Appendix

Appendix 1: interview notes

Interview 1
Q: thought the knowledge aspect in your thesis was very interesting. You had a persona for BMETs which are often not available, nurses and surgeons. BMETs are the only knowledgeable people in operating the equipment, however in practice it's often others using it. Do you have any suggestions for how to tackle this lack of knowledge and minimise risks?

A:
- it was shocking to see that the knowledge was the way it is
- their knowledge was experienced based, try out base
- knowledge became old because it's only. been passsed down through generations
- previous saved settings on many devices —> interface design could help
- sounds: they often just turned out the volume because it just keeps making noise (e.g. if it's really a hazard, volume shouldn't be allowed), forcing to address the issue
- look at "nudging"
- providing information is always tricky (e.g. Ikea manuals) —> has to be really out there and really visual (nobody reads)
- integrate within interface seems like the best option
- go for more forced actions (e.g don't allow for mistakes)
- quite trick that screen is blinking, sounds are being made, device is behind heir back, nobody looks at it anymore so nobody is paying attention to it
- there is only one person focusing on it during surgery unless there's a biome specifically on task
-think of what is "too important" to ignore?

Q: Another aspect I found quite interesting (correct me if I am wrong) is there seems to be quite a general lack of protocol (e.g. a quote - requests are not addressed to a particular person, lots of people in the room, unclear what to do in case of an alarm). Why do you think this is the case?

A:
- focused on providing the basics
- they were very proud of showing her the national hospital
- focus: lack of things, they are unable to focus on making work processes more efficient
- there are a lot of patients just laying on the hallway waiting to be addressed (because they can't do things)
- there's not enough time and resources to focus on processes (assumptions), unsure if there's protocols that they should follow
- lots of people of training in the or just watching
- she was asked many times if to be a surgical assistant, nobody knows who's there or what's going on
- you can just walk into any surgery, there are wooden doors
- make shift surgery in an office
- very small surgery room
- she almost fell over the foot of the leg that was amputation
- they needed an extra room for surgery very quickly
- too narrow and too small

Interview 2

Q: One aspect I found interesting in your thesis is that you mentioned that non-doctors are starting to get trained to perform medical procedures such as surgeries or that there is a lot of lack of experience. How did you experience this limited experience?

A:
- equipment is very specialised for very special needs, designed based on knowledge of users that are very specialized
- simplify the settings, more generic surgeries
- different uses of the product

Q: Did you experience how the surgical theather is set up?

A: not really, protocols are not as strict

Q: What other infrastructural issues did you encounter in operating theatres?

A:messy surgery rooms

Interview 3

Q: What were the most important requirements?

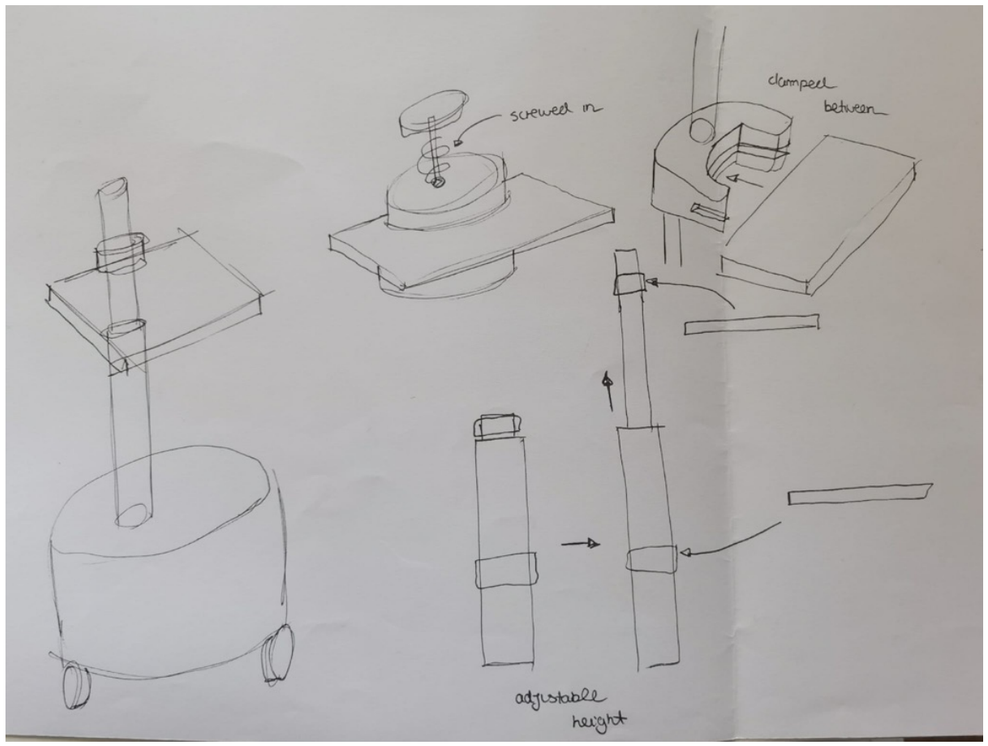
A:
- re-useability (purchase price increases) — cleaning like cidex; dissasembly, decrease the amount of steps, make it as easy as possible, avoid smol parts (not needing supply chain as it's unreliable)
- intuitive (very limited skills)

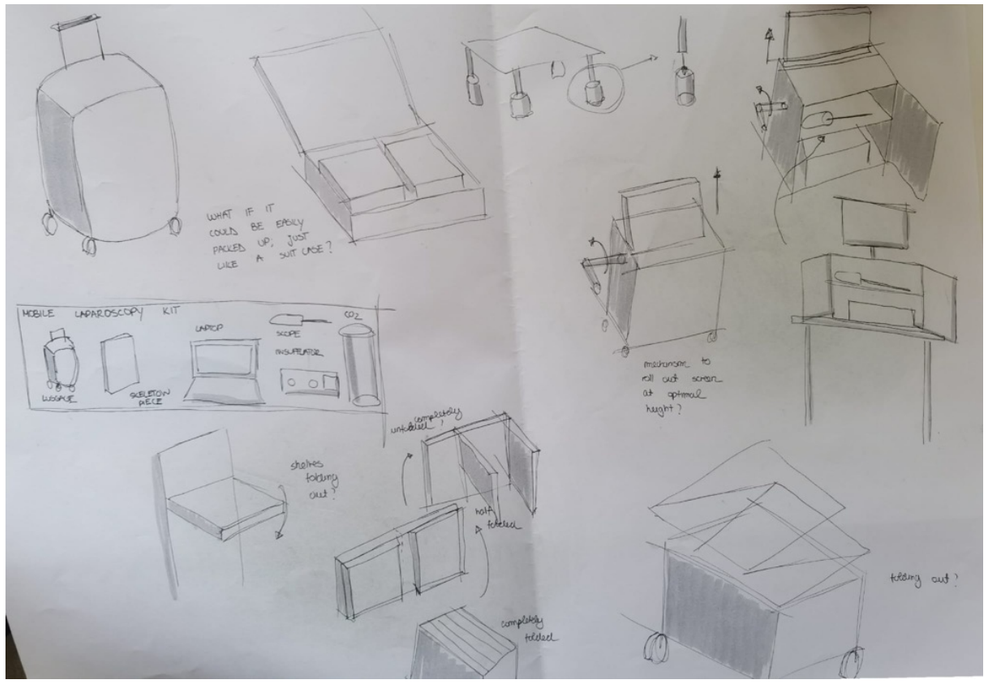
Q: How are district hospitals different from other hospitals?

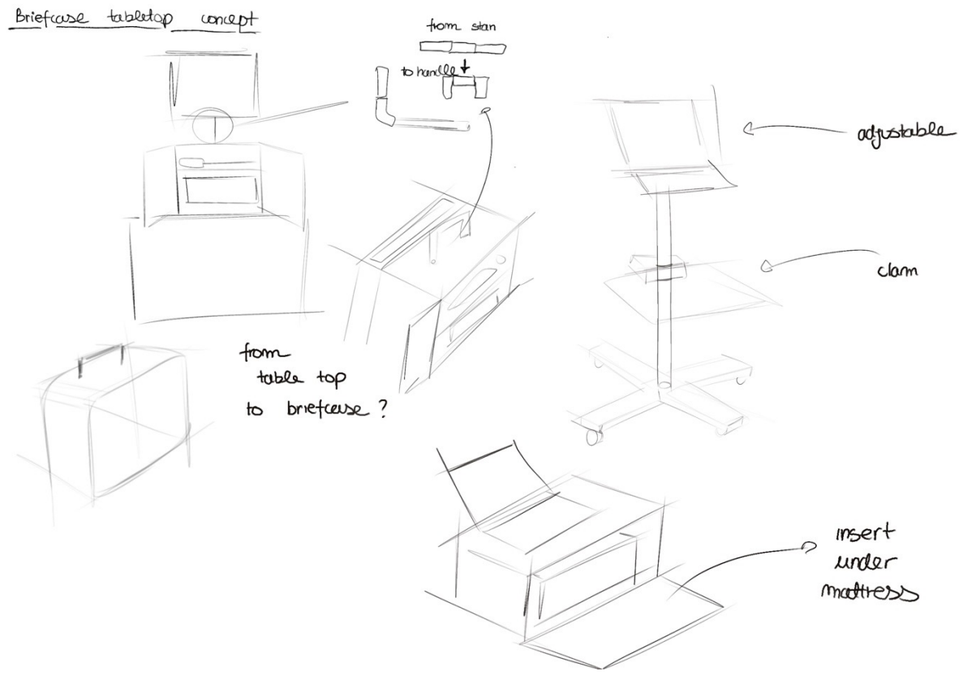
A:
- price = most important
- reusability
- they pay higher price because harder to reach
- lack of staff —> operate with 1 person
- very basic autoclave (Moree like a pressure cooker)
- limited training in cleaning

Appendix 2: ideation phase

Sketches







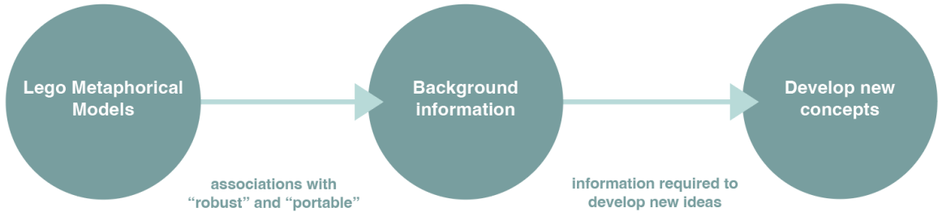
The ideation phase includes a brainstorming session and ideation done outside of it before and after the session. The goal of this phase is to gather concrete ideas and directions to augment individual ideation.

Brainstorming

A brainstorming was held with the purpose of generating new ideas and concepts for a laparoscopic tower that is both robust and portable. This section describes the method that was used for the brainstorming session, the participants that were selected and the results of the session are shown and discussed.

Method

Participants were welcomed to the session and signed the consent forms. Once the consent forms were signed, the session was started up with a short energizer. The goal of the session is to generate new concepts and ideas for a new laparoscopic tower that is both robust and portable. To achieve this, three activities are distinguished. The first activity consisted of building metaphorical models by using Lego (Lego serious play, retrieved 2023) based on the associations participants had with the words “robust” and “portable”. Once complete, the participants were provided with background information about laparoscopy, the laparoscopic tower, and the need for re-designing it for low- and middle-income countries was explained. The participants had a chance to ask for clarifying questions and additional information. Finally, the final activity asked participants to integrate their associations from the first and second activity into new concepts and ideas for a laparoscopic tower.

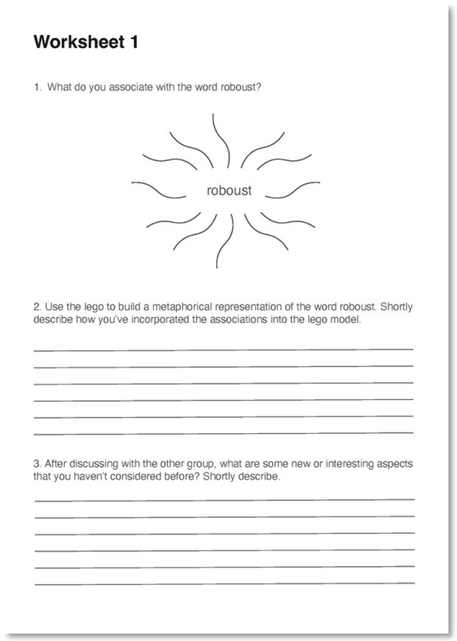


Lego metaphorical models
Participants were asked to develop tangible associations with the words "robust" and "portable" by using the Lego serious play method (Lego serious play, retrieved 2023). The terms were defined as follows:

Portable = something that is easily carried or transported from one place to another. It often implies that the object is lightweight, compact, and convenient to move around.

Robust = refers to something that is strong, sturdy, and able to withstand a range of conditions or challenges. It often implies that the object or system is durable, reliable, and resilient.

Participants were guided step-by-step through the exercise. First, the exercise was explained verbally, and a worksheet was offered for additional guidance. The exercise took around half an hour in total (15 minutes per word). The participants first wrote associations with the word (around 1 minute), after which they were asked to use Lego to build and incorporate their associations into tangible models (around 10 minutes). Once the models were finished, the two groups shared their insights with each other and had a short moment to reflect upon aspects that they might have not considered yet.


Worksheet 1

1. What do you associate with the word roboust?

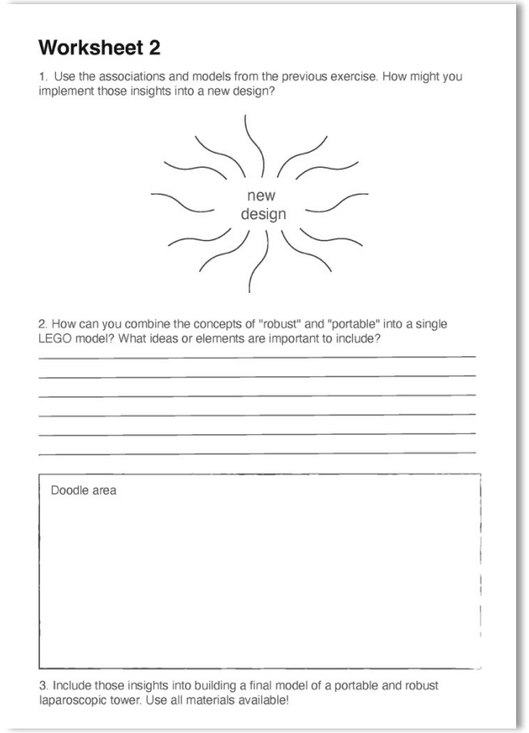
roboust

2. Use the lego to build a metaphorical representation of the word roboust. Shortly describe how you've incorporated the associations into the lego model.

3. After discussing with the other group, what are some new or interesting aspects that you haven't considered before? Shortly describe.

Background information
Once the Lego exercise was complete, the models were put aside, and the worksheets were collected. The participants were provided with background information about laparoscopic surgery. The core concept was explained, together with the devices that are required for laparoscopy, the setting of the operating theater and the challenges of implementation in low- and middle-income countries. A prototype was also shown to give a tangible representation of the tower.

Developing new ideas and concepts
For the final exercise, the participants were asked to develop ideas and concepts for a new laparoscopic tower that is both robust and portable. They were reminded to integrate their associations from the previous exercise into the concepts and encouraged to sketch and create tangible prototypes. A second worksheet was provided for guidance.



Worksheet 2

1. Use the associations and models from the previous exercise. How might you implement those insights into a new design?

new design

2. How can you combine the concepts of "robust" and "portable" into a single LEGO model? What ideas or elements are important to include?

Doodle area

3. Include those insights into building a final model of a portable and robust laparoscopic tower. Use all materials available!

Participants

As recruiting medical professionals for this brainstorming proved to be challenging, students from the three different master programs at Industrial Design Engineering were recruited for the brainstorming. Participants with affinity for medical design or global surgery were prioritized. Table X gives an overview of participants and their backgrounds.

Study background	Number of participants	Area of expertise/interest	Number of participants
Integrated product design	4	Medical design specialization	2
Strategic product design	2	Global surgery graduates	2
Design for interaction	2	General background, limited experience with medical design	4

The total of 8 participants were divided in 2 teams of 4. Each team combined students from the three master programs. The teams were divided so that each team had a good combination of students that were experienced in medical design and or global surgery and inexperienced students.

Results and discussion

The output of the brainstorming session consists of 12 Lego models associated with the word “robust”, 13 “lego” models associated with the word “portable”, several associations with each and 10 distinct directions/ideas for a new laparoscopic tower that is both portable and robust.

Associations with robust

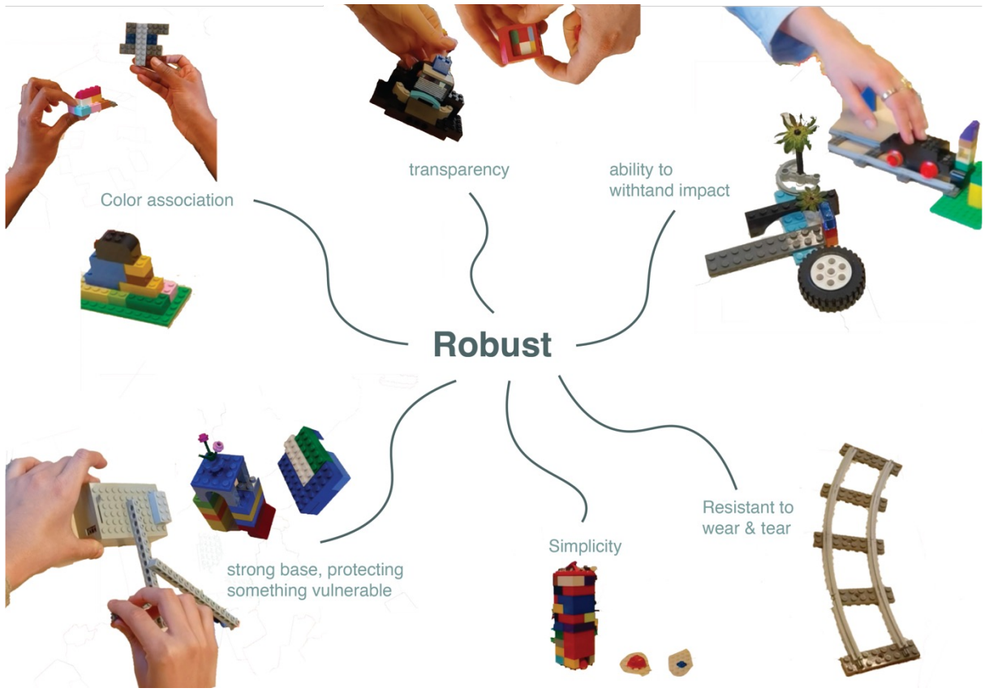


Figure 21 shows an overview of the models that were created in association with the word robust. Robustness was associated with transparency, as it allows users to see what is happening and gain confidence that everything is functioning accordingly. Another association with robustness is ability to withstand impact, weather that is in the form of toughness and direct resistance to impact, or ability to be flexible and resist to impact. Train tracks were also associated with robustness as wear and tear and external factors don’t comprise their quality. Simplicity was also associated with robustness, while a full structure might be big and robust, so is a single Lego brick. Another occurring theme was a strong base that is used for protecting something vulnerable, thus making it robust. Finally, darker colors were associated with robustness.

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Theme	Word associations
Durability and strength	rugged, unbreakable, rough, heavy, not fragile, protection, shockproof, dense, reliable, strong, firm, durable, non-flexible, indestructible, bulky, rubberised, over-engineering, shock proof, unbreakable, sustainable, heavy, hard
Longevity and resistance to external damage	Sustainable, long lasting, minimal repair, weatherproof, old, castle, built in the Middle Ages.

Associations with Portable

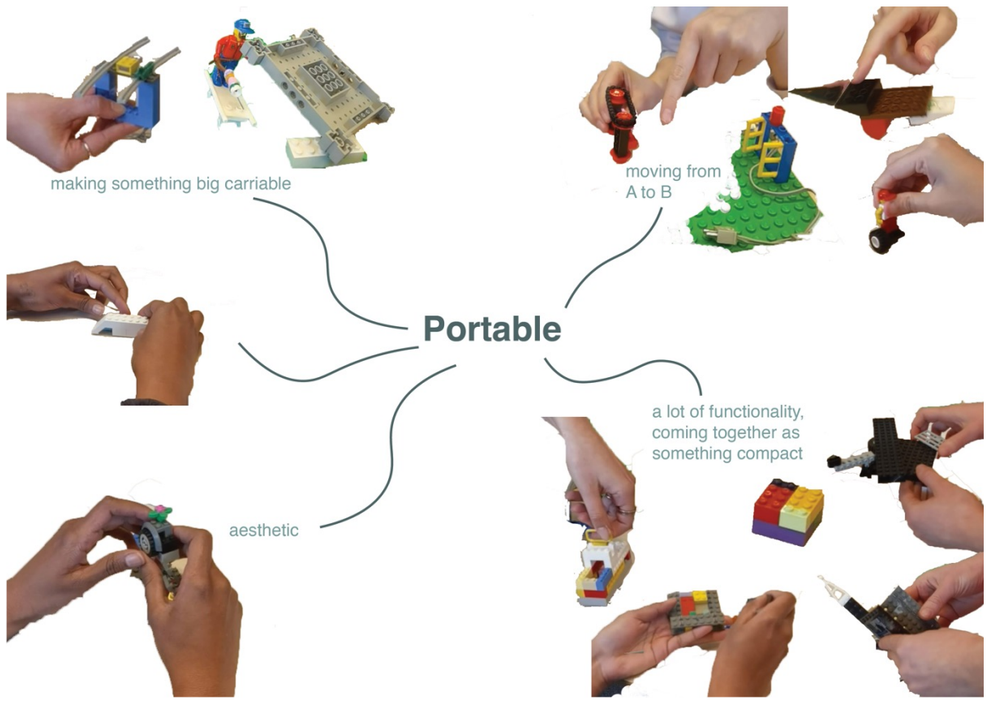
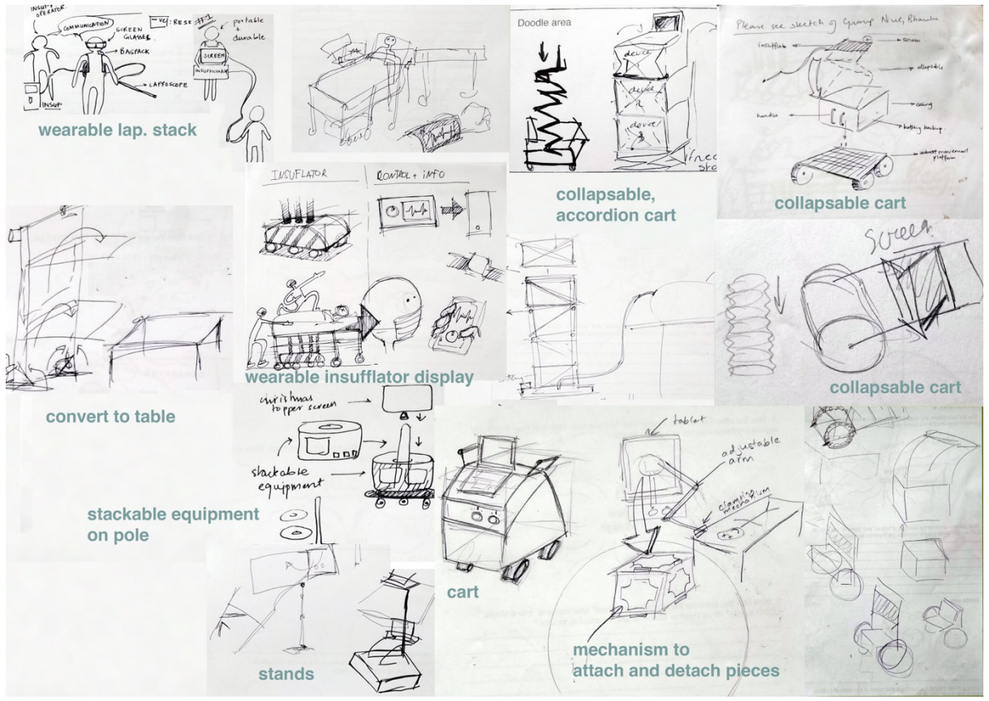


Figure 22 gives an overview of the models made in association with the word portable. Portability was associated with movement from A to B, both in the form of mechanical movement through wheels and pulleys and more abstract transitions. Another occurring theme was the idea of having a lot of functionality coming together in something compact, such as pocketknives or baskets carrying a lot of different parts. Portability was also associated with an aesthetic solution and small components fitting within larger components. Finally, portability was also associated with creating functionality that would make something large carriable (e.g handles)

Theme	Word associations
Compactness	Foldable, small, collapsible, easy storage, light, compressible, camping, compressible, telephone, handy
Features enabling portability	Wheels, modularity, attachable, flexible, something that moves
Aesthetics and design	Amorphous, cute, simple

Figure 23 gives an overview of the concept directions developed during the session. Different ideas for collapsible carts are presented. Mechanisms to attach and detach pieces, and stackable equipment are also recurring themes.



Conclusion

- Many ideas of different ways to make something that is compact and robust
- Many stackable and attachable/detachable options
- Hard to decide without more expert input
- Based on the brainstorming and additional ideation two distinct directions were chosen
- One concept integrated within bedside and one flight case inspired concept

Appendix 3: inital survey

The survey consists of three sections: an introduction section consisting of biographical questions, about the type of hospital participants work in (district, provincial, national) , the location of hospital (E.g urban, suburban, rural), their expertise area (general surgery, biomed, obstetrics and gyn) and their level of experience (e.g. beginner, intermediate, advanced)

The second part of the survey asks the participants to rank different requirements according to importance, and about the barriers encountered when implementing laparoscopy. The ranking questions are augmented with open questions.

Score the following design requirements of the laparoscopic tower, in the context of using it together with a USB scope solution (1 = not important, 5 = very important)
The tower should have low purchase costs
The tower should be easy to install and set-up
The tower should be easy to maintain
The tower should have low maintenance costs
The tower should be easy to clean
The tower should be moveable from one operating room to another
The tower should be rugged and robust
The tower should be modular
The tower should be portable and compact
The insufflator should be visible at all times
The screen height should be adjustable
The tower should hold/contain the CO2 supply

Open questions:

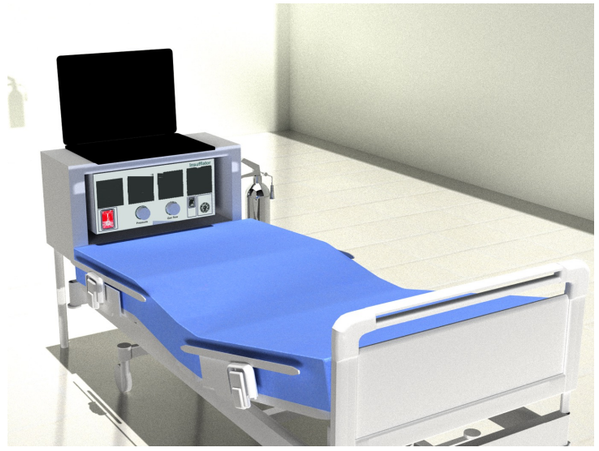
- Please specify any additional requirements
- What problems do you encounter using laparoscopic equipment. Shortly describe

What are current barriers that you experience with performing laparoscopic surgery, rank from high to low barrier (1 = low barrier, 5 = high barrier)
High costs associated with purchasing laparoscopic equipment
Time required to set-up and perform laparoscopic surgery
Difficulties with setting up laparoscopic surgery
Availability of laparoscopic equipment
Difficulty using laparoscopic equipment
Difficulty sourcing spare parts
Lack of maintenance and costs associated with maintenance
Cleaning infrastructure for laparoscopic equipment
Limited opportunities to learn and practice laparoscopy skills
Skepticism/reluctance from patients to undergo laparoscopic surgery
Open questions:

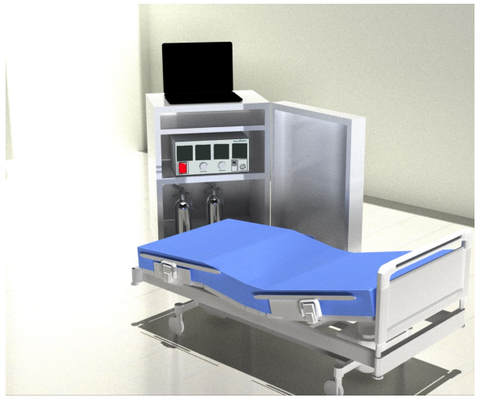
- Please specify any additional barriers you encounter

The third part of the survey asks participants to describe the two different concepts directions and indicate their preference. The concepts are presented both visually and with a short description.

Afterwards two different concept directions were presented:



Concept 1: solution integrated within surgical bed
The first concept, consists of an attachment piece to the surgical bed. This design allows for a fixed location of the tower during the operation, thus creating a dedicated space for the screen and insufflator. With this concept, one attachment piece is required per operating room (OR), as the tower is attached to the surgical bed. Equipment can be moved on or off accordingly.
What do you like about this concept and what would you change or improve?



Concept 2: flight case inspired laparoscopic tower
The second concept is inspired by flight cases, with a focus on a highly mobile solution. Flight cases are rugged containers on wheels, used to transport delicate equipment for professionals that travel frequently. This concept makes use of those advantages to enable mobility within a hospital setting. The tower is equipped with different shelves allowing for equipment to be moved from one room to another, eliminating the need for additional equipment carts.

Appendix 4: validation survey

TU Delft – Laparoscopic tower design

Hello and thank you for taking the time to help with my thesis! Currently, we are in the process of designing a new **laparoscopic tower for global surgery, that will be used together with a USB laparoscope solution (also currently under development within TU Delft).** As part of the design process, we would like to gather feedback from experts and users like you, to understand what your thoughts are on the new design of the laparoscopic tower.

Please note that **your participation in this exercise is voluntary and your responses will be anonymous.** Filling in the questions and being part of the demonstration should take 20 minutes in total. This survey is being conducted for research purposes only, and your responses will be used to inform our design process and improve our understanding of laparoscopic surgery for a master thesis project at Delft University of Technology.

Your input will be invaluable in helping us develop a laparoscopic tower that meets the needs of surgeons, biomedical engineers, medical professionals, and patients alike. **Thank you in advance for taking the time to share your insights with us!** In case of any questions or in case you would like to be updated about our research please do not hesitate to contact us (i.drilea@student.tudelft.nl).

Ioana Drilea, Master Student, Integrated Product Design, Delft University of Technology, The Netherland *(Also, on behalf of: Prof. Jenny Dankelman, Prof. Jan Carel Diehl, Assistant Prof. Roos Marieke Oosting PhD, Stefan Persaud)*

- o I consent to have my responses used for the purpose mentioned above!

Part 1 - Introduction

In which area do you currently work in?

A. Biomedical engineering
B. General surgery
C. Obstetrics and gynaecology
D. Other, namely: .....

How would you describe your experience with laparoscopic surgery or working with laparoscopic equipment?

A. Beginner: I have little to no experience with laparoscopy/ maintaining the equipment
B. Intermediate: I have some experience with laparoscopy/ maintaining the equipment but am not yet highly proficient.
C. Advanced: I am highly proficient in laparoscopy and have extensive experience with performing surgery /maintaining equipment

What are, in your opinion, current challenges with implementing laparoscopy in your hospital?

Challenges	1 – no barrier	2	3	4	5 – high barrier
High costs associated with purchasing laparoscopic equipment	o	o	o	o	o
Time required to set-up and perform laparoscopic surgery	o	o	o	o	o
Difficulties with preparing room for laparoscopic surgery	o	o	o	o	o
Availability of laparoscopic equipment	o	o	o	o	o
Difficulty using laparoscopic equipment	o	o	o	o	o
Difficulty sourcing spare parts	o	o	o	o	o
Costs associated with maintenance	o	o	o	o	o
Cleaning infrastructure for laparoscopic equipment	o	o	o	o	o
Limited opportunities to learn and practice laparoscopy skills	o	o	o	o	o
Costs associated with consumables	o	o	o	o	o
Scepticism/reluctance from patients to undergo laparoscopic surgery	o	o	o	o	o

Screenshot

TU Delft

2. On a scale from 1 to 5 was it easy to use:

1 – difficult to use	2	3	4	5 – easy to use

3. What was the easiest part and why?

_____
_____
_____

4. What was the most challenging part and why?

_____
_____
_____

5. Based on your interactions with the prototype what would you improve?

_____
_____
_____

B. Imagine you are moving the laparoscopic tower around from operating room to operating room, with all the equipment inside. You might also have to move it around to another department or to a storage area. Answer the following questions:

Challenges	1 – not suitable	2	3	4	5 – very suitable
Is the tower suitable for regular use in a clinical setting?	o	o	o	o	o
Is the tower suitable to withstand impacts and accidents without getting broken?	o	o	o	o	o
Is the tower suitable for moving equipment around across the hospital?	o	o	o	o	o
Is the tower suitable for long term storage?	o	o	o	o	o
Difficulty using laparoscopic equipment	o	o	o	o	o

1. Are there any parts that might break or need frequent replacement? If so, which?

_____
_____
_____

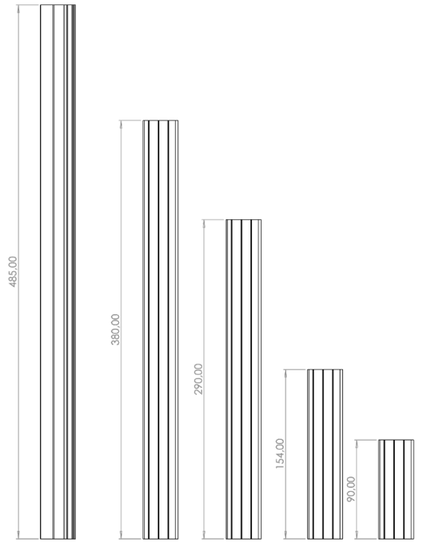
2. Overall, how would you improve the laparoscopic tower for transportation and storage?

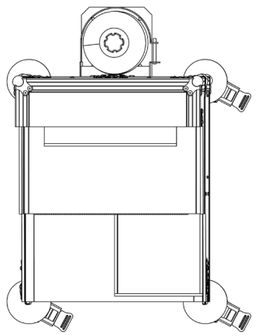
_____
_____
_____

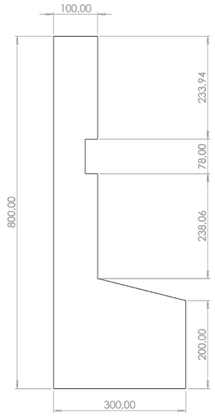
3. Anything else you would like to add?

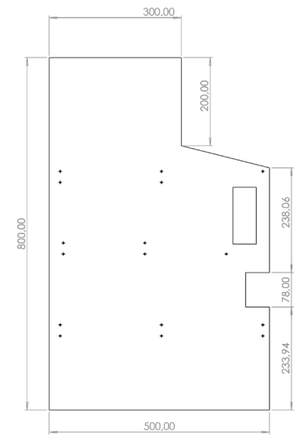
_____
_____

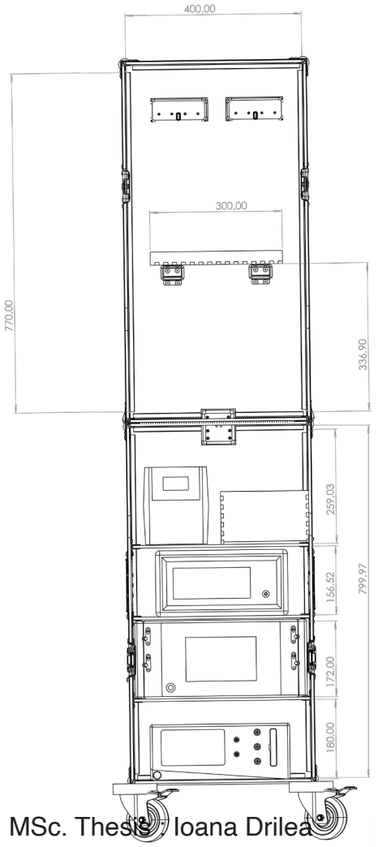
Appendix 5: bill of materials

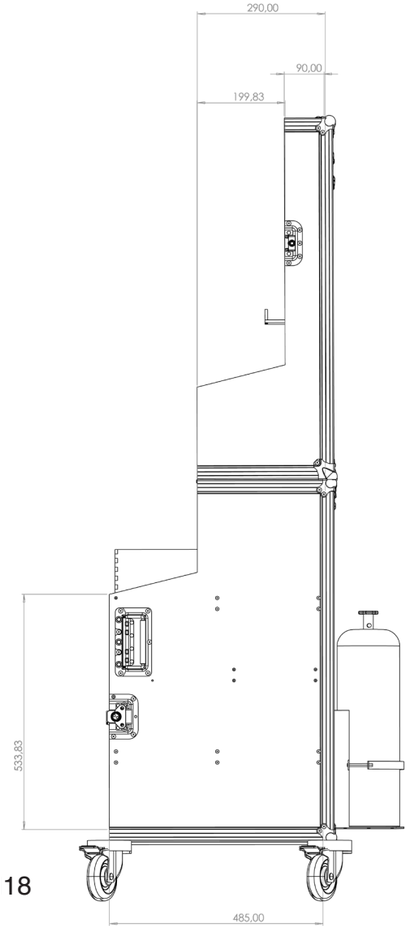








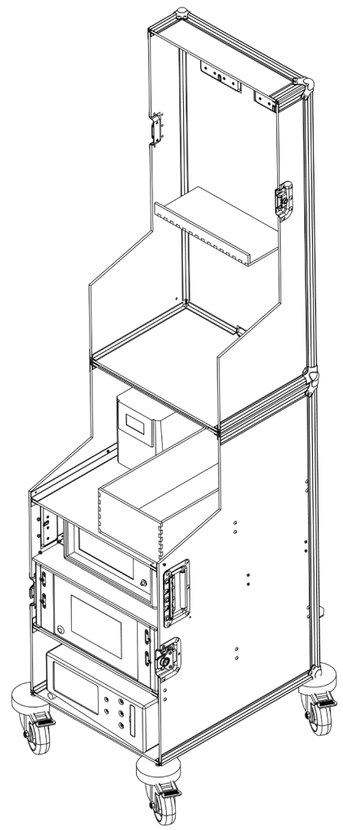




ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	EasyTower Full assembly	NOT SPECIFIED	1
1.1	EasyTower_Body		1
1.1.1	bottom		4
1.1.2	Configured Penn Elcom-3051		9
1.1.3	Door side		2
1.1.4	back side		1
1.1.5	L905-927		3
1.1.5.1	D928-905		1
1.1.5.2	Penn Elcom-L905-927_L0928		1
1.1.6	Penn Elcom-C1345		2
1.1.7	MirrorPenn Elcom-C1345		2
1.1.8	profile shelves		6
1.1.9	Penn Elcom-H7148		2
1.1.9.1	Penn Elcom-H7148_H7148-Dish_new		1
1.1.9.2	Penn Elcom-H7148_H7148-CP		1
1.1.9.3	Penn Elcom-H7148_H7148-Bail		1
1.1.9.3.1	Penn Elcom-H7148_H7148 Wire		1
1.1.9.3.2	Penn Elcom-H7148_H7148-Grip		1
1.1.9.4	Penn Elcom-H7148_04-048-10 (No9 7-32 OOH Rivet, Zinc)		7
1.1.10	top		1
1.2	EasyTower_Door		1
1.2.1	side of door4		1
1.2.2	top		1
1.2.3	door back		1
1.2.4	Configured Penn Elcom-3051		9

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1.2.5	Mirrorside of door4		1
1.2.6	Penn Elcom-C1345		1
1.2.7	MirrorPenn Elcom-C1345		1
1.2.8	door top		1
1.2.9	Penn Elcom-C1081-01		1
1.2.10	MirrorPenn Elcom-C1081-01		1
1.2.11	L905-927		3
1.2.11.1	D928-905		1
1.2.11.2	Penn Elcom-L905-927_L0927-CP		1
1.2.12	Penn Elcom-H7148		2
1.2.12.1	Penn Elcom-H7148_H7148-Dish_new		1
1.2.12.2	Penn Elcom-H7148_H7148-CP		1
1.2.12.3	Penn Elcom-H7148_H7148-Bail		1
1.2.12.3.1	Penn Elcom-H7148_H7148 Wire		1
1.2.12.3.2	Penn Elcom-H7148_H7148-Grip		1
1.2.12.4	Penn Elcom-H7148_04-048-10 (No9 7-32 OOH Rivet, Zinc)		7
1.2.13	DIN 6791-5x8-St-4.5		14
1.3	wheel base v2		1
1.4	WH-5084H-76 4in SWIVEL BRAKE BOLT HOLE H=129.stp	NOT SPECIFIED	4
1.4.1	50184_1.stp	NOT SPECIFIED	1
1.4.2	540-14_1.stp	NOT SPECIFIED	1
1.4.3	504-986_1.stp	NOT SPECIFIED	1
1.4.4	570-33_1.stp	NOT SPECIFIED	1
1.4.5	570-34_1.stp	NOT SPECIFIED	1
1.5	Part6^EasyTower Full assembly		1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1.6	Piano Hinge		1
1.6.1	Hinge fglat		2
1.6.2	Part5^Piano Hinge		1
2	stryker console		1
3	diathermy		1
4	Insufflator		1
5	20Lb_CO2_TankBracket		1
6	20Lb_CO2_Tank		1
7	DIN 6791-5x14-St-10.5		178
8	Part1^Easytower Filled		1
9	stand23		1
9.1	Attempt 2 plate		1
9.2	Penn Elcom-P1995		2
9.2.1	Penn Elcom-P1995_P1995-1		1
9.2.2	Penn Elcom-P1995_P1995-2		1
9.2.3	Penn Elcom-P1995_P1995-3		1
9.2.4	Penn Elcom-P1995_P1990-4		1
9.3	Part4^stand23		1
9.4	DIN 6791-5x8-St-4.5		16
10	Parts Drawer		1
10.1	base		1
10.2	Part7^Parts Drawer		2
10.3	Part8^Parts Drawer		2
11	UPS		1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME | SIGNATURE | DATE
DRAWN
CHK'D
APP'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO. Easytower Filled
A0
SCALE:1:10
SHEET 1 OF 1