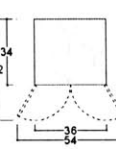
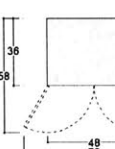

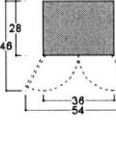
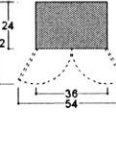
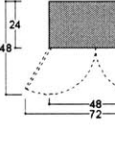

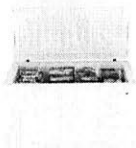
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		Wmin = 24		Wmin = 28		Wmin = 33		Wmin = 36		Wmin = 48	
	C		18.1		21.7						
	P	\$900			\$1,050						
	W		31		33						
	D		31		35						
	H		67		69						
	C	10.3	16.9		21.7		24.6				
	P	\$500	\$600		\$950		\$1,100				
	W	24	28		33		36				
	D	28	32		34		34				
	H	60	68		68		68				
	C		19.8		22.7		26.7		?		
	P		\$850		\$2,100		\$1,800		?		
	W		32		36		36		48		
	D		33		28		35		36		
	H		68		70		70		70		
	C				26.6		22.7		?		
	P				\$2,500		\$2,600		?		
	W				36		36		48		
	D				28		24		24		
	H				70		70		70		
	C	14.1	17.1		20.6						
	P	\$300	\$400		\$450						
	W	28	32		32						
	D	29	27		29						
	H	59	65		70						
	C	7	8.8		14.8		19.7		24.9		
	P	\$200	\$250		\$300		\$400		\$500		
	W	38	41		48		62		74		
	D	23	2		30		30		30		
	H	34	35		35		35		35		

Table 4-35. Recommended Refrigerators




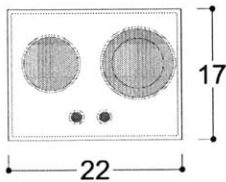
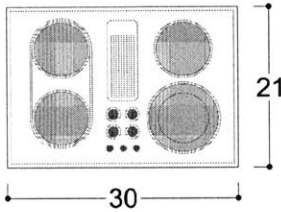
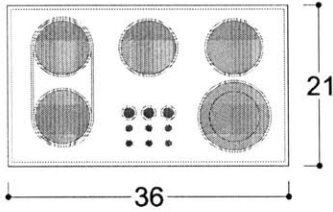



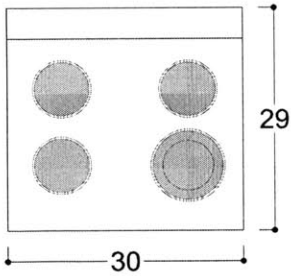
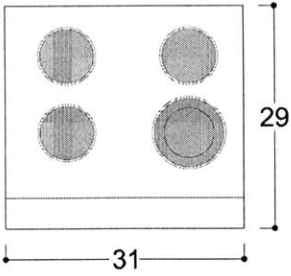
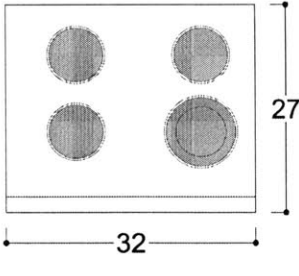
1P[A] Cooktop					2P[A], 3-4P[A], 5-6P[A] Cooktop					7-8P[A], 7-8P[B], 7-8[C] Cooktop				
														
														
\$	Burners	W	D	H	\$	Burners	W	D	H	\$	Burners	W	D	H
\$450	2	22	17	19	\$700	4	30	21	4	\$850	5	36	21	4
Free-standing Range					Slide-in Ranges					Drop-in Ranges				
														
														
\$	Burners	W	D	H	\$	Burners	W	D	H	\$	Burners	W	D	H
					\$2,000	6	31	29	36	\$1,800	6	32	27	28
					\$1,900	5	31	29	36					
\$1,000	4	30	29	45	\$1,400	4	31	29	36	\$1,000	4	32	27	28

Table 4-36. Recommended Cooktops

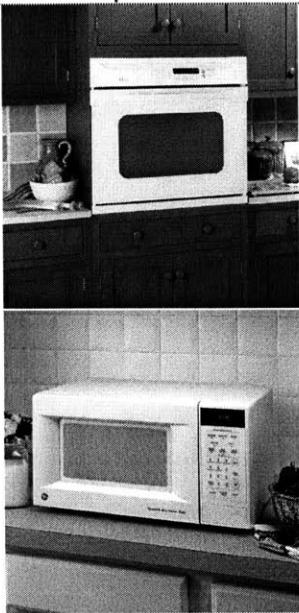
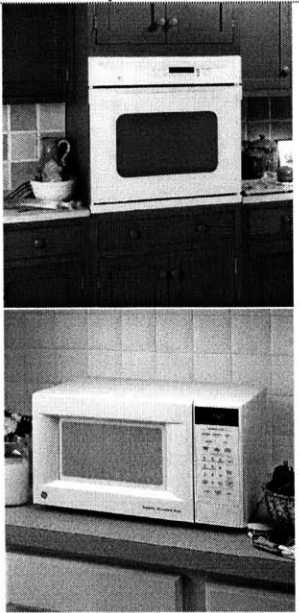
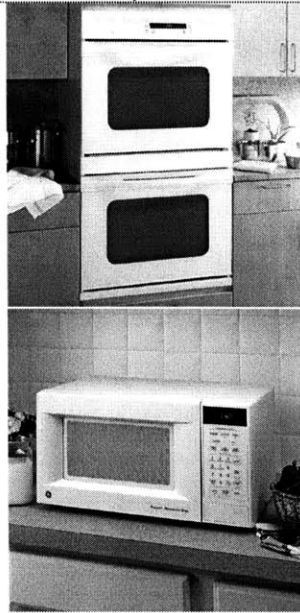


1P[A] Option 1				2P[A], 3-4P[A], 5-6P[A] Option 2				7-8P[A], 7-8P[B], 7-8[C] Option 3			
											
\$	W	D	H	\$	W	D	H	\$	W	D	H
1200	27	24	29	1400	30	24	29	2100	30	24	53
100	20	16	12	100	20	16	12	150	24	19	14
Option 2				Option 2							
											
\$	W	D	H	\$	W	D	H				
1700	30	24	44	1700	30	24	44				

Table 4-37. Recommended ovens


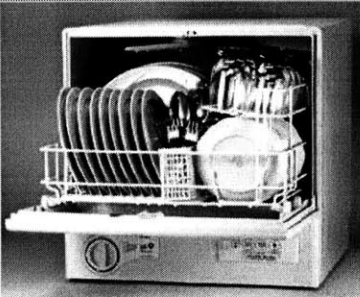

1P[A], 2P[A], 3-4P[A] Option 1. Space maker				Option 2 Countertop				5~6P[A], 7-8P[A], 7-8P[B], 7-8P[C] Built-in			
											
\$	W	D	H	\$	W	D	H	\$	W	D	H
400	18	26	35	400	20	20	20	600	24	26	35

Table 4-38. Recommended dishwashers

4.5.2 Implementing universal design products

After a certain kitchen layout that fits the user typology is chosen and refined, universal design products can be embedded into it. For this purpose, a proper link between kitchen layouts and universal design should be stated first.

The physical conditions of each family member, especially those who act as the main cooks, are criteria to determine what universal design strategies should be implemented. The basic disabilities caused by either injury or aging include several aspects:

- (1) Visual impairment
- (2) Hearing impairment
- (3) Physical impairment/limitation
- (4) Cognitive/language impairment

Each kind of disabilities or limitations may trigger one or more universal design strategies. In this project, physical limitations are the focus among all kinds of disabilities; since physical impairments/limitations are direct barriers for people's work in kitchens. Some examples of the corresponding relationship between family member profile and the universal design items can be:

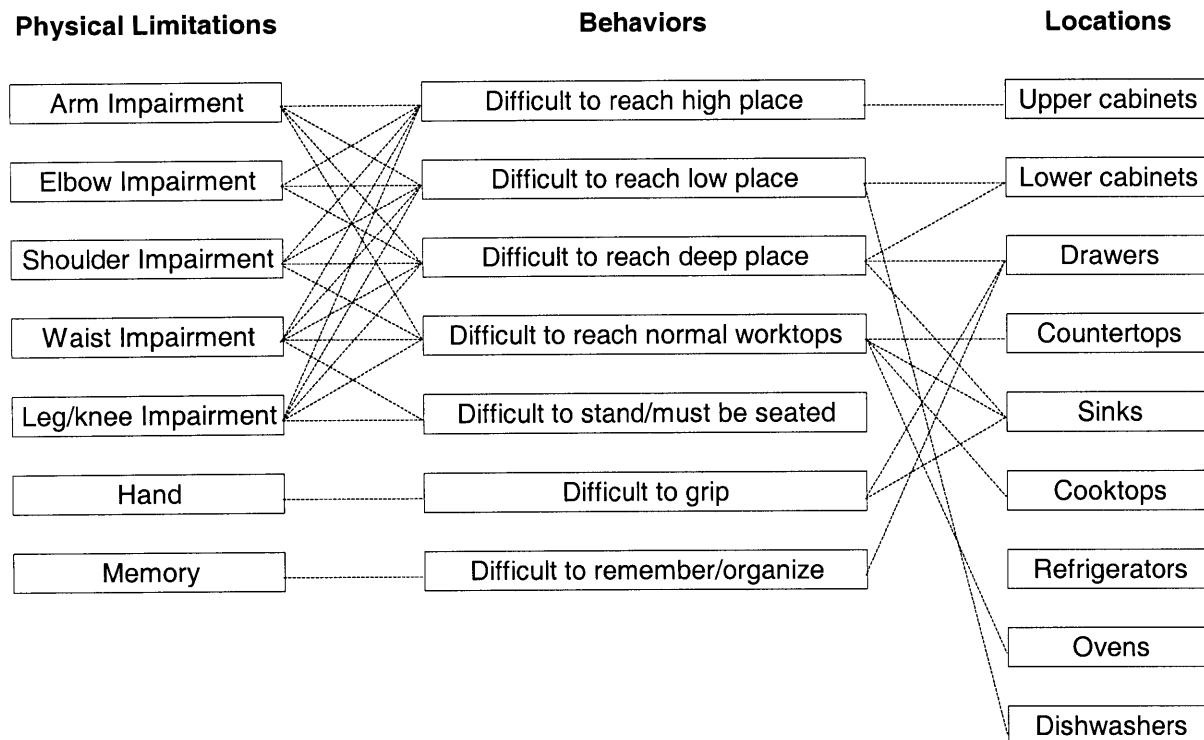


Table 4-39. Linking relationship between users' physical condition and universal solutions

4.5.3 Putting the design in the context

The kitchen is not only a place for cooking and eating, but also a social center for the family. In the previous chapters, kitchen activities like party preparation, kids playing, and watching TV have been stated. A larger context is needed to better convey the characteristics of each kitchen type. For those kitchens that the family does not eat in, the conditions are very simple, as shown in Table 4-45, while for those kitchens that the family eat in and have other activities in, family rooms are typically connected to the cooking and dining space and therefore form a larger kitchen context. Table 4-42 through Table 4-45 show the possible contexts for each kitchen type.

	Dining Inside Kitchen			Dining Both Inside and Outside Kitchen			Family Size	Cook's Number	Bar Shape	Party Prep	Kids Playing	Refrigerator Alcove	Refrigerator Flap
	Living-room NOT There	Informal Living-room Involved	Formal Living-room Connected	Living-room NOT There	Informal Living-room Involved	Formal Living-room Connected							
							4	3	0	0	1	1	0
							6	6	L	1	1	1	0
							6	6	L	1	1	1	0
							6	6	1	1	1	1	0
							6	6	L	1	1	1	0
							6	3	0	0	0	1	0
							6	3	1	0	0	1	0
							6	3	1	0	0	1	0
							6	6	0	0	1	0	1
							6	3	1	0	0	0	1
							6	3	1	0	0	0	1
							6	3	L	0	0	0	1
							6	3	L	0	0	0	1

Table 4-40. Kitchen in larger context –Part 1

	Dining Inside Kitchen			Dining Both Inside and Outside Kitchen			Family Size	Cook's Number	Bar Shape	Party Prep	Kids Playing	Recess: Alcove	Recess: Flp
	Living-room NOT There	Informal Living-room Involved	Formal Living-room Connected	Living-room NOT There	Informal Living-room Involved	Formal Living-room Connected							
							10	6	0	1	1	0	1
							10	6	1	1	1	0	1
							10	6	1	1	1	0	1
							10	6	L	1	1	0	1
							10	6	L	1	1	0	1
							6	6	0	0	1	0	0
							6	3	1	0	0	0	1
							6	3	1	0	0	0	1
							6	3	L	0	0	0	1
							6	3	L	0	0	0	1

Table 4-41. Kitchen in larger context –Part 2

	Dining Inside Kitchen			Dining Both Inside and Outside Kitchen			Family Size	Cook & Number	Bar Shape	Party Prep	Kids Playing	Reviser: Alcove	Reviser: Flip
	Living-room NOT There	Informal Living-room Involved	Formal Living-room Connected	Living-room NOT There	Informal Living-room Involved	Formal Living-room Connected							
							10	6	0	1	1	0	0
							10	6	1	1	1	0	0
							10	6	1	1	1	0	0
							10	6	L	1	1	0	0
							10	6	L	1	1	0	0
							10	3	0	0	0	0	0
							10	3	1	0	0	0	0
							10	3	L	0	0	0	0
							10	3	L	0	0	0	0
							10	3	L	0	0	0	0

Table 4-42. Kitchen in larger context –Part 3

For the family who do not have activities other than cooking, the conditions are simple as shown in Table 4-45.

		Dining Outside Kitchen	Family Size	Cook's Number	Bar Shape	Party Prep	Kids Playing	Revlac. Alcove	Revlac. Flip
		Living-room NOT There							
			4	3	0	0	0	1	0
			6	3	0	0	0	1	0
			6	6	0	0	0	0	1
			6	6	0	0	0	0	0
			10	3	0	0	0	0	0

Table 4-43. Kitchen in larger context –Part 4

Although kitchen layout design is the focus of this user-oriented tool, a connected family room can help lay people to understand the characteristics of the layout. Table 4-47 shows a set of dimensional rules that define a typical family room in terms of each family size and comfort levels. Obviously, the assemblies are not the only solutions but recommended ones. Further research about the way to assemble furniture in terms of each family activity is needed in future.

4.5.4 Considering the parametric rules for the height

In current kitchen design process, height is the element that is less considered by architects. Typically architects choose the kitchen products or determine the height according to the architectural standards. However, most cooks may be more sensitive to the height dimensions than to the horizontal dimensions. For instance, some users complain that most sinks are lower than they need while most counter top is higher than they like when chopping. Universal design products pay more attention to the height through adding pull-down shelves, pullout counter and other flexible units. Hence, a further research about the criteria that helps to determine the real height that the user feels comfortable with is needed.

In Table 4-48, critical heights about human dimensions are taken as the reference to determine proper heights of the kitchen parts. These references are the shoulder level of the wheelchair user and the maximum reaching height and elbow height of the common users. This kind of reference is free from different genders, ages, and various physical conditions.

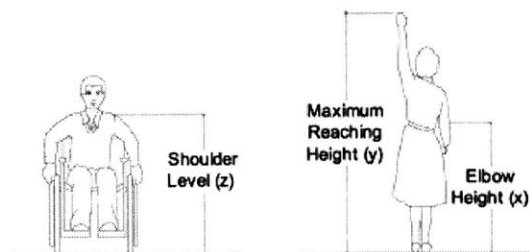


Table 4-44. Reference for the parametric height rules

Table 4-47 shows the recommended height dimensions of the main kitchen appliances in terms of these references. Implementation of these dimension rules can help lay people learn the benefit that proper heights can bring them, and then determine the typical height of the appliances even if they choose flexible universal design products.

	Formal Dinner	Informal Dinner	Eating Breakfast at a Bar	Family Gathering	Kids Playing	Reading/Computer	Ironing	Assembly
1:00 PM								
1:30 PM								
3:00 PM								
3:30 PM								
5:00 PM								
5:30 PM								
7:00 PM								
7:30 PM								
8:00 PM								
8:30 PM								

Table 4-45. Recommended furniture and dimensions in the connected family room

	Wheelchair Users	Normal Users
Reference		
work top		
Sink		
Stove and hood		
Full-height pantry		
Wall Oven		

Table 4-46. Parametric height rules

4.6 Samples of the user-oriented interface

Because the project is still in process, the user interface is not complete to be shown systematically. However, several interface examples are extracted in order to explain the basic method to implement the research data mentioned throughout the paper.

4.6.1 Preference engine and design engine

User interface can benefit from multiple presentation methods, such as graphical composition, storytelling, and interactive interface. Figure 4-1 and 4-2 show the way that graphical representation helps users to figure out the basic conditions of the family members, such as who are the primary and secondary cooks, who have certain physical limitations, who are wheelchair users, whether there are kids at home, and other questions. Simple mouse operations like clicking, dragging and dropping help users positively delineate family profiles.

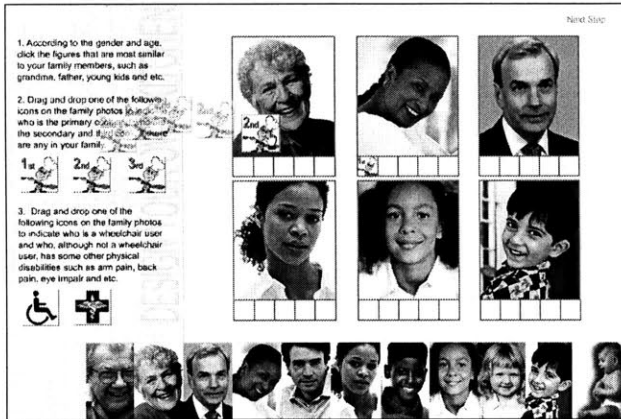


Figure 4-1. Interface excerpt 1

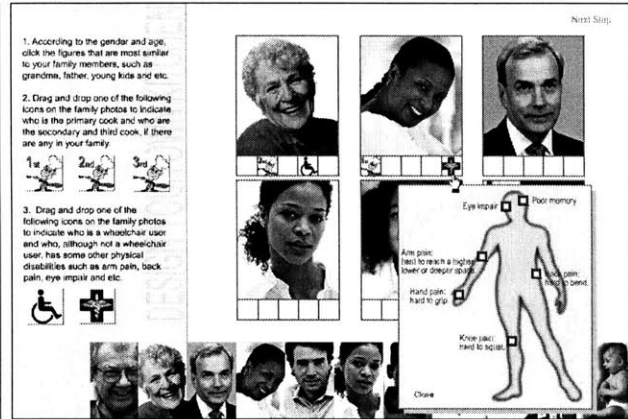


Figure 4-2. Interface excerpt 2

To help users clearly express their preferences for the arrangement of the kitchen, some blurring options should be provided. Figure 4-3 shows that the sliding bars provide blurring space for those users who are not sure where to have each meal. A quick response to the user input also gives users the chance to instantly change their minds. Ideally, the preference interface and corresponding design interface should be combined into one screen so that it is more straightforward for the user to compare the results from different options.

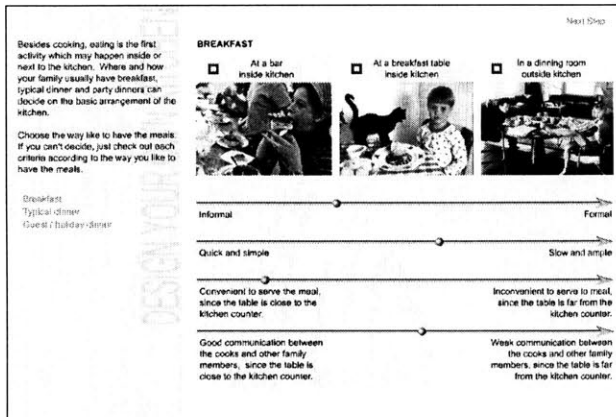


Figure 4-3. Interface excerpt 3

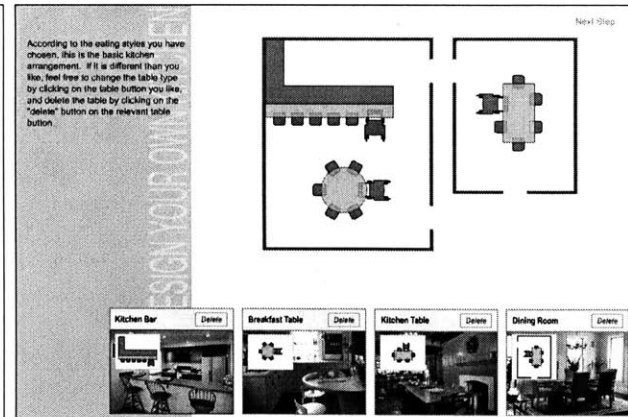


Figure 4-4. Interface excerpt 4

Typical scenarios or representative examples of the family lives can remind users of a complete life image. Figure 4-5 allows users to choose their activities in the kitchen and the typical meal types, while Figure 4-6 introduces several meal types using typical food images. Images always work well for the users who have little patience or those who cannot read. Extra explanations are welcome for those who like to explore the problem in depth.

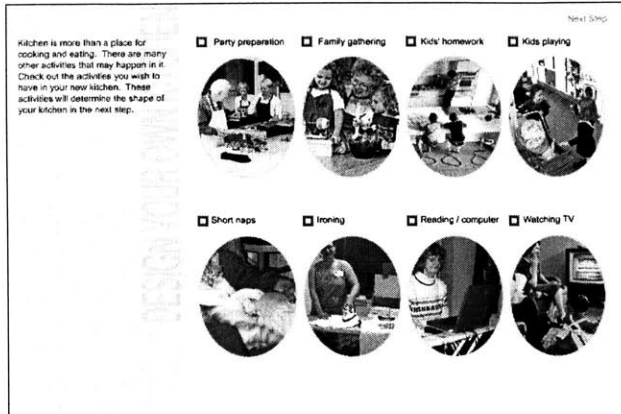


Figure 4-5. Interface excerpt 5

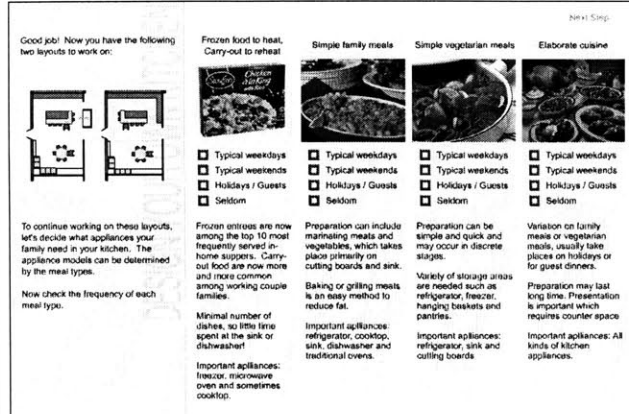


Figure 4-6. Interface excerpt 6

Clear explanations also help users understand the relationship between the options and results. Even after users have decided on some options, an extra round of explanations to allow users to make clear what they have chosen and give them chances to revise the result is help. Figure 4-7 explains using diagrams for how each part of the kitchen works for responding family activities. Figure 4-8 explains using graphics how the kitchen works for a quick breakfast, party dinner preparation and a mother who is cooking and keeping an eye on kids who are playing around the kitchen.

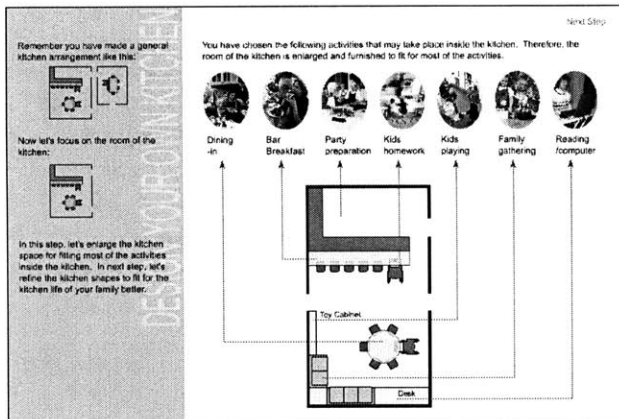


Figure 4-7. Interface excerpt 7

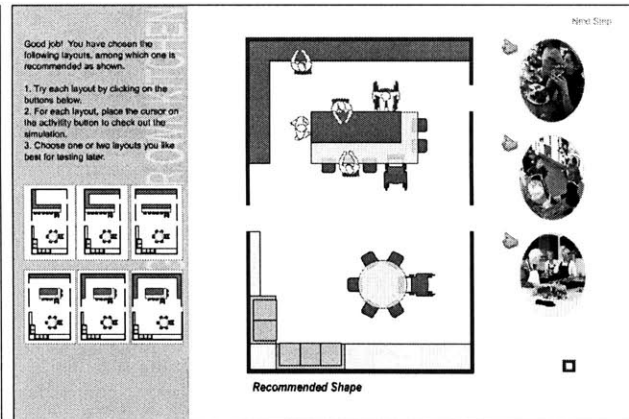


Figure 4-8. Interface excerpt 8

The system should always recommend some solutions corresponding to the options that users have chosen. However, users always have the freedom to choose the solution they like, though it may not be recommended by the system according to the best practice. In this case, the system should provide relevant information or warning messages. Figure 4-9 shows an example that when a wheelchair user chooses a traditional range instead of the recommended cooktop, there is a pop-up message warning that there is no knee-space under this range, which puts the wheelchair user in trouble. Figure 4-10 shows the recommended layout after the preference engine records all the information that the user input, while there are still several other design results laid out for the user to choose.

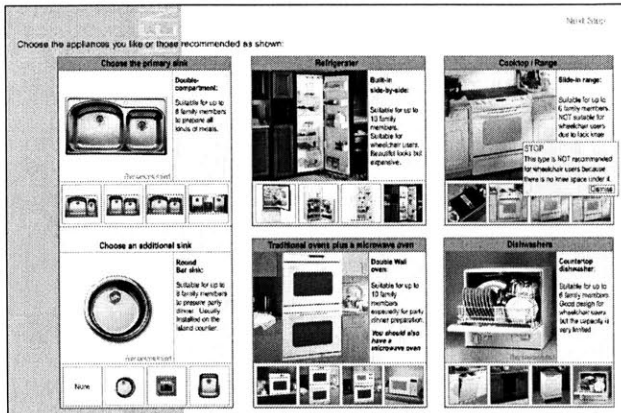


Figure 4-9. Interface excerpt 9

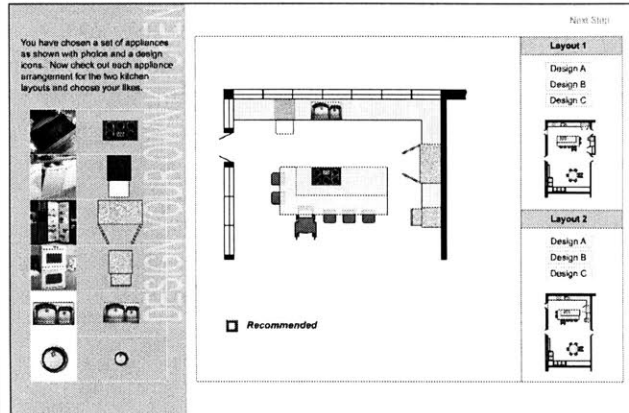


Figure 4-10. Interface excerpt 10

4.6.2 Evaluation engine

Evaluation engine is not only the space for users to check out whether universal design principles work in the design, but also the space where users can “experience” the design before they make the final decisions.

Figure 4-11 shows the interface with which users can drag some cookware and drop them into the “kitchen”. In this environment, users are actually arranging the new kitchen according to their preference. Ideally, the system can provide an “adjustment” engine within this interface, with which the kitchen can be revised responding to the users’ operation. For instance, if the user places too many dishes on some part of the countertop, the system can automatically enlarge that countertop area. The parametric rule can be the reference for the adjustment.

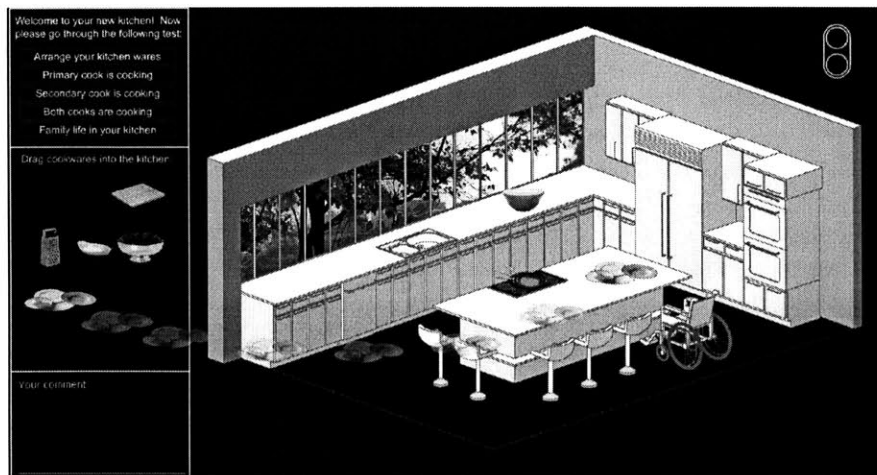


Figure 4-11. Interface excerpt 11

Figure 4-12 through 4-14 simulates the case when the primary cook works in the new kitchen. The preference engine recalls that the primary cook has arthropathy and the design engine retrieves that upper-cabinets has the connection between arthropathy and certain universal design products. As a result, when the user places the cursor on top of the upper-cabinet, a message pops up, “too high!” When the user click it, their pops up a product list that can lower the cabinet. Figure 4-13 shows that the system automatically “installs” the pull-down shelf into the new kitchen as the user choose that product.

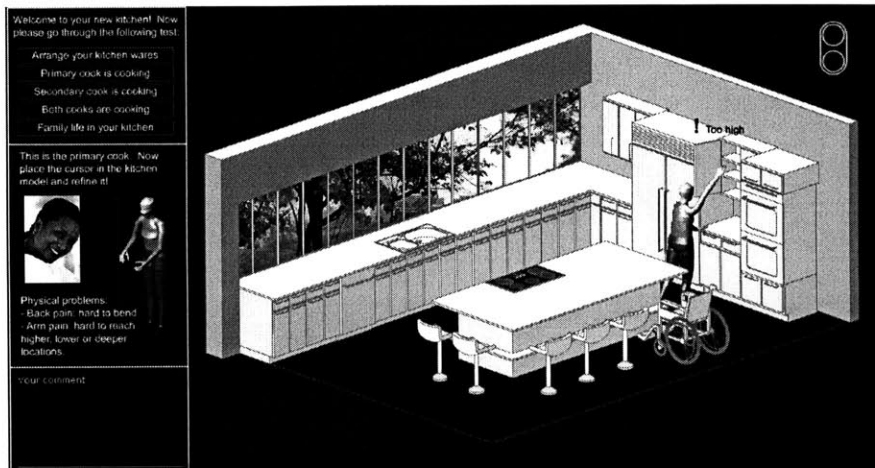


Figure 4-12. Interface excerpt 12

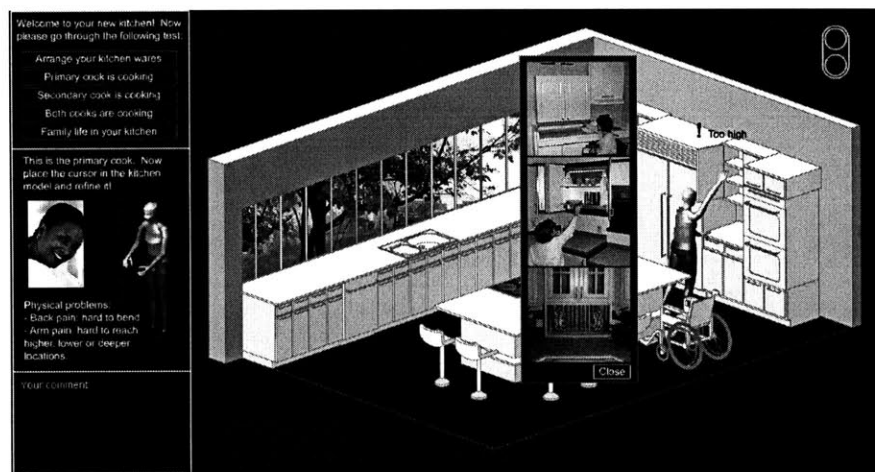


Figure 4-13. Interface excerpt 13

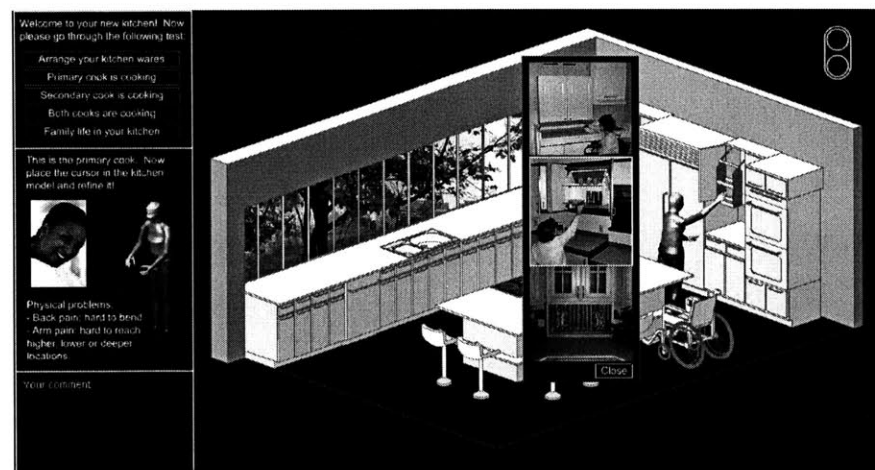


Figure 4-14. Interface excerpt 14

Figure 4-15 through 4-20 simulates the process the usability is improved for a wheelchair user. Figure 4-15 shows a “knee space!” warning message pops up when the user places a wheelchair model around the sink. In the next two steps, the interface shows the revision of the sink that is assigned enough underneath knee space and is lowered to fit the seated wheelchair users. Figure 4-18 through 4-20 shows a similar process of improving the usability of the dishwasher.

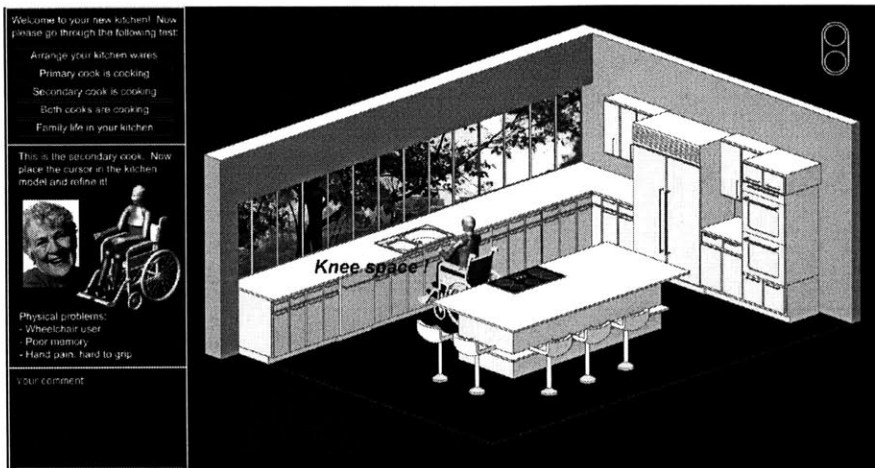


Figure 4-15. Interface excerpt 15

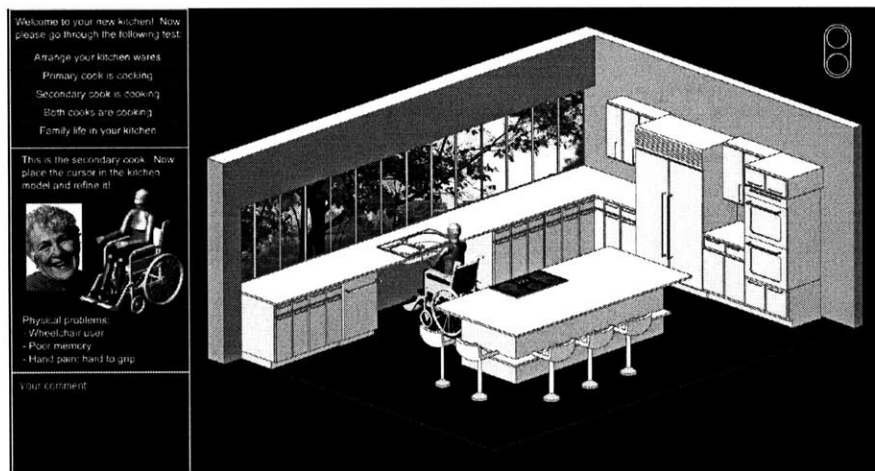


Figure 4-16. Interface excerpt 16

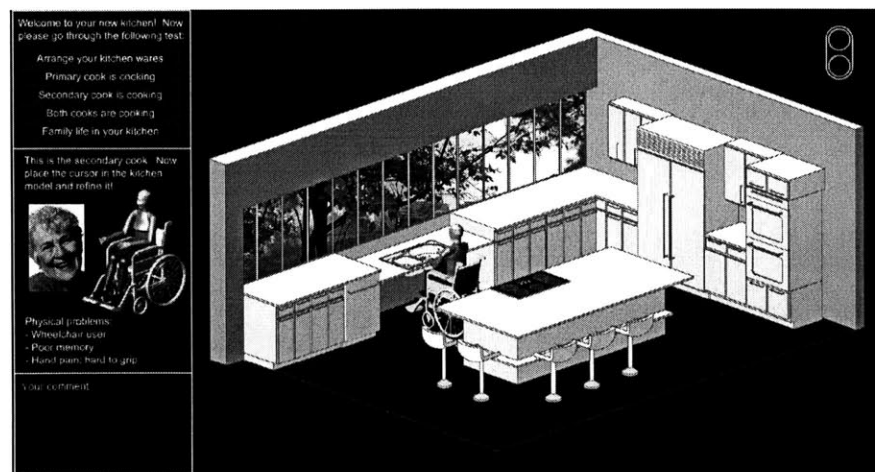


Figure 4-17. Interface excerpt 17

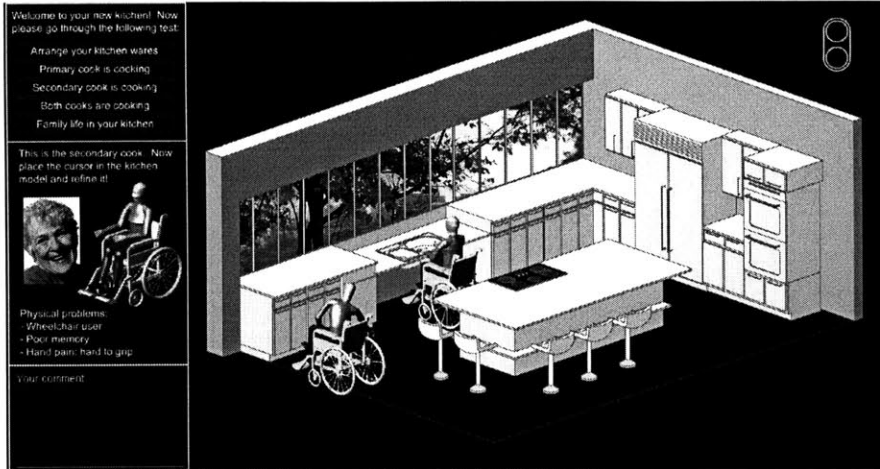


Figure 4-18. Interface excerpt 18



Figure 4-19. Interface excerpt 19

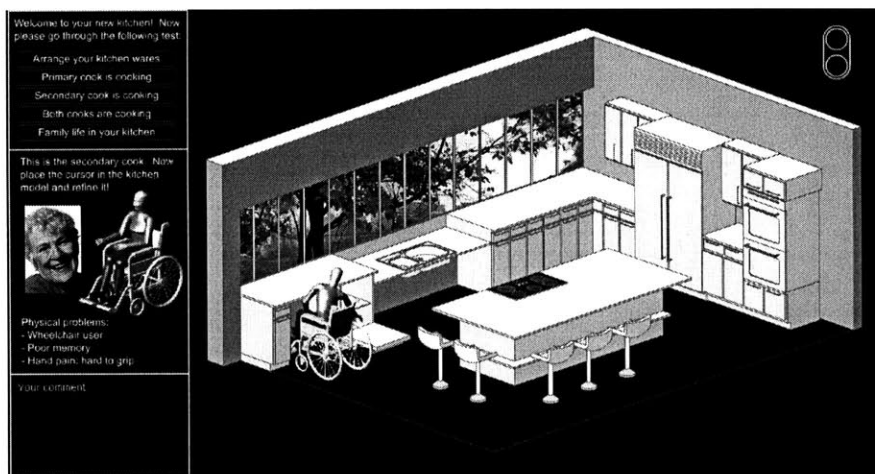


Figure 4-20. Interface excerpt 20

4.6.3 Recommendations about the interface to implement the universal kitchen design rules

Based on user-oriented interface design rule and the above examples, several suggestions are recommended to implement the universal kitchen design rules:

- (1) Take advantage of graphical interface, which is more accessible for lay people than plans and explanation in text.
- (2) Organize several questions in an indirect, storytelling way, which is more interesting and efficient for lay people.
- (3) Combine each option with certain design results in successive screens or ideally, in one screen, so that the user can instantly check out the design results from each option.
- (4) More explanation provided after the users have chosen certain options can help them to consider the problem in depth.
- (5) Ideally, one recommended “best” design solution should be provided at one time, with less than three other good design solutions provided as reference.
- (6) Users’ freedom to choose solutions that are not recommended by the system should also be permitted. In the meantime, relevant information or warning messages should be accompanied.
- (7) Universal design principles, solutions, and products should be embedded in each part of the kitchen, so that users can “experience” them when they navigate around the design representation interface.
- (8) Games based on certain story boards such as a mother arranging the kitchen, grandma in the wheelchair cooking, or the family preparing the Christmas dinner are greatly helpful for users to capture the characteristics of the design and learn the universal design principles as well.

5 Conclusion

5.1.1 Larger context: universal home design tool

This kitchen design tool is the first step of the universal home design tool. It actually demonstrates one of the methodologies of this kind of user-oriented tools:

First, it emphasizes the connection between user preferences and design solutions, which is the main difference between a designer-oriented tool and user-oriented tool. Second, it takes a pre-defined guided searching method to educate lay people how to consider the whole problem and make the eventual design. In the meantime, it avoids frustrating people with random choices without any directions. Third, it takes advantage of indirect ways such as storytelling and graphical representation to interpret design so that it is accessible to lay people.

Based on these methodologies, the entire home design tool can be an analysis of how people envision their future home, how each of their ideas can be implemented with certain design solution and how they make trade-off among different criteria.

The following diagram shows the relationship between the home design criteria and each of the partial home design criteria. As shown in Figure 5-1, home design criteria offer sub-design criteria for each part of the home, while each part of the home may provide certain constraint to other parts.

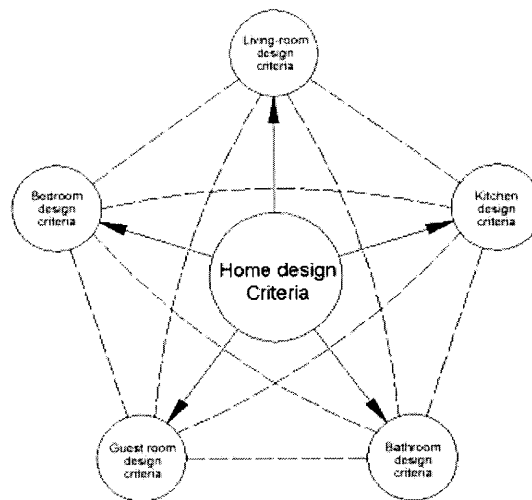


Figure 5-1. Relationship between the kitchen design tool and home design tool

5.1.2 Connection between the kitchen design tool and the larger context

To connect this kitchen design tool with the larger context of the home design tool, some criteria are required to point out the user needs and preferences. An example of such a connection is provided below.

A modular apartment is designed based on a 13x28 feet unit. The combined information between the number of the modules and the family size can determine a basic family profile and thus determine the size of the kitchen. Figure 5-2 shows some sample layouts for each size.

For single house design, this module may be different in terms of the size and style. In a word, the modular apartment can be one of the ways to connect the partial problem and whole, and thus put this kitchen design tool into a larger context.

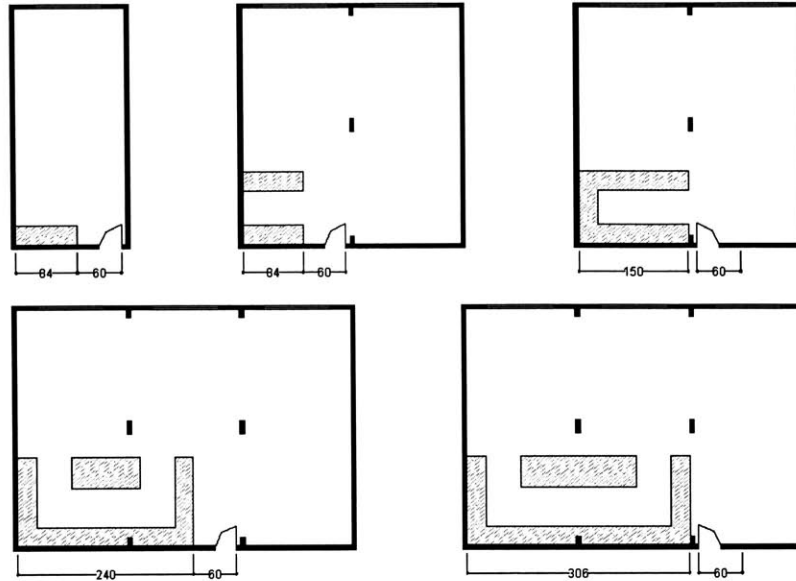


Figure 5-2. Sample of modular apartment

5.1.3 Extensibility of the user-oriented kitchen design tool

New design layouts, especially new universal design solutions ought to be able to input in this kitchen design tool. In the future development of this tool, in order to insert a new solution into the internal network of the tool, information in several aspects needs to be provided according to the methodology stated in this paper. Conflict may happen between this new entry with the existing ones, and thus recommended solutions should be provided accompanied with the new entry. In a word, along with more and more new entries added in, this user-oriented kitchen design tool is supposed to be an information center among homeowners, designers, builders, and manufactures.

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