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Space Efficiency by Way of Modular Furniture: Working from Home in an Era of Shrinking Housing

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by

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ABSTRACT:

In the current housing market, rental prices are increasing and the size of apartments are shrinking[1]. This combined with increased demand from increasing urbanization[2] and jobs moving to work-from-home arrangements[3], renters face challenges in fitting their lives into their smaller living spaces. One of the most common challenges reported is a lack of working space in the home[4]. As a means to address this, I designed a system of modular parts that can be built into a variety of desks, providing a customizable work-from-home environment. The system will allow consumers to purchase precisely what they need or can afford, with the ability to upgrade or modify the desk as needs change. The flexibility and part standardization of this system allow for greater sustainability by optimizing part production and extending the lifespan of the product. The long-term advantages of this system are optimal consumer experience (achieved through modularity and flexibility), a high level of environmental sustainability (through material choices, production optimization, and longer product lifespan), and a wide array of potential expansion opportunities for the product system. The larger goal of this exploration is to design a system of parts that can be used and re-used to create a variety of furniture for the home, allowing consumers to make the most of their space and their money.

INTRODUCTION:

I have chosen to work in the home furnishing space, with a particular focus on working from home (WFH) and small housing. This area has seen a number of challenges arise in the last decade, particularly for young professionals. This demographic has continued to gravitate towards large urban centers[2] and the majority are renters. According to the Pew Research Center, in 2016 65% of US households headed by people 35 and under lived in rented homes, up from 57% in 2006[5]. As the percentage of young people renting has risen, rental costs have also risen. On average, rental costs have increased by 28% between 2008 and 2018[1]. Work-from-home (WFH) arrangements have existed for some time now, but since the emergence of Covid-19 the prevalence of WFH has risen drastically. Between 2019 and 2021, the percentage of WFH has risen from 5.7% to 17.9%.[6] This trend does not seem to be slowing down, with 92% of WFH employees expecting to work from home at least one day per week and 80% expecting to WFH at least three days per week. Reports project that WFH arrangements will only increase, with a predicted 22% of Americans working from home by the year 2025, an ~87% increase from pre-pandemic levels.[7] This increase poses a great challenge to young renters, who are now being asked to account for another functional space in their homes on top of their living space. This problem is exacerbated by shrinking apartment offerings. During the 2008-2018 period in which we have seen a dramatic rental cost increase, we have also seen a decrease in apartment size. The average apartment size has shrunk 5% during this ten year period, with the most drastic decrease being seen in studio apartments (10%).[1] The lack of office space in the home was identified as one of the primary problems of small housing[4], a problem that will only continue to worsen with current trends in rental cost increases.

PROBLEM STATEMENT:

Young professionals need affordable, space-efficient, flexible solutions for their working space in their homes.

PROJECT OVERVIEW:

For this project I chose to focus on a modular furniture system, making use of sectional modularity to create flexibly configured furniture, enabling consumers to choose the variation that most closely fits their precise needs. Work-from-home furniture seems to be the most needed for efficient furniture in light of the issues discussed earlier in the paper. It was apparent from the earlier data findings that the most suitable option for this study is a system oriented towards flexible desk design.

The first question was a matter of how granular the modular system should be. Much of what is on the market today is modular on a much larger scale. Relevant office furniture products consist primarily of larger desk sections which can be arranged in various combinations to provide the user the shape or size of desk desired. These products tend to be expensive and large, making them a poor choice for my target demographic of young professionals. The only system available that approaches the flexibility of this project is from IKEA. IKEA produces several different desktops and eight different styles of support for them. The IKEA system is somewhat limited, as the desktops do not necessarily attach to the supports, and the options are limited to a choice of leg style and desktop size. Additionally, IKEA materials are relatively low-quality, with the desktops being made primarily of a corrugated cardboard matrix. While this material is remarkably structurally sound, it deteriorates with time and is vulnerable to pests who might find the interior cavities inviting.

My initial concept was a desk system made primarily from hardwood, designed to provide maximum durability and flexibility. I wanted to create a system that was more modular than IKEA's while providing a higher quality and longer product lifespan. In order to determine the level of modularity that was appropriate, I constructed a number of small cardboard models (Figure 1.). As benchmarks, I looked at LEGO as the extreme end of the scale (the most possible granularity), IKEA desks in the middle, and common sectional desks as the low end.

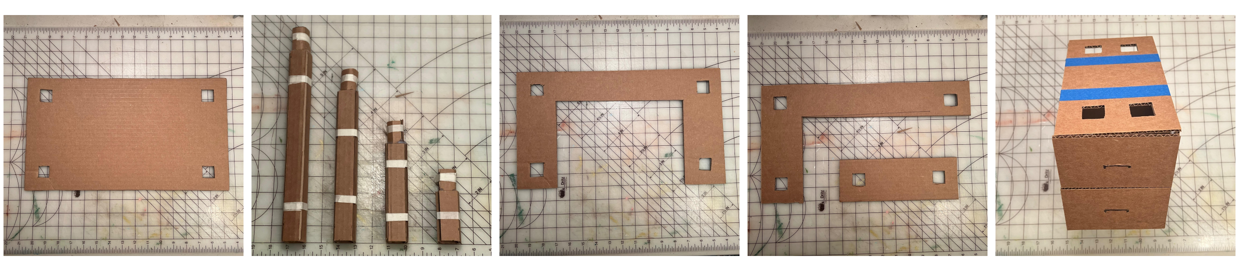

Figure 1a. Preliminary Cardboard Model Parts

Figure 1b. Cardboard Model Assembly Variations

After experimenting with the cardboard models and assessing the effectiveness of the parts that I had made, I came to the conclusion that the correct balance lay between the extreme flexibility of LEGO and the IKEA systems. For this system that would mean sectional legs, multiple modular options for storage, and desktops in multiple sizes that would accommodate a variety of storage solutions.

The initial engineering problem to solve was how to connect the whole system in a way that addressed the following areas: affordable production, low part count, high stability, and ease of assembly. For ease of assembly benchmarking I used IKEA as the standard for user-friendly construction. For this purpose I conceptualized several solutions. The simplest was a peg system which would provide very simple manufacturing, absolute minimum part count, and extremely easy construction. The second solution was similar to the fitting systems used in plumbing. The wooden leg parts could be threaded and connected using collars with matching threads. This system would also provide a low part count and easy assembly, as well as a distinctive visual quality. The third concept was the most standard, entailing inset threaded inserts in the hardwood components, attaching to each other via threaded rods. This solution required a slightly larger number of parts overall, but provided greater stability than previous options and maintained a similar ease of use.

I designed a couple iterations of each of these connection systems and informally interviewed several experts on their efficacy. This group included Furniture Design MFA Candidates at the RIT School of American Crafts and professionals from both the design and manufacturing departments of STAACH Inc., a local furniture design and manufacturing firm. The conclusion from these interviews and my own testing was that the third option (threaded inserts) was the most effective solution (Figure 2.). The first concept (simple pegs) severely lacked stability. The second (threaded legs and collars) would have provided the necessary stability, but lagged in the manufacturability and durability categories. The selected option filled the manufacturing requirements, while providing the best balance of easy construction, long-term durability, and stability.

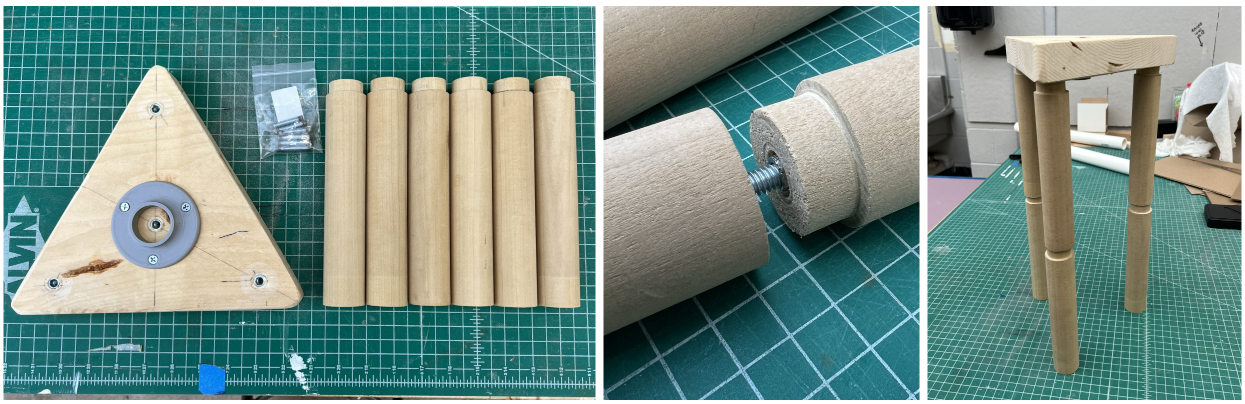

Figure 2. Connection System Prototype

With the connection method decided, the next decision was the sizing and what accessories would be desirable to the target market (young WFH professionals). In order to determine this, I created three full scale foam and PVC mock-ups: a 36” wide desk with built-in storage underneath the desktop, a 42” desk with a desktop storage solution, and a 48” desk with a storage cabinet underneath (Figure 3.). They were built with a 29” desktop height, roughly the standard for modern tables.

Figure 3. 36” Model w/ internal storage   42” Model w/ desktop Storage   48” Model w/ under storage

After these foam models were built, I put together a user testing survey and held testing sessions with several people, lasting about half an hour each. The testing and survey were in two sections, the first being an evaluation of the three full-sized mock-ups. The questions focused on the sizing of the desk (height, depth, width) and the storage accessories included in the mock-ups. The size options were all received well, but most users responded that the 42” variation provided the best balance in length. The height was satisfactory for most participants, with complaints only arising for outliers (respondents who were very short or very tall). The bulk of the feedback concerned the storage and accessory options available with the system. Of the options presented, the favorite was the storage underneath the desk, be it shelving or drawers. The storage directly beneath the desktop was also favored, but there was concern with it being too deep, opening the possibility of stored objects being hard to reach. The most requested features were shelving that would accommodate a PC tower and a monitor stand with room to store a keyboard beneath it.

The second section addressed the connection system, testing ease of use and user confidence in the stability of the method. Participants were asked, without instructions, to assemble a small stool using the leg pieces provided. These sessions were recorded for later viewing. The questions given revolved around ease of assembly, confidence in strength, and the intuitiveness of the construction method. The benchmark given was IKEA, as the standard for consumer-end furniture assembly. The respondents rated the construction method to be easier and more intuitive than IKEA assembly, and expressed confidence in the stability and strength of the system. The major criticism was that, without instructions, the respondents were confused as to the correct orientation of the parts initially. It was requested that the parts either be more obvious in orientation or designed such that orientation did not matter.

With this information to consider, I designed the final iteration of the desk. The main material for the final prototype is solid oak. The connection system requires several pieces of custom hardware, primarily for the purpose of attaching shelves to the desktop and the leg assemblies. I designed five different pieces of hardware; spacers to fit between the legs segments; spacers that would accommodate the shelves; plugs that would attach accessories to the desktop; caps to fill the unused connection points on the desktop; and flanges to attach the legs to the desktop. The leg design was modified slightly to accommodate the hardware and to account for the feedback from user testing (Figure 4.). I prototyped the hardware using 3D printed polylactic acid(PLA), a quick, efficient method of testing shape, size, and fit.

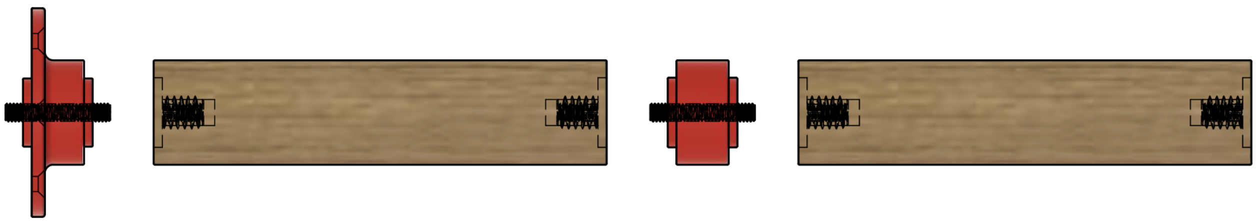

Figure 4. New Leg Connection Design

For accessories, I included three shelves. Two of the shelves are a reversible design, usable as both monitor stand/desktop storage and a shelf under the desktop. This shelf design allows for simple cord management and keyboard storage, while blocking things from falling in either configuration. The third shelf is simple, mountable at any joint along the legs of the desk on either side, and sized to fit the average PC tower. The desktop surface was redesigned to flexibly accommodate connection points for the desktop shelving and any future accessories.

Once these designs were modeled and assembled in Fusion 360 I reviewed the results with designers at the furniture design studio where I work. The primary suggestion was to add support panels between the legs on at least two faces of the desk for added strength and rigidity. This necessitated two more spacer variations in order to mount the support panels, bringing the total hardware design count up to seven individual hardware designs, as well as a custom tool to help with assembly (Figure 5.).

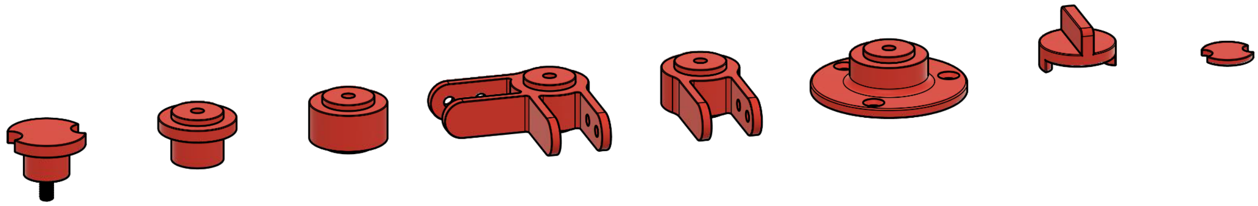

Figure 5. 3D Printed PLA Hardware

The final design is a combination of traditional joinery and new technology. The majority of the woodwork can be done using standard woodworking tools and machinery, with exception of the final steps for the desktop and lower shelf, which are best handled by a CNC routing machine (3-axis+). Using CAM and a CNC machine allows the desktop to be trimmed and routed quickly, efficiently, and precisely. The PLA hardware is largely designed to be easily manufactured using injection molding technology.

In order to manufacture the design without the use of CNC machinery, I used a series of 3D printed jigs to ensure accuracy and consistency throughout the process. The final prototype was built in the RIT Industrial Design workshop, where I used the table saw, a routing table, a disc sander, a drill press (via a combination of standard drill bits and Forstner bits). The finishing work was done using an orbital sander and a combination of Danish oil and polyurethane for natural color and protection. The final design consists of six unique wood components, seven unique custom hardware components, and three standard hardware components (16 unique components). The part count for the desk assembly is 24 wooden parts, 32 custom hardware parts, 16 connecting rods, 16 screws, and 6 leveling feet, for a total of 94 parts (Figure 6.).

Figure 6. Included Parts

The final prototype stands at approximately 30” floor to desktop height, is 42” long by 22.5” deep, and is configured to accommodate a desktop computer with a tower and a monitor. The monitor stand includes storage underneath, and the desk is configured with a shelf below the front of the desk. Total assembly time is approximately 15-20 minutes. Two people are needed during construction to flip the desk upright after attaching the legs. The only tools required for assembly are the included custom tool and a Phillips-head screwdriver. The desk can be leveled and the height adjusted slightly with the included leveling feet.

Figure 7. Final Prototype

Conclusion:

This project was intended to address multiple issues. The main issue is the intersection between small living spaces and WFH arrangements. Rental housing is shrinking, costs are increasing, and the demands put on these spaces are higher than ever. The purpose of this design is to provide a flexible work from home furniture system that is customizable to the consumers' needs, even as they change. There is also an environmental mission to tackle consumerism and environmental waste. The system is intended to have a long lifespan, longer even than the life of the specific piece of furniture that the consumer has purchased. The system is designed to allow for parts to be reused in a number of ways, even to build other pieces of furniture. With a modular system like this one, a consumer can extend the life of the furniture even after the original purpose is gone. The overarching idea is that the system would be offered in many configurations, using the standardized parts to build a variety of different objects. Standardized parts allow for mass production to be optimized for minimal waste and maximum efficiency. Shipping disassembled parts flat-packed allows for more efficient transportation, reducing emissions involved in the delivery process. The material choices and product design aim to maximize lifespan, reducing the need to purchase further goods and thereby future post-consumer waste.

There were problems that I encountered that I was unable to solve, either due to time or unavailable resources. The first of these is the affordability of the system. I chose to use hardwood because of its durability and environmental qualities. Hardwood is a renewable resource if the logging is done responsibly, and provides the extended lifespan that I was looking for. Unfortunately, it does not meet the affordability standard that I had hoped to meet. I looked at several alternatives to hardwood, but none of them afforded the durability that I was looking for while balancing cost, availability, and eco-friendliness. I had anticipated this problem, but it proved far more difficult to circumvent than I had thought. I am not sure there is currently a solution to this problem, but further research could eventually yield different results. The second of these problems is the relatively high part count. I had hoped that I would be able to keep the part numbers much lower, particularly the plastic parts. In future development, I would hope to be able to redesign the system to include fewer non-wood parts, and to explore alternative materials for those parts that might be more sustainable. Practical next steps include further iterations of the system (ideally simplifying it), solidifying the most efficient production methods, and expanding the system to include parts suited for other furniture designs. The system has a core flexibility that is a strong backbone for the development of an entire line of modular furniture products that can follow the consumer through many stages of life.

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