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Hospital Bedside Table

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Abstract

Hospital bedside tables are considered a Class 1 medical device and are prevalent in hospitals and nursing homes. They are a necessity for patients for medical and personal use. The two major issues patients and nurses encounter when using bedside tables are difficult functionalities and poor user friendliness. The Rochester Institute of Technology engineering team & industrial design team, Rochester General Hospital & Unity Hospital within the Rochester Regional Health Network, worked together to identify, brainstorm, and resolve major issues with current bedside tables by re-designing and creating a new prototype bedside table. The three target areas of bedside tables are: the base, support column, and tabletop. Each feature was re-designed to account for patient comfort and user friendliness, hospital room size, and unique hospital bed features while improving overall functionality. Sponsored by the Rochester Regional Health Network, the engineering team was given a budget of $1,500 to purchase parts to manufacture a working prototype. $1,261.58 was spent out of the $1,500 to manufacture the working prototype.

Nomenclature

Table 1: Medical Nomenclature

Term	Definition
Antimicrobial	An agent that kills microorganisms or stops their growth.
Class 1 Medical Device	Devices that have a low to moderate risk to the patient and/or user.
Edgeband	Is the name of both a process and an associated narrow strip of material used to create durable and aesthetically pleasing trim edges during finish carpentry.
Pneumatic	Containing or operated by pressurized air or gas.
Warp	A twist or distortion in the shape or form of something.

Table 2: Mathematical Terms and Definitions

Term	Definition
F	Is an interaction that causes an affected object to be pushed or pulled in a certain direction
Fy	Is an interaction in the y-direction(axis) that causes an affected object to be pushed or pulled in a certain direction
g	Gravity
m	Mass
M	A force that measures the tendency to cause a body to rotate about a specific point or axis
P	Force per unit area
ρ	Density
V	Volume

Background

The objective of this project was to redesign a hospital bedside table in order to make it easier to use for both patients and caretakers: primarily patients and secondary caretakers. The primary complaints from customers this project set out to address were as follows: patients knock objects off of the table too easily, difficulty moving the table towards or away from themselves, not enough room for their personal items; caretakers found the table difficult to maneuver around the room, it often gets in the way of them doing their work, and the frequent calls from patients requesting help in moving the table or adjusting its height.

Given these issues with current designs, two different brands of current hospital bedside tables available on the market were benchmarked: Stryker Tru-Fit Overbed Tables, and Hill-Rom Overbed Tables.

Stryker Tru-Fit Over Bed Tables				
Type			Single-top	Split-top
Overall	Cost ($)		535.05 to 989.00	
	Dimensions	Weight (lb)	43	54
		Weight Capacity	75	
Tabletop	Dimensions	Shape	Rectangle	
		Length (in)	31	31
		Width (in)	17.5	35
		Surface Area (in^2)	542.5	1085
	Tabletop Material		Laminate	
	Edge	Material	Dura-edge (unknown material, but advertised as giving tabletop high durability)	
		Spill Resistance Mechanism	Lip	
Support Rod	Height	Min (in)	27	21.25
		Max(in)	43.75	32
	Material		Anodized Aluminum	
	Mechanism		Pneumatic	
Base	Dimensions	Height (in)	2.2	
		Length (in)	42.75	
		Width (in)	21.25	
		Footprint (in^2)	908.44	
		Shape		
	Material		Durable high-impact ploystyrene cover	
	Casters	Type	twin swivel	
		Diameter (in)	1.46	
Additional Features	Vanity	Weight (lb)	7	
	Storage compartment	Weight Capacity (lb)	40	
		Weight (lb)	25	
		Length (in)	42.75	
		Width (in)	17.5	

Figure 1:Stryker Tru-Fit Overbed Tables [1]

Hill-Rom Overbed Table						
Type			Patient Mate Jr.	Patient Mate	Standard	C-bed
Overall	Cost ($)		345	UNKN	UNKN	UNKN
	Dimensions	Weight (lb)	58	69	40	UNKN
		Weight Capacity	UNKN			
Tabletop	Dimensions	Shape	Rectangle			
		Length (in)	36	44	36	31
		Width (in)	15-30	15-30	15	18
		Surface Area (in^2)	540-1080	660-1320	540	558
	Tabletop Material		Wood Grain Laminate			
	Edge	Material	Rubber			
		Spill Resistance Mechanism	Lip			
Support Rod	Height	Min (in)	30	30	29	28.5
		Max (in)	46	46	44	42.5
	Material		UNKN			
	Mechanism		Pneumatic			
Base	Type:		Low	Standard	C-shape	
	Dimensions	Height (in)	2	3	UNKN	
		Length (in)	19	19	UNKN	
		Width (in)	35	31	UNKN	
		Footprint (in^2)	665.00	589	UNKN	
		Shape	H	H	C	
	Material		Plastic			Metal
	Casters	Type	twin swivel			
		Diameter (in)	UNKN			
Additional Features	Food Tray	Width (in)	14.5	14.5	NA	NA

Figure 2: Hill-Rom Overbed Table [2]

Description of Design

The goals of the redesign were to improve functionalities and user friendliness by initially examining hospital room settings, recording constraints, testing existing bedside tables, and getting feedback from hospital nursing and facilities management. From there, customer and engineering requirements were created and verified by the customer. In Table 3 and 4, each criterion was ranked according to importance determined by the customer and engineering team. Each criterion was taken into account during the brainstorming and design process.

Table 3: Customer Requirements

Customer Requirement	Rank	Comments
Can support applied load to the table	10	Table won't tip, can hold weight
Easy to disinfect	10	Easy to clean base, and tabletop
Base fits under bed	10	
Practical base design	9	Wheels and base won't bump structures beneath hospital bed. Wheel formation is encompassed in base design
Convenient mobility	7	Easier to move entire structure
User Friendly	7	Intuitive design
Eliminate gap on existing tabletop	5	

Table 4: Engineering Requirements (English Units)

Engineering Requirement	Target Value	Acceptable Value	Tolerance (+/-)	Measure	Importance
Caster diameter size	2	3	1	in	9
Max tabletop load	20	15	5	lbs	9
Underbed clearance (height)	4	5	0.5	in	8
Tabletop weight	10	15	5	lbs	8
Overall base size (length x width)	8 x 18	20 x 18	2	in	7
Standard hospital room size (length x width)	11' 5" x 9' 8"	n/a	n/a	ft, in	6
Bed to wall	30	36	1		
Current tabletop gap size	0	0	0	in	5
Base weight	35	45	10	lbs	5
Base material	Steel	n/a	n/a	kg/m^3	

Constraints that played key roles in the table's design included: the hospital bed's underclearance which limited the height of the base, and the hospital bed's fifth wheel located at the center of the bed. This was the biggest constraint since it refuted existing bedside table's base design, requiring a full reanalysis on feasible base designs.

Mathematical calculations were performed to determine the weight the base should be to prevent tipping. This can be found in the following calculations section.

A series of brainstormed concepts were created to choose a final design for the tabletop and base. This process involved thinking in-depth and from the perspective of a bedside table to determine its functions. Thinking from this perspective made determining the design of the base and tabletop more efficient.

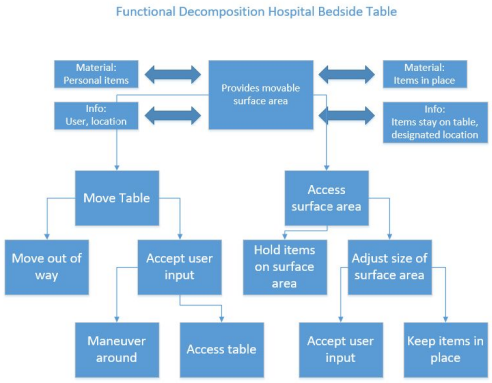

Figure 3: Bedside Table Key Functions

The final design of the bedside table involved three components: the tabletop, support column, and base. Figure 7 shows the fully assembled bedside table.

Figures 5 and 6 show the tabletop shape and how it functions. The tabletop's shape was pre-determined by the customer to be circular since it provided the patient easier arm movement. The tabletop final design was determined to be able to swivel to increase or decrease surface area as needed.

The support column was sourced from an outside vendor that makes custom pneumatic table columns. The table column sourced would be able to support thirty-five pounds of weight. To prevent bumps or injuries from edges or corners, the table column's shape was chosen to by cylindrical.

Figure 4 shows the final base design. The base shape was determined to be an X-shape as the shape took into account the hospital bed's fifth wheel. By having a wide base shape, more room is allowed for the table to move away or towards the patient. Current bedside table base shapes are typically rectangular which don't allow for a long range of movement toward or away from the patient. By increasing the weight of the base, the center of gravity for the entire table shifts towards the bottom, which allowed for adjustable dimensions. The overall length of the base is about half the length of the hospital bed, which means only the tips of the base would be in contact with the bed's fifth wheel.

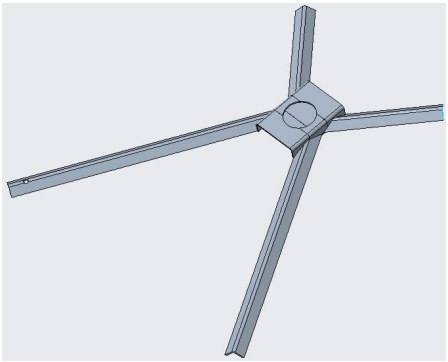

Figure 4: Final Base Design shape

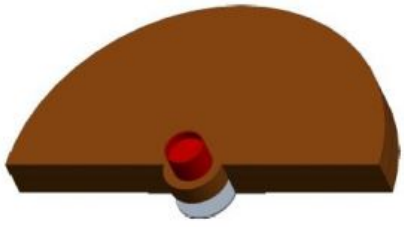

Figure 5: Retracted Tabletop

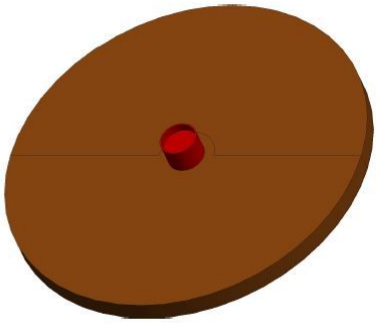

Figure 6: Expanded Tabletop

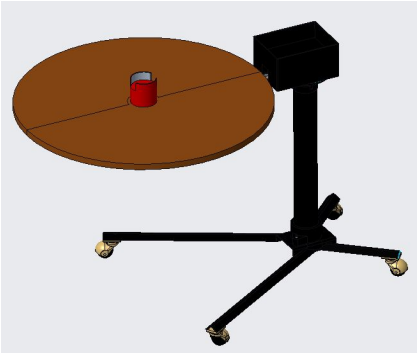

Figure 7: Fully Assembled Hospital Bedside Table Prototype

A total of eleven test plans were performed to confirm aspects of the chosen design, make decisions on what specific parts should be used, test functions, and make any changes that would improve the final design and manufacture of the bedside table prototype. The results for the test plans can be found the in the Testing Results section. The combination of customer and engineering requirements, concept design and selection, feasibility analyses, and test plans all contributed to the final design and manufacture of the bedside table redesign.

Calculations

Mathematical calculations were made to determine what the weight of the base should be based on the weight of the tabletop. Table 3 shows the target values and range of acceptable values that need to be taken into account during the calculation process

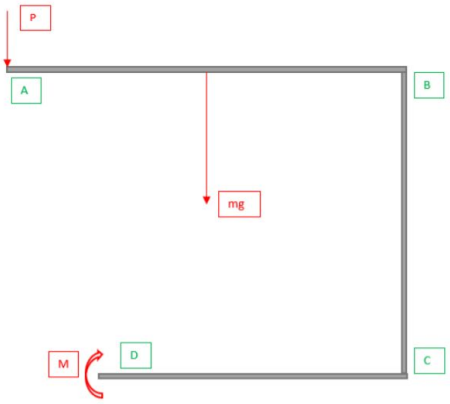

Figure 8: Free-Body Diagram of Bedside Table

Figure 8 shows the overall forces acting on the table and table sections where tipping could potentially occur. It shows the worst-case scenario for the bedside table when all the weight will be concentrated at the end of the table. It's assumed the maximum weight that will be placed on the table is 20 pounds. The calculations below show that the base should be about 33 pounds in order for the design concept not to tip over.

$P = 20lbs = 9.07kg\ P = (9.07kg)\ (\ 9.81m\ s\ 2\ ) = 88.98\ \mathrm{N}$ (1)

Poplar Wood Tabletop Weight
$\varrho = 300kg/m3$
$m = \varrho V$
$m = (\ 300kg\ m3\ )\ (1.5in * 0.0254m\ 1in\ )\ (\pi)\ (16in * 0.0254m\ 1in\ )\ 2\ m(plywood) = 5.93kg = 13lbs$ (2)

Base Weight
Section AB
$\Sigma MB = 0 = P(32in = 0.8128m) + mg(table)(16in = 0.4064m) - M1$
$M1 = (88.98N)(0.8128m) + (6kg)(\ 9.81m\ s\ 2\ )(0.4064m) = 96.24Nm$ (3)

Free-Body Diagram Section CD - Moment

$\Sigma MD = M2 = 0 = -M1 - mg(base)(16in)$

$M2 = 96.24Nm + (3186kg)(\ 9.81m\ s\ 2\ )(0.4064m) = 108.92Nm \quad (4)$

Free-Body Diagram Section CD - Sum of Forces

$\Sigma Fy = 0 = -P - mg + F$

$F = P + mg\ F = (88.98N) + (5.94kg)\ (\ 9.81m\ s\ 2\ ) = 147.25N \quad (5)$

Free-Body Diagram Section CD - Sum of Forces to find Mass of Base

$\Sigma Fy = 0 = -F + mg$

$F = mg = 147.25N = (m)\ (\ 9.81m\ s\ 2\ )$

$\boldsymbol{m = 15kg = 33lbs} \quad \textbf{(6)}$

Testing Results

A series of eleven test plans were performed to confirm the chosen design concept, choose specific products to integrate into the final prototype, make improvements, and recognize and details that may have been overlooked during the design phase.

An Ease of Maneuverability category of testing consisted of three tests that involved testing various base shapes and different caster types to determine which combination yielded the easiest maneuverability. Three different base shapes and three types of casters were mixed and matched and pushed certain distances to determine the best configuration. The X-shape base with four ball casters was the most ideal. The X-shape base proved to be a rigid structure while the ball casters allowed for easy turning and movement in small spaces. Figure 9 shows the selection criteria each base and caster type were graded to determine which configuration was the most feasible. Each configuration was graded against the current bedside table the customer uses.

	DATUM	1	2	3	4	5	6
	Stryker Table Base	3 swivel casters	2 static +1 swivel casters	1 static + 2 swivel casters	3 swivel casters	2 static + 1 swivel caster	4 swivel casters
Selection Criteria							
Fits under bed		+	+	+	+	+	+
Easy to start moving		-	S	S	S	S	S
Easy turning		-	+	+	S	+	+
Easy continuous moving		-	+	-	-	-	+
Size of base		+	+	+	S	S	+
Total S		0	1	1	3	2	1
Total +		2	4	3	1	2	4
Total -		3	0	1	1	1	0
Sum		-1	+4	+2	0	+1	+4

Figure 9: Different Base Shape and Caster Configuration Selection Criteria and Results

A Base Disinfection category consisted of three tests that determined how easy it was to clean the chosen base shape and sourced casters. Using Lysol wipes, selected casters were cleaned to determine how easy or difficult it was to clean dirt off of the caster. From this, the ball casters were chosen since the surface material was the easiest to clean and the design was simplistic without small, hard to reach gaps. Figure 10 shows the caster cleanability results.

	DATUM (generic office caster) Polyurethane	1. Rubber	2. Nylon	3. Polypropylene
Selection Criteria				
Maneuverability on tile		+	+	+
Moving linearly		S	+	S
Rotating		+	S	+
Cleanability of material		S	+	+
Cleanability of design		+	-	S
Cost	~$3.00 +/- $1.00	S	-	S
Dirt Resistance		S	S	+
Ease of Swivel		S	S	+
Mount Height (+ = shorter, - = taller)	2.5"	S	S	S
Sum of +		**3**	**1**	**5**

Figure 10: Caster Cleanability Selection Criteria and Results

To determine what brand and type of surface laminate to apply to the tabletop, a laminate cleanability test was performed. Samples of Formica and WilsonArt brand laminates, an acrylic surface, and the existing bedside table surface were tested by cleaning dirt and food crumbs off the table and scratching the surface with sharp objects. The Formica Infiniti laminate was chosen as the final laminate since it had the best results while meeting hospital requirements. The Formica Infiniti brand laminates had an antimicrobial feature that are specifically made for hospital settings. Figure 11 shows the laminate cleanability and scratch results.

	DATUM (HillRom Tabletop)	1.WilsonArt	2. Formica	3. Acrylic
				
Selection Criteria				
How much dirt/dust stays on surface after initial shake off		-	-	S
Easy/Smooth wipe down		S	S	S
Dirt/Dust remaining		+	+	+
Smooth feeling after wipe down		S	S	S
Scratch Resistance		+	+	-
Cost	n/a			
Sum of +		**2**	**2**	**1**

Figure 11: Surface Cleanability and Scratch Results

Results, conclusion, and recommendations

A working prototype was built that met most of the customer and engineering requirements. The customer was satisfied with the base design, its easy maneuverability, and cleanability. The table column's height is more easily adjustable compared to the bedside tables they currently use. The tabletop has room for design improvement. The entire table is structurally stable but the tabletop currently wobbles and tilts. This is because the tabletop has a static and moving component. The moving component will shift the weight of the tabletop to one side if it's stacked on top

of the static component. Overall, the prototype functionally works because the base is easy to meanurver, the table column adjusts easily, and loads up to 15 pounds can be placed on the tabletop without affecting the structural integrity of the entire table. From a user standpoint, the tabletop is perceived as stable because it wobbles and tilts.

If we had more time with the project, we would've liked to test some of our tabletop retracting and expanding ideas for rectangular tabletop shapes because the tabletop was approved for a circular shape before we were assigned this project. As a team, it was beneficial to all work together during the entire process, but it slowed down progress. We should have assigned people to the different subsystems early on to improve efficiency.

A recommendation for the future would be to consider different table top materials as we experienced a lot of warpage with the wood or potentially gluing the wood pieces so that the grains don't align. We also recommend that for the edging around the table, to consider the Rehau edgeband [3]. From our research, the Rehau edgeband is known to complement the Formica laminates and Rehau has an antimicrobial line which is a necessity for hospital settings.

If this project continues on, we believe bedside table can go through several iterations of prototypes, with functional and aesthetic improvements to each.

References

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