

Usability of an adjusted IndoorTubes map design for indoor wayfinding on mobile devices

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1. Introduction

1.1 Background and motivation

Unlike outdoor cartography, indoor cartography has gathered much less attention both by the industry and academia

Reasons:

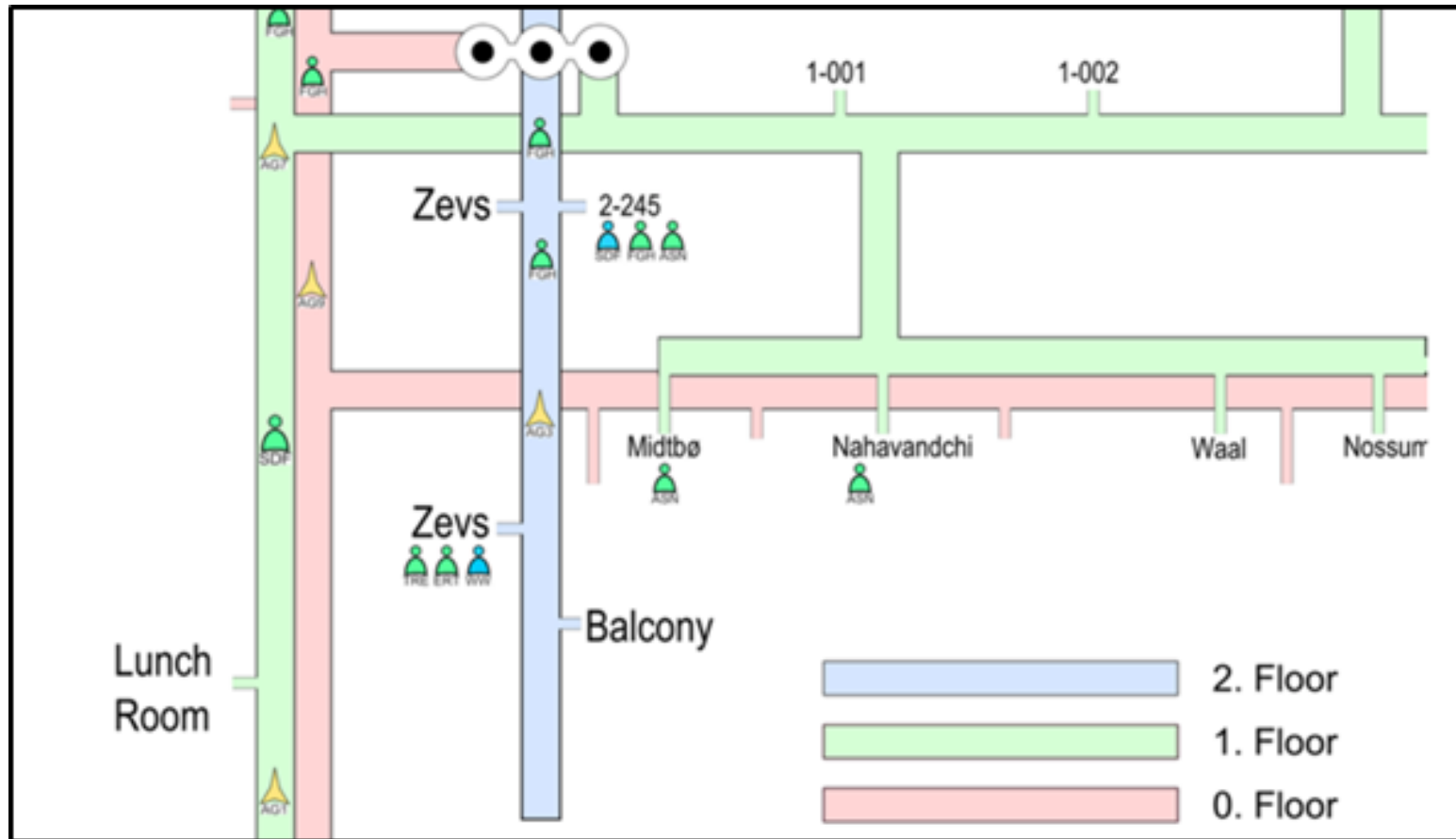
- a. Not yet an established indoor positioning solution
- b. No automated way to extract data and create indoor maps from architectural blueprints quickly and efficiently

1.1 Background and motivation

There is hope these technical issues will soon be resolved

This thesis focuses on the cartographic design aspect of indoor maps and how that can affect the wayfinding experience of users

1.2 Main inspiration: IndoorTubes



1.3 Hypothesis and scope

- All a user needs to help for indoor wayfinding are corridors, some general shapes for things like big waiting rooms, atriums and basic indoor landmarks (staircases, elevators, WC positions)
- IndoorTubes too minimalistic and inclusion of multiple floors questionable.

Create a balanced design and test it by conducting a user study focused on mobile devices

1.3 Hypothesis and scope

- Focus on 2D, no 3D because:
 - a. Time constraints
 - b. 3D makes more sense if it can be manipulated, thus requiring the development of an interactive solution

1.4 Research objectives

1. Develop an alternative design based on IndoorTubes for mobile devices focusing on corridors, being flexible with - but not completely disregarding - shapes, sizes and distances and only depicting one floor at a time.
2. Conduct a user study to determine the usability of the new adjusted design.

2. Literature review

Current indoor map solutions

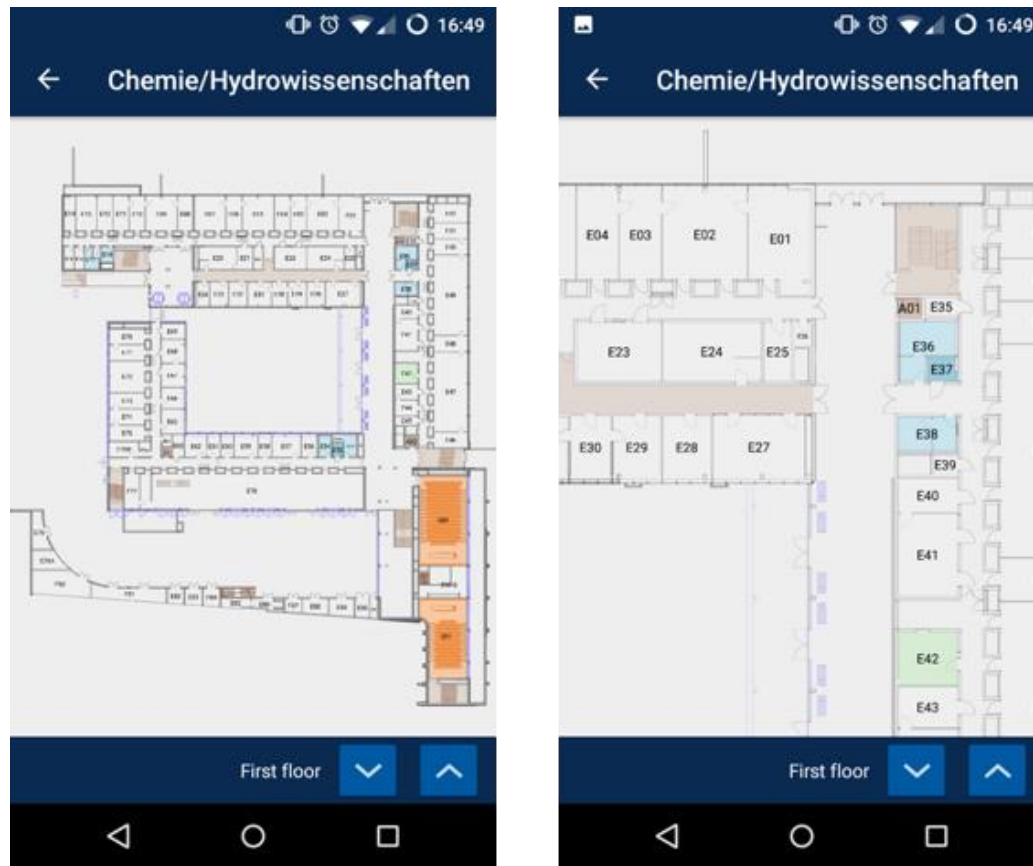
2.1 Raw blueprints

- They already exist, no additional effort to create them, so sometimes they are used in products

But...

- Include too much unnecessary information
- Overload the user cognitively
- Not created with indoor wayfinding in mind

2.1 Raw blueprints



TU Dresden Campus Navigator app

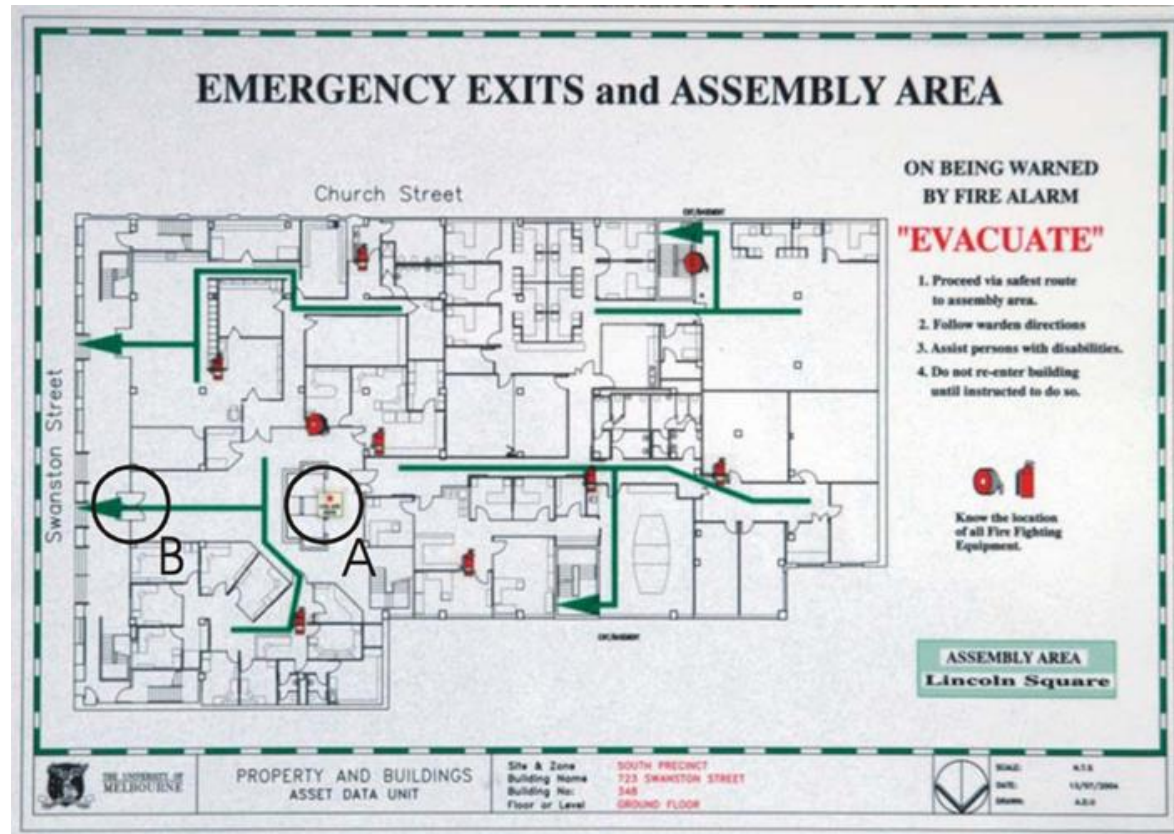
2.1 Raw blueprints

Popular use case:

You-Are-Here emergency maps

- Annotated floor plans
- Usually follow guidelines from authorities
- Design tends to be conservative

2.1 Raw blueprints

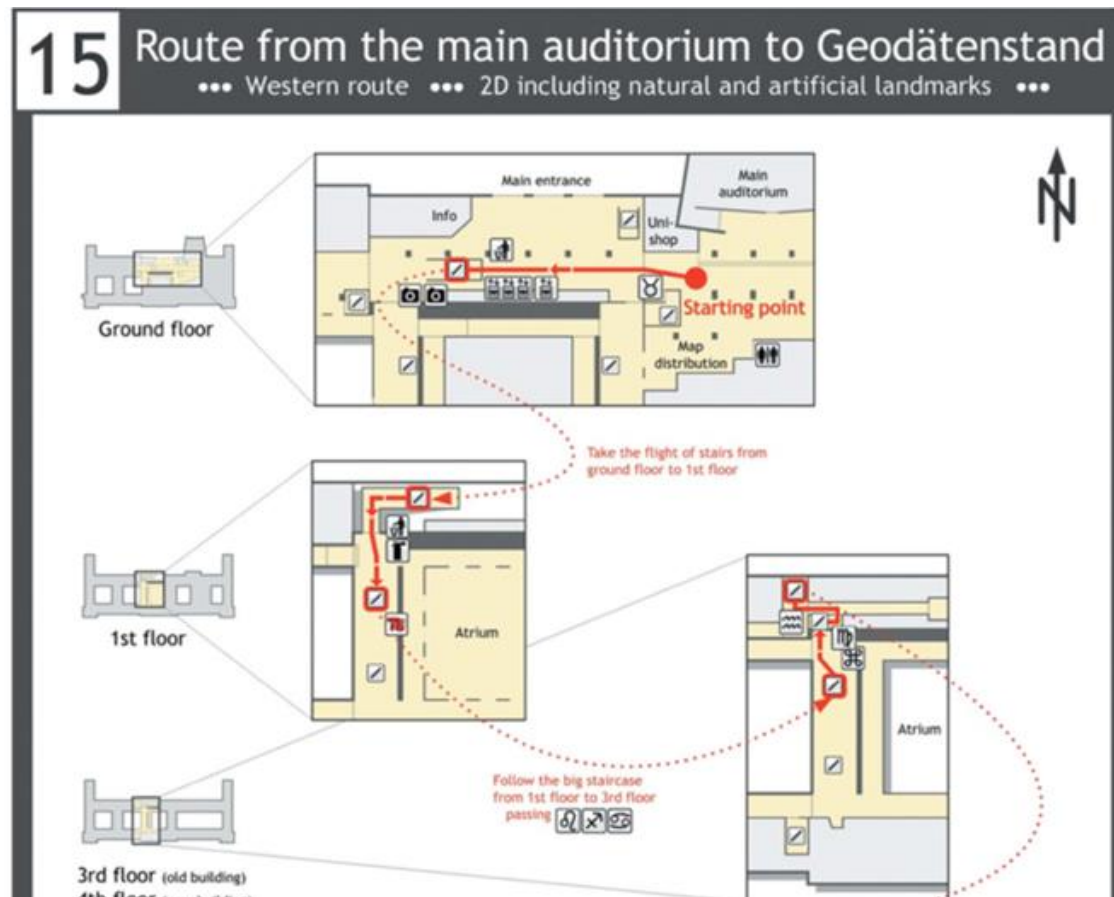


Example of emergency YAH map (Klippel, et al., 2006)

2.2 Simplified blueprints

- Based on raw blueprints
- ***They preserve:*** shapes, sizes, geometry and usually the general outline of the rooms and/or the building
- ***They discard:*** wall thickness, exact position of windows, direction in which doors open, exact design of staircases etc.
- Used in most commercial applications

2.2 Simplified blueprints – in academic research



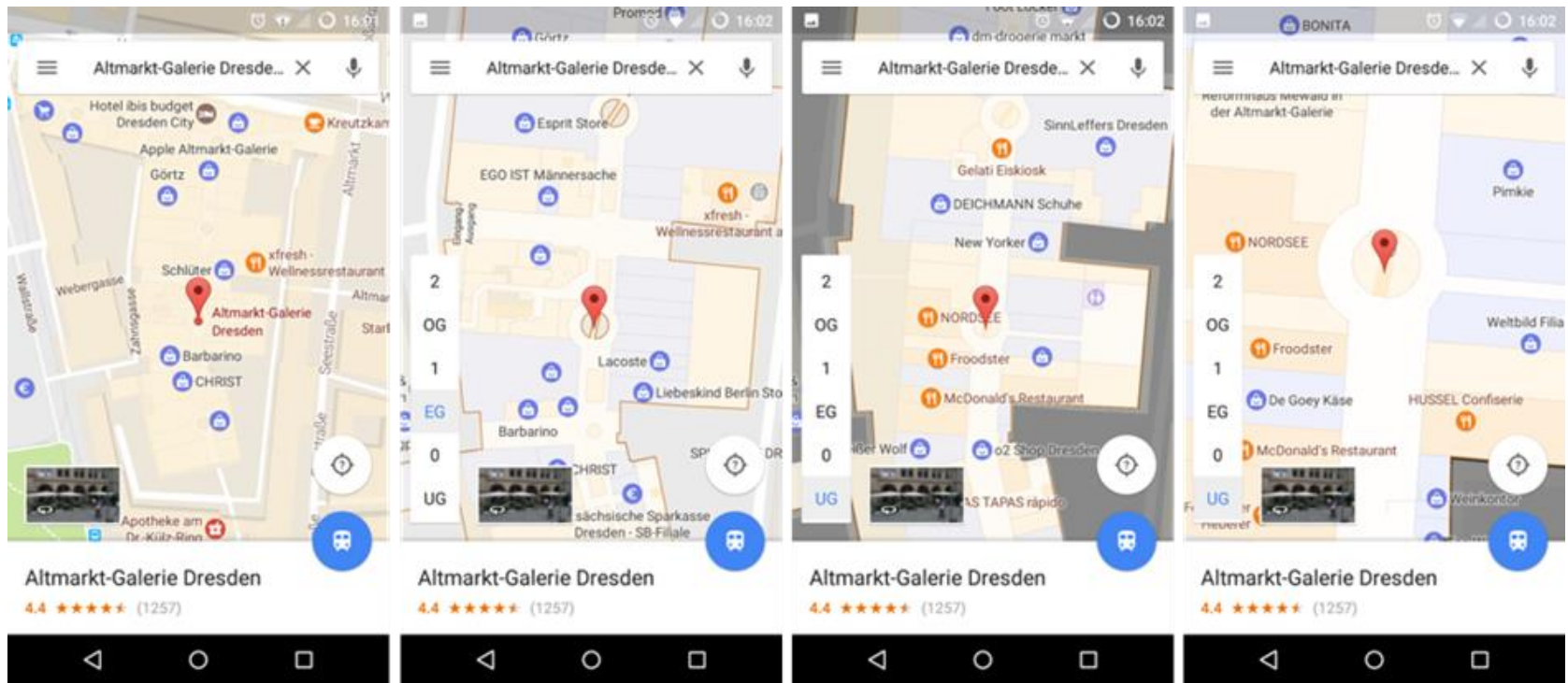
2D indoor map design (Lorenz, et al., 2013)

2.2 Simplified blueprints – in academic research



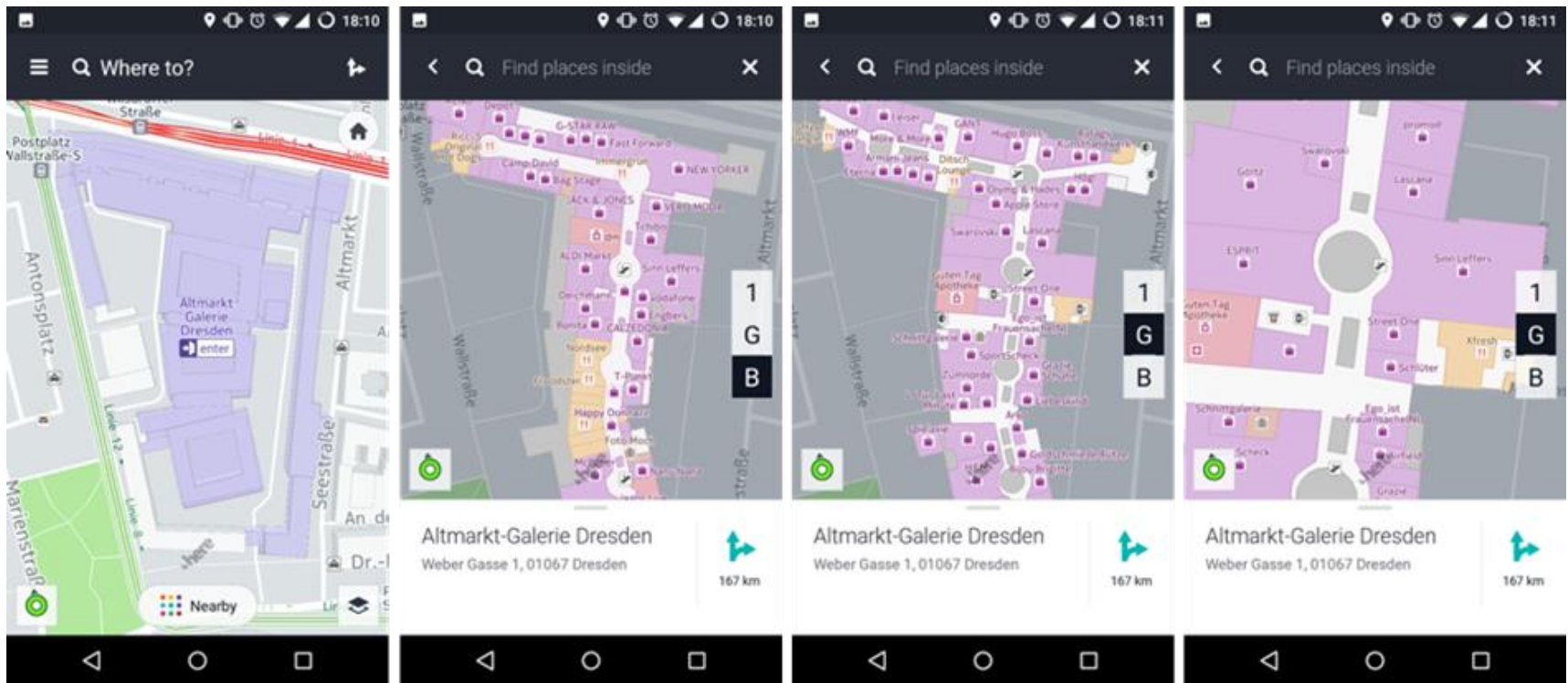
Kamppi mobile map (Puikkonen, et al., 2009)

2.3 Simplified blueprints – Google Maps



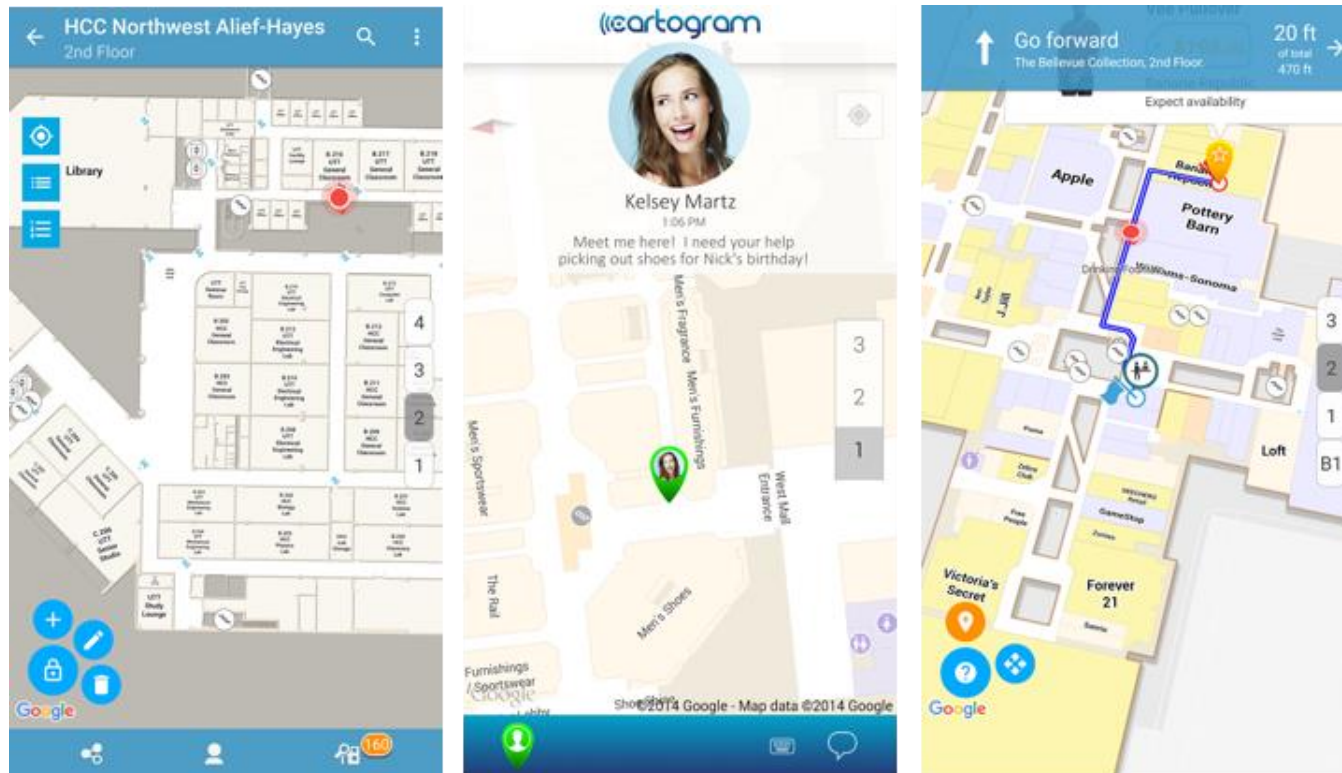
Google Maps indoor map example (Google Maps, 2017)

2.3 Simplified blueprints – HERE WeGo



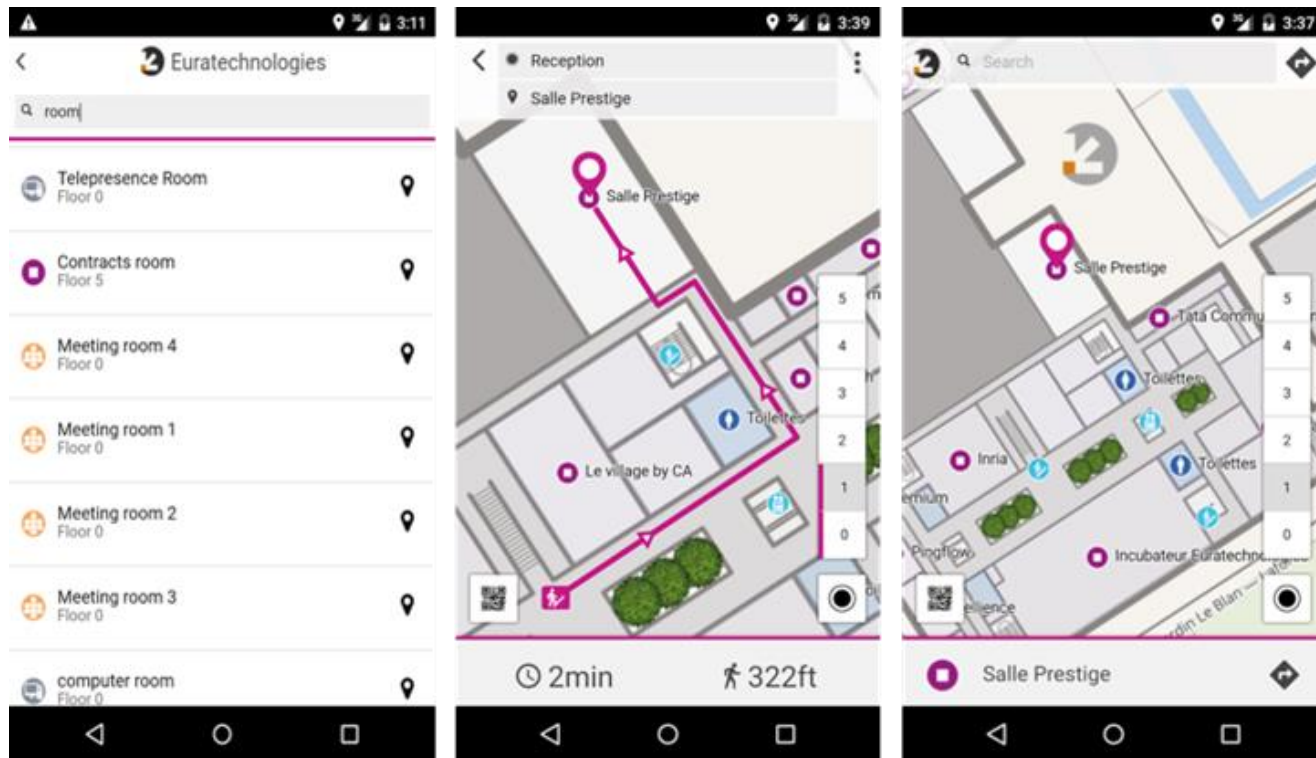
HERE WeGo indoor map example (HERE WeGo, 2017)

2.3 Simplified blueprints – Cartogram



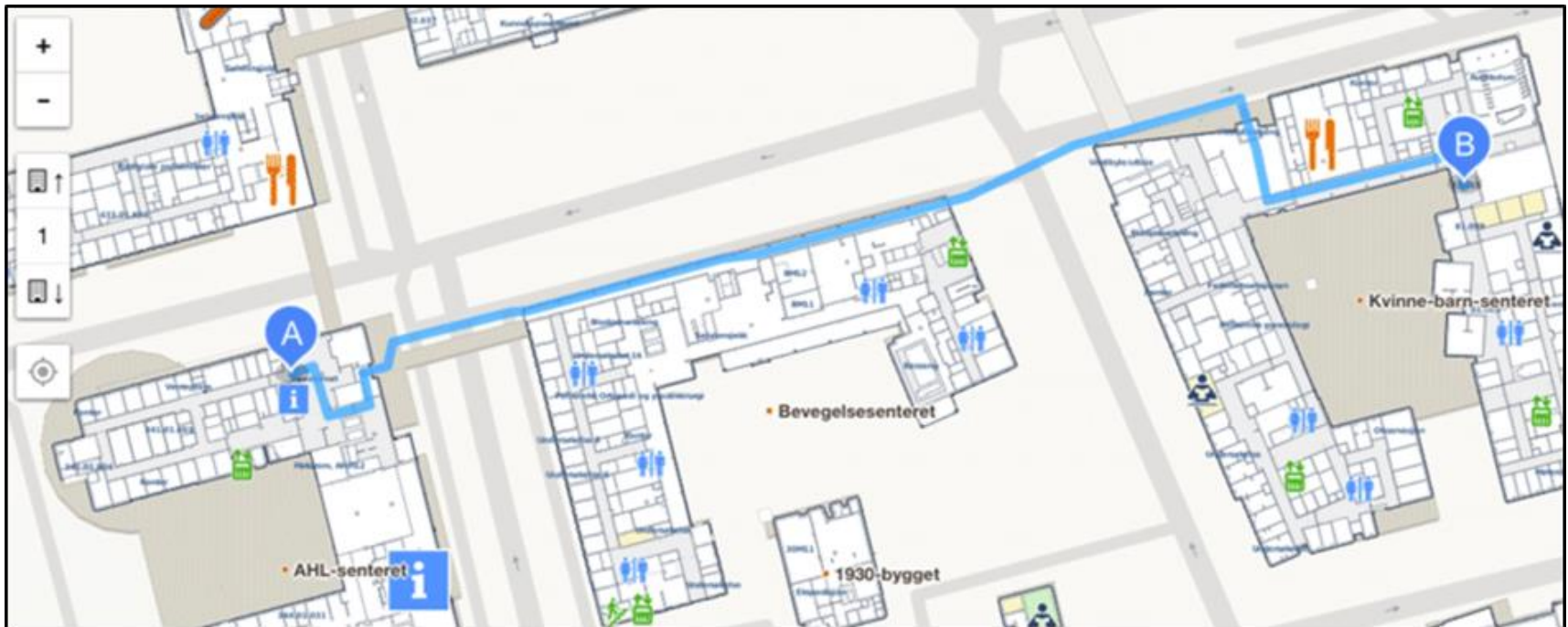
Cartogram indoor map example (Cartogram, 2017)

2.3 Simplified blueprints – Mapwize



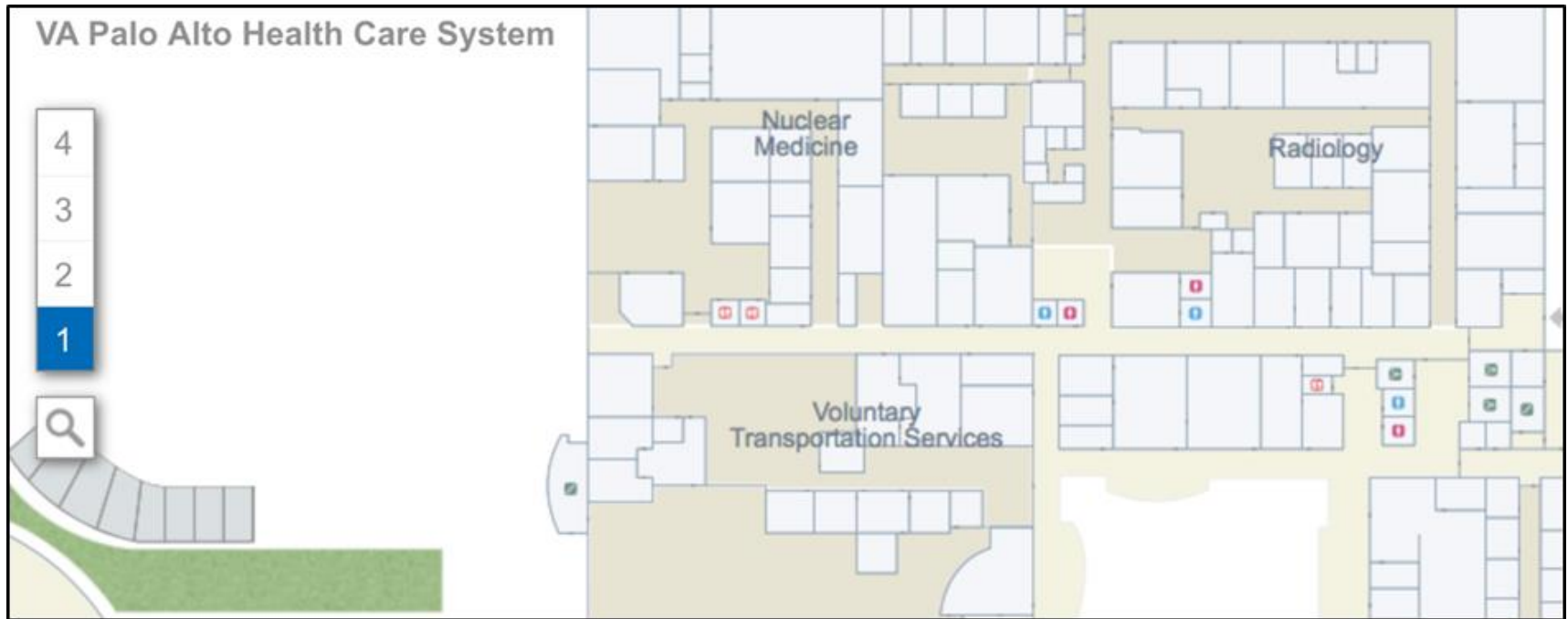
Mapwize indoor map example (Mapwize, 2017)

2.3 Simplified blueprints – MazeMap



MazeMap indoor map example (MazeMap, 2017)

2.3 Simplified blueprints – Micello

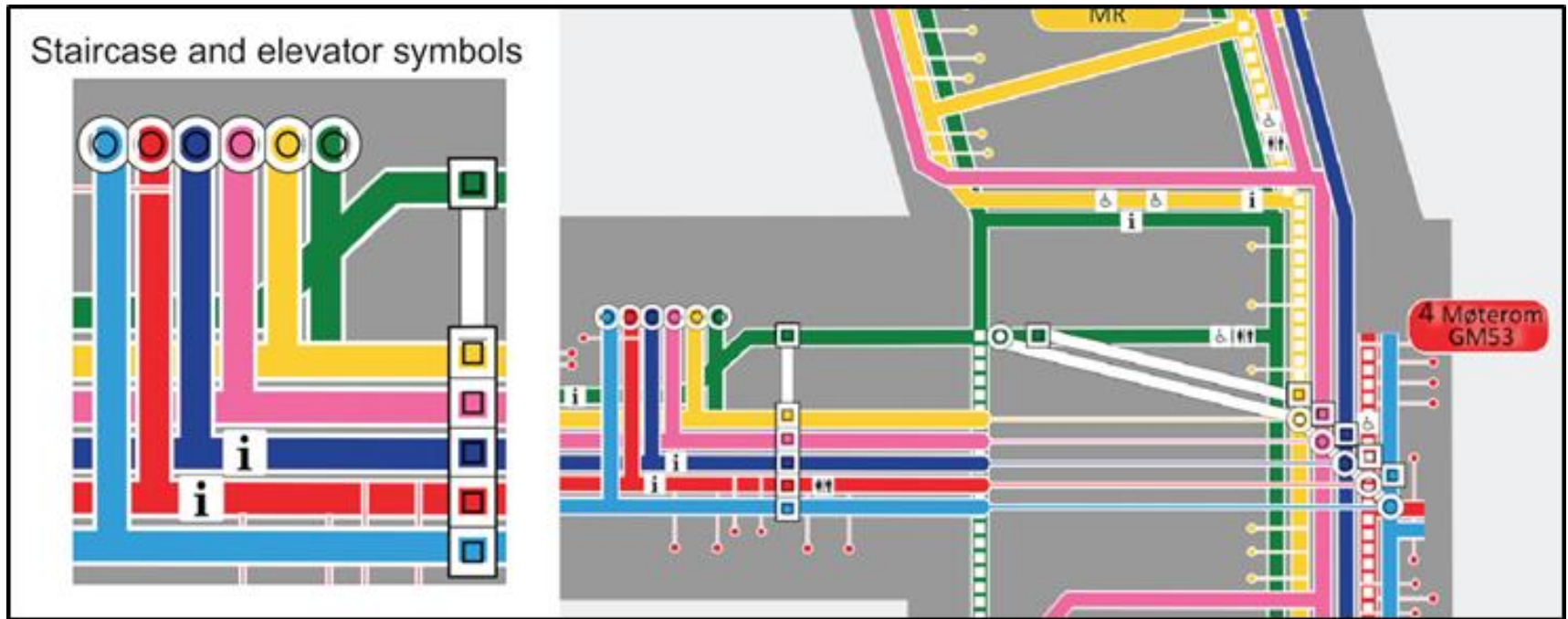


Micello indoor map example (Micello, 2017)

2.3 IndoorTubes

- Topology more important in indoor environments than geometry
- Connections between floors are depicted as “stations”
- Corridors as simple lines
- Geometry, shapes, sizes and distances are discarded as not very important
- Multiple floors are depicted simultaneously

2.3 IndoorTubes



IndoorTubes example 2 with legend (Nossum, et al.)

3. Methodology and implementation

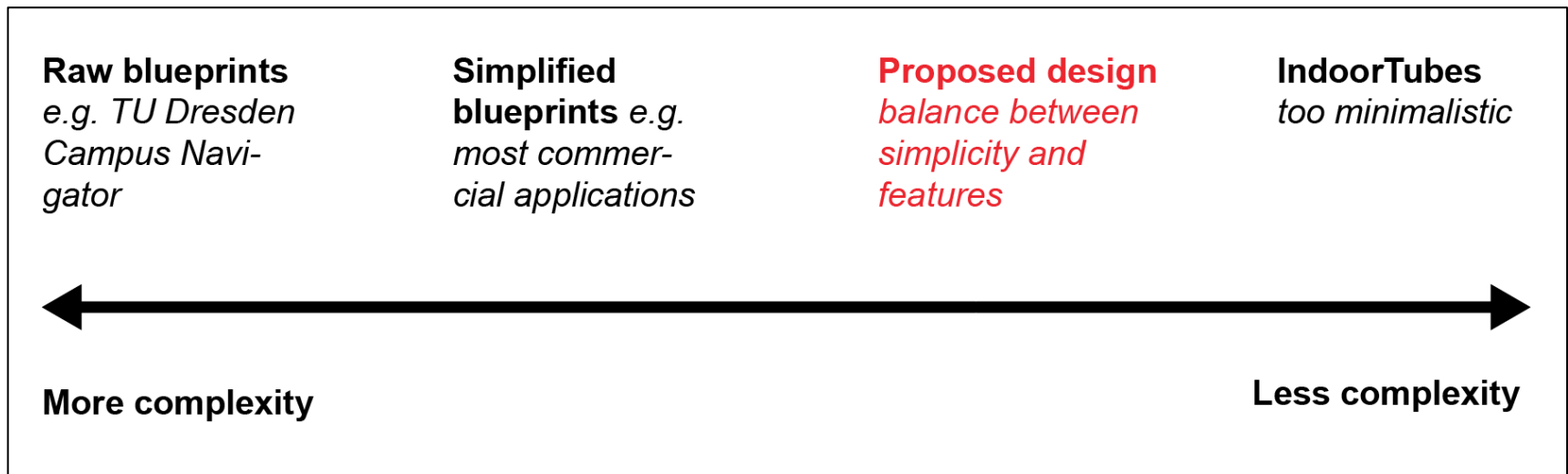
3.1 Building and time-slot selection

- Identify candidate buildings in TU Dresden's campus
- Reasonably big and complicated enough
- Make sure the participants had no prior experience (so the wayfinding task would be based on the maps and not from memory)
- Identify the best time-slot for the study to be conducted

Finally the Chemie/Hydrowissenschaften-Bau was selected and the study was planned for Thursday 16 and Friday 17 of February 2017

3.2 Proposed design – draft 1

Current solutions and the new proposal in terms of complexity



3.2 Proposed design – draft 1

Preserve:

- Corridors
- General shapes for things like big waiting rooms, atriums etc.
- Basic indoor landmarks (staircases, elevators, WCs and their positions)
- Geometric accuracy (not very strict)

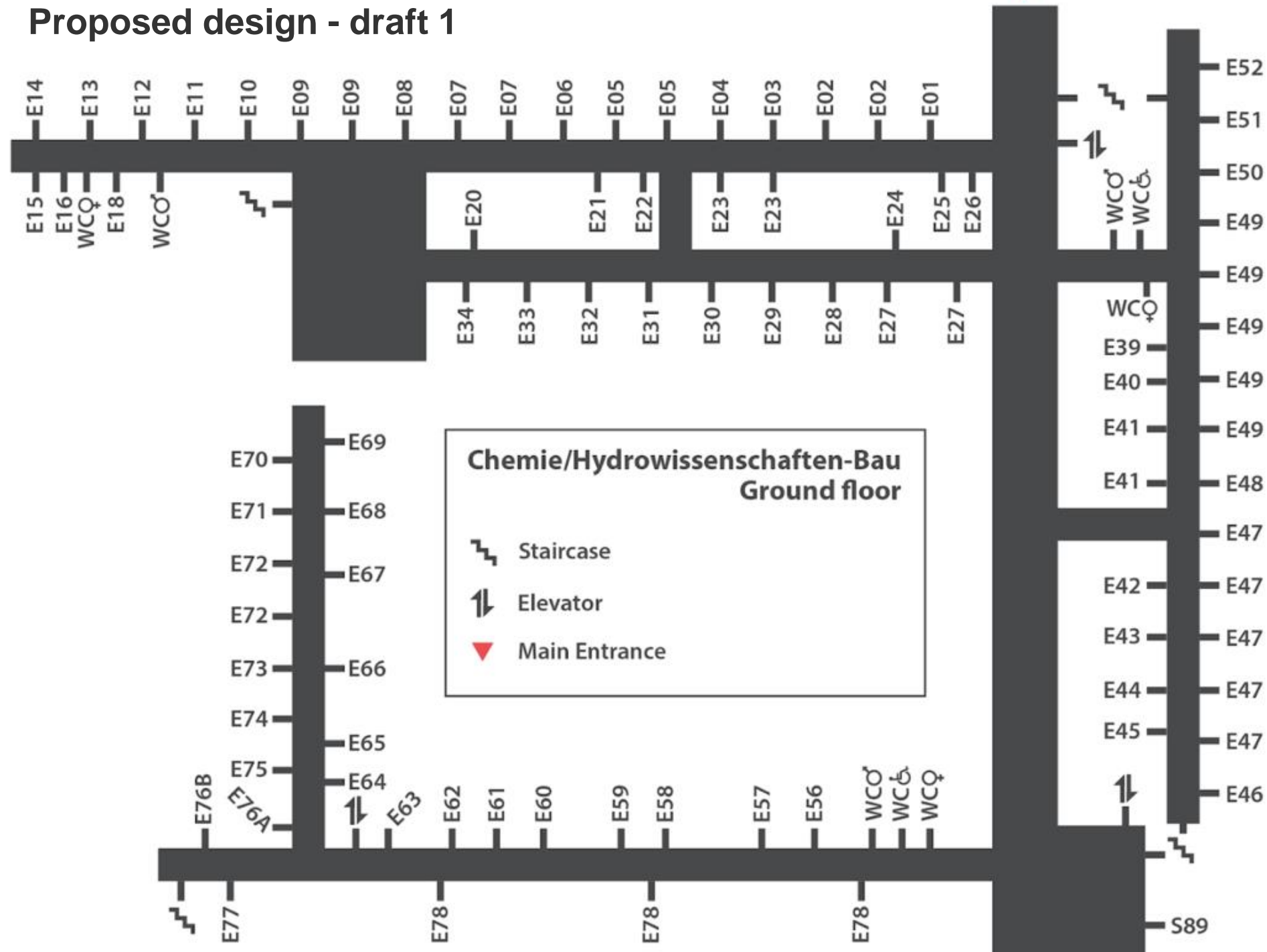
3.2 Proposed design – draft 1

Discard:

- Wall thickness
 - Exact position of windows
 - Direction in which doors open
 - Exact design of staircases
-
- Multiple floors per view



Proposed design - draft 1



3.2 Proposed design – draft 1

Adaptation for mobile devices:

- Clean and uncluttered design
- Sans serif typeface used
- Only two colors
- Self explanatory symbols
- High resolution JPEG when distributed so zooming would not create artifacts

3.3 Research structure

So the research had ***two main*** parts:

- a) Two *almost* identical online surveys sent to two different user groups asking them to compare the proposed design, Campus Navigator and the IndoorTubes concept
- b) The user study conducted in the Chemie/Hydrowissenschaften-Bau in TUD comparing the proposed design with the Campus Navigator

3.4 Research methods

Each part of the research corresponds to a research method:

a) Method 1: online surveys

- Easy and practical to organize
- Convenient for participants – higher likelihood that they will reply
- Digital at all steps – easy to analyze results
- Ask for both route planning and navigation (different functions)

3.4 Research methods

Each part of the research corresponds to a research method:

- a) Method 2: follow and record users during the user study
 - Method already used by other researchers
 - Exact time measurements
 - Recording of thoughts and comments (think aloud)
 - Collect additional information

3.4 Research methods

Method 2 (think aloud):

Advantage:

- Spontaneous and natural feedback

Disadvantages:

- Not natural behavior
- Might distract from wayfinding task
- Might affect user performance (timewise)

3.5 User study preparation

User group composition

- In total 32 participants were invited
- 22 replied positively
- Eventually 19 showed up
- Of the 19, 16 were cartography students
- 3 were TUD students (also engineering)

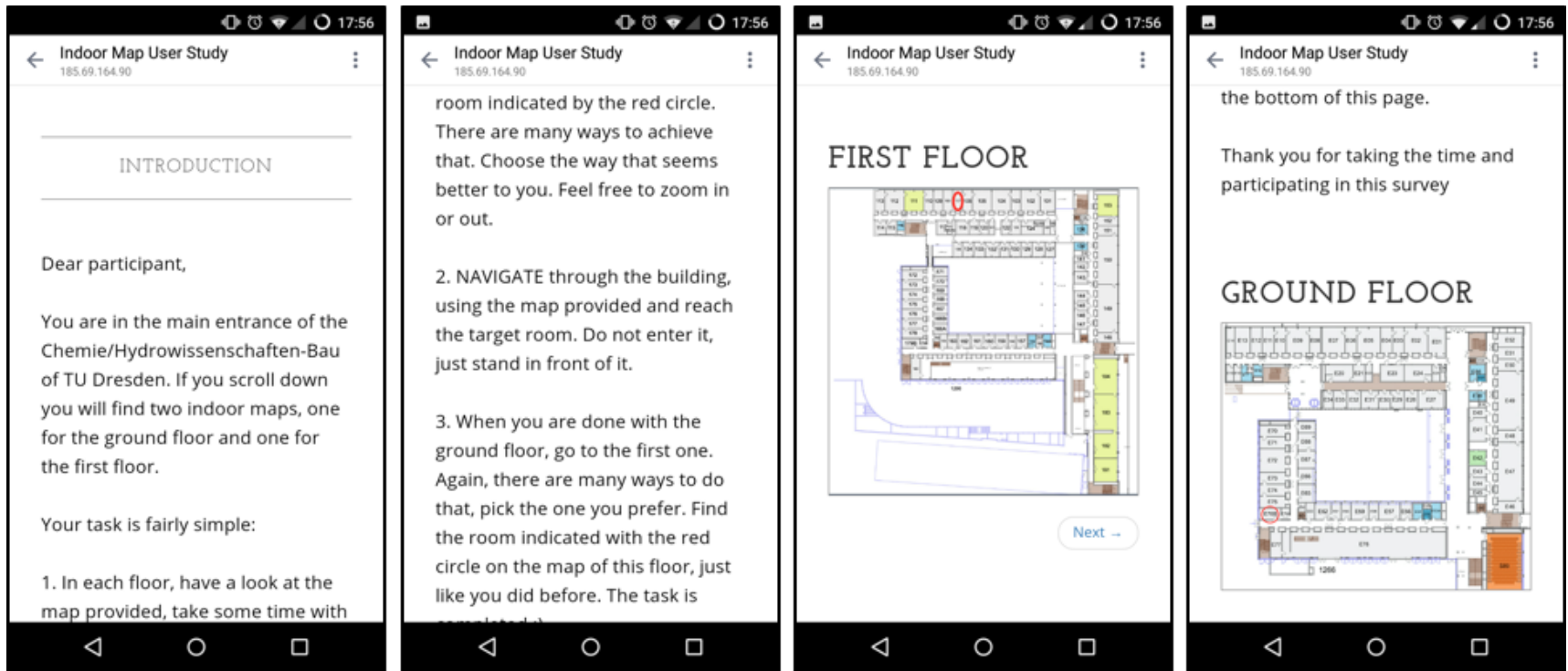
3.5 User study preparation

Mobile websites

- Creation of 2 websites for the 2 groups
- Group A had website with Campus Navigator design
- Group B had website with new proposed design
- In the beginning of the website there was an introduction explaining the task

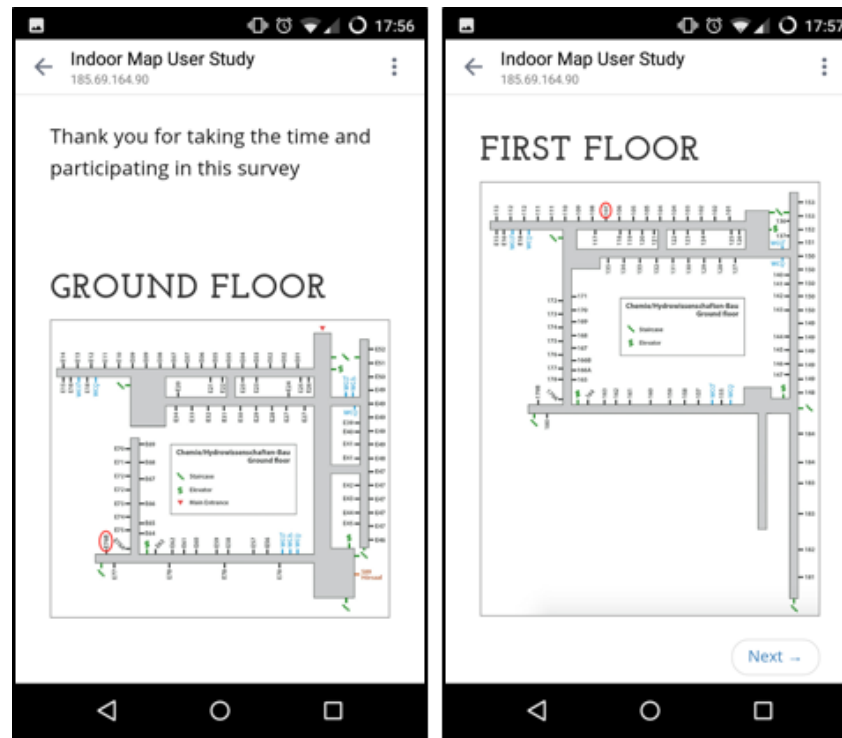
3.5 User study preparation

Mobile websites – Group A



3.5 User study preparation

Mobile websites – Group B



3.7 Online questionnaires/surveys recap in chronological order

1. **Building and time selection survey**
2. ***Experts' evaluation survey***: questions about all three designs to a group of cartography experts and feedback on draft-1 of proposed design
3. **Pre-study questionnaire**: background information and Santa Barbara Sense of Direction Scale
4. ***After-study questionnaire***: same questions as in 2 plus some additional ones (used draft-2 of proposed design)

4. Results and discussion

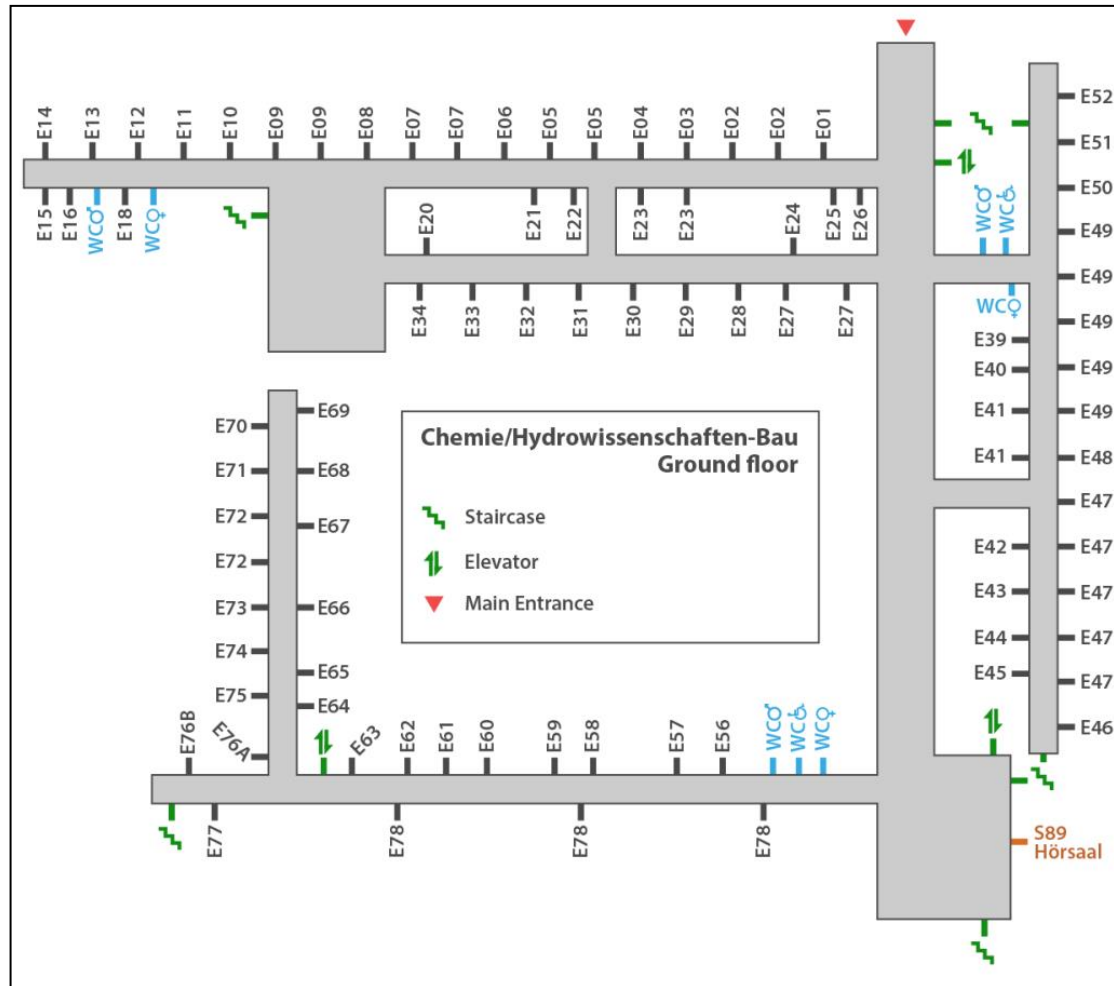
4.1 Proposed design – draft 2

The cartography experts provided feedback:

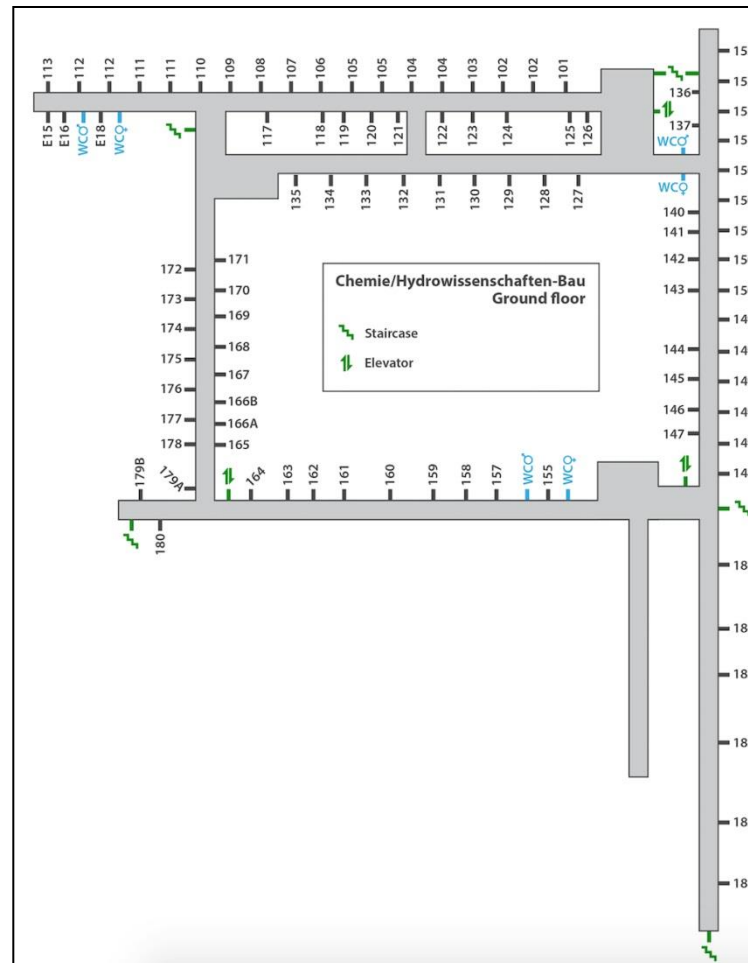
- Only one color in draft-1 not enough and monotonous
- The dark gray used was too dark and dark colors are associated with non-walkable parts of a building
- Colors could be used to distinguish the different symbols or special drive focus to special areas or rooms in the building

Based on the feedback, draft 2 was created

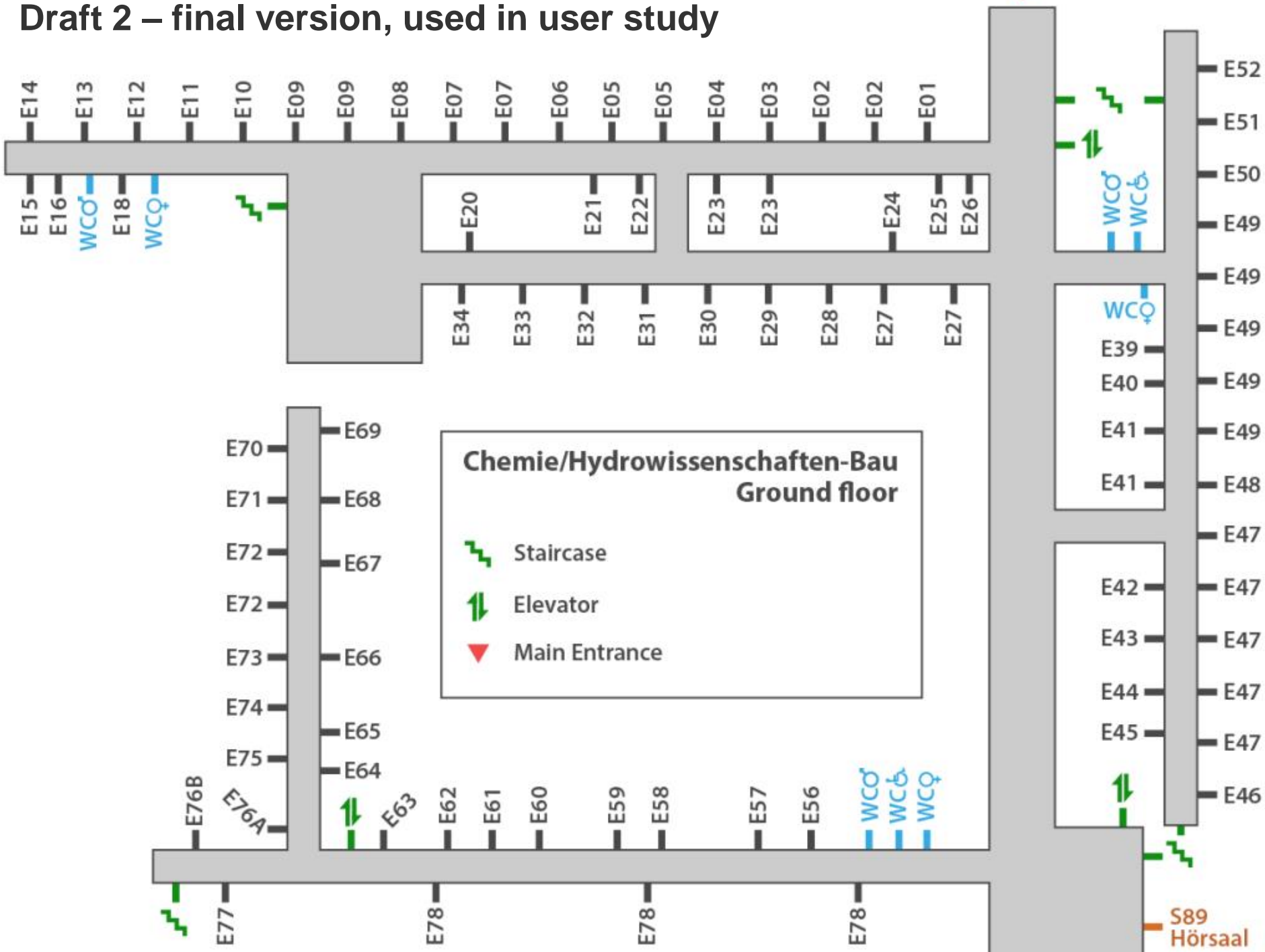
4.1 Proposed design – draft 2, ground floor



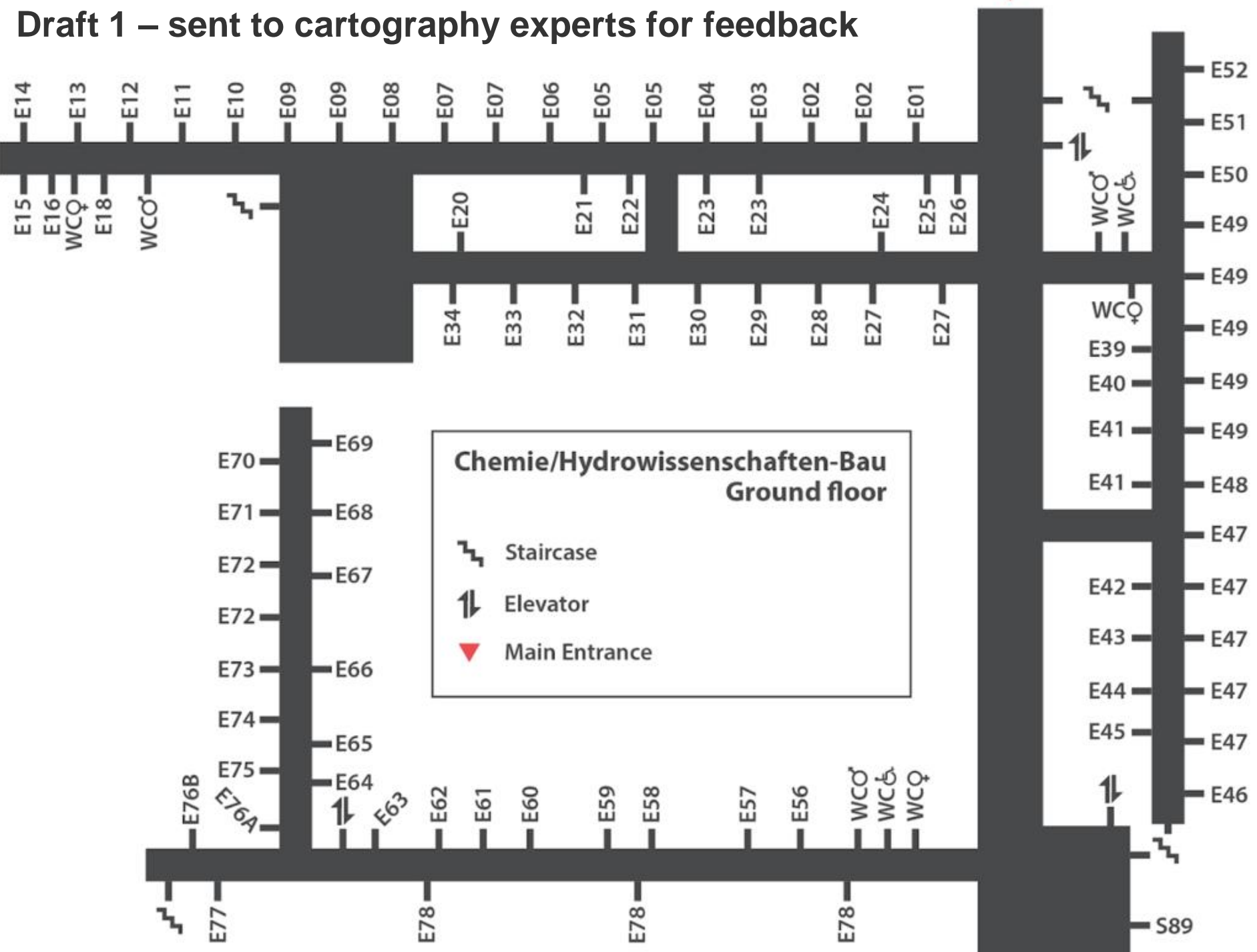
4.1 Proposed design – draft 2, first floor



Draft 2 – final version, used in user study



Draft 1 – sent to cartography experts for feedback



4.2 User study results

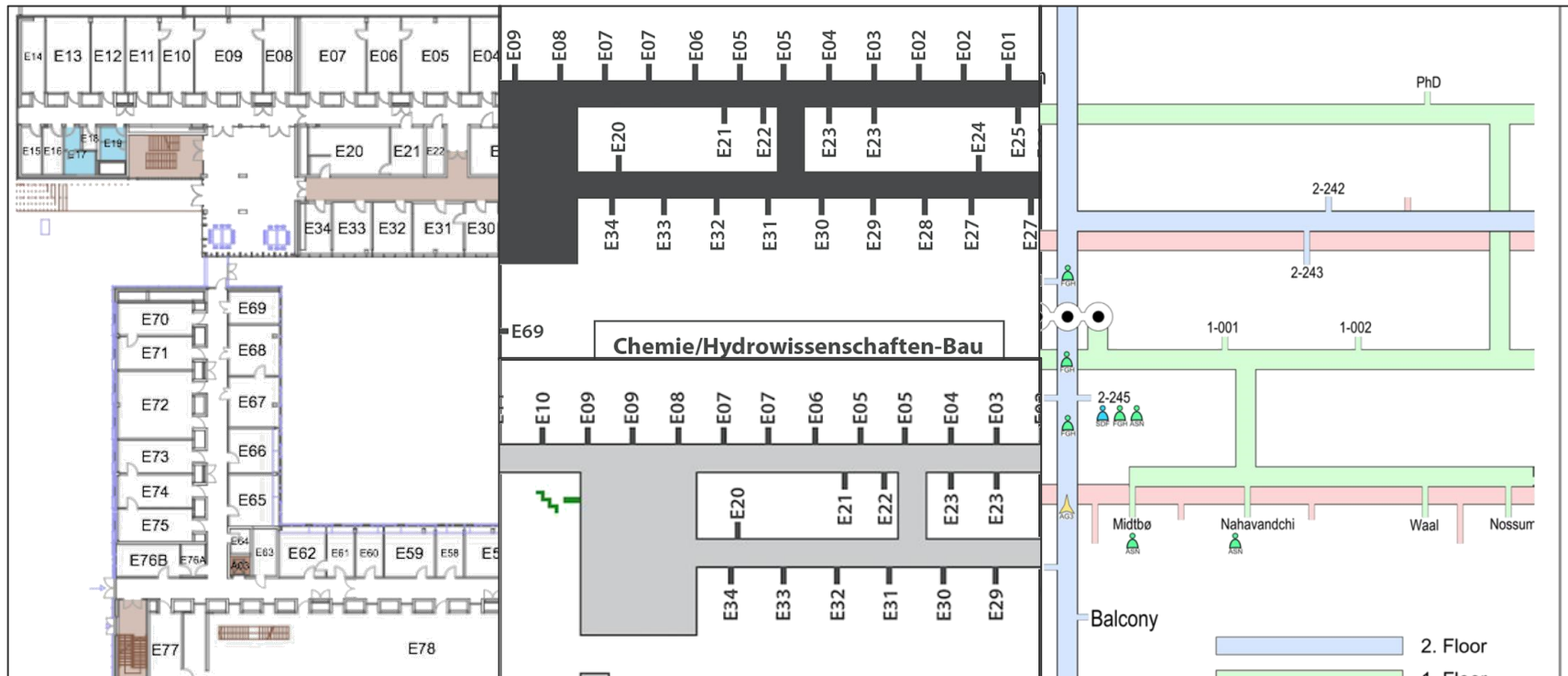
<i>Final number of User Study Participants who successfully participated</i>			
Group A		Group B	
Males:	5	Males:	4
Females:	3	Females:	6
Total:	8	Total:	10

4.2 User study results

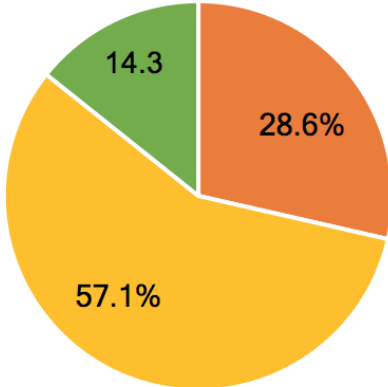
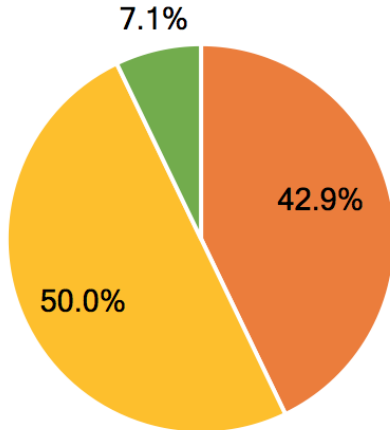
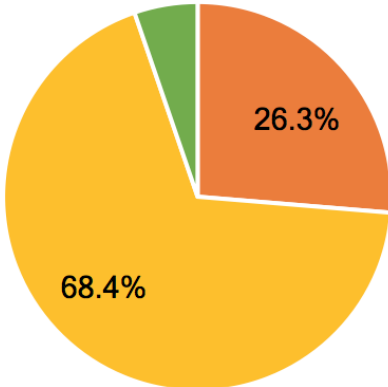
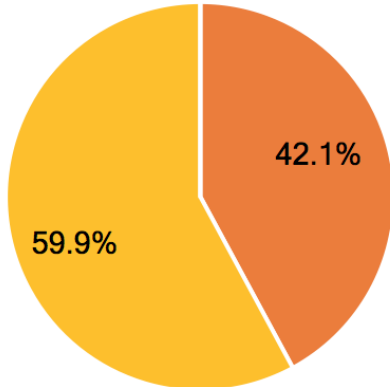
Group A					Group B				
<i>ID</i>	<i>Gender</i>	<i>Ground floor</i>	<i>First floor</i>	<i>Both floors</i>	<i>ID</i>	<i>Gender</i>	<i>Ground floor</i>	<i>First floor</i>	<i>Both floors</i>
2	Female	3:34	2:21	5:55	1	Female	1:40	3:27	5:07
5	Male	1:16	1:35	2:51	3	Female	2:17	2:14	4:31
6	Male	1:16	3:05	4:21	4	Male	1:40	2:03	3:43
9	Male	1:26	2:04	3:30	7	Male	2:59	2:33	5:32
13	Female	3:36	5:18	8:54	8	Female	1:49	2:57	4:46
16	Female	3:11	3:05	6:16	10	Female	1:17	1:31	2:48
18	Male	2:09	1:58	4:07	12	Female	1:50	2:58	4:48
22	Male	1:34	3:20	4:54	14	Female	1:32	6:58	8:30
					19	Male	1:42	2:08	3:50
					20	Male	1:31	1:49	3:20
Total:		2:15	2:51	5:06			1:50	2:52	4:42

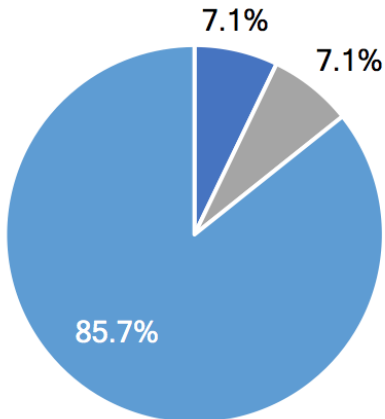
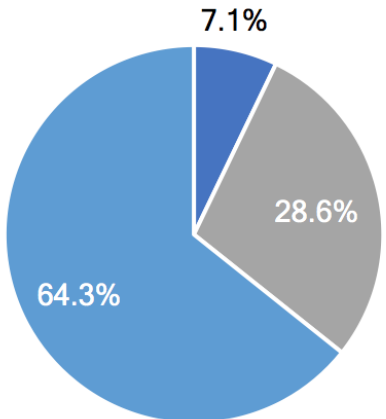
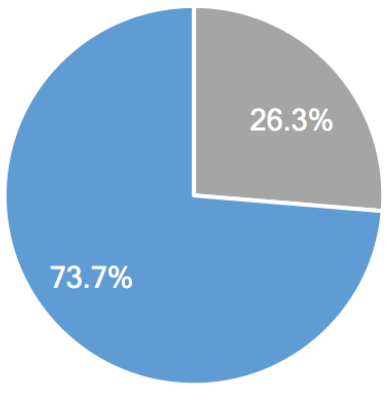
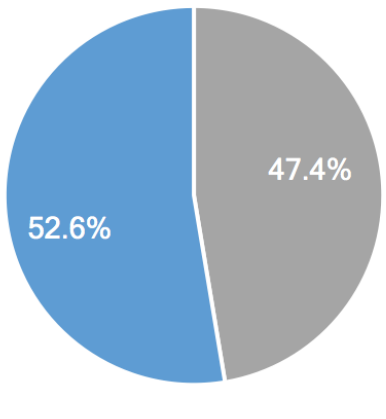
4.3 User surveys' results

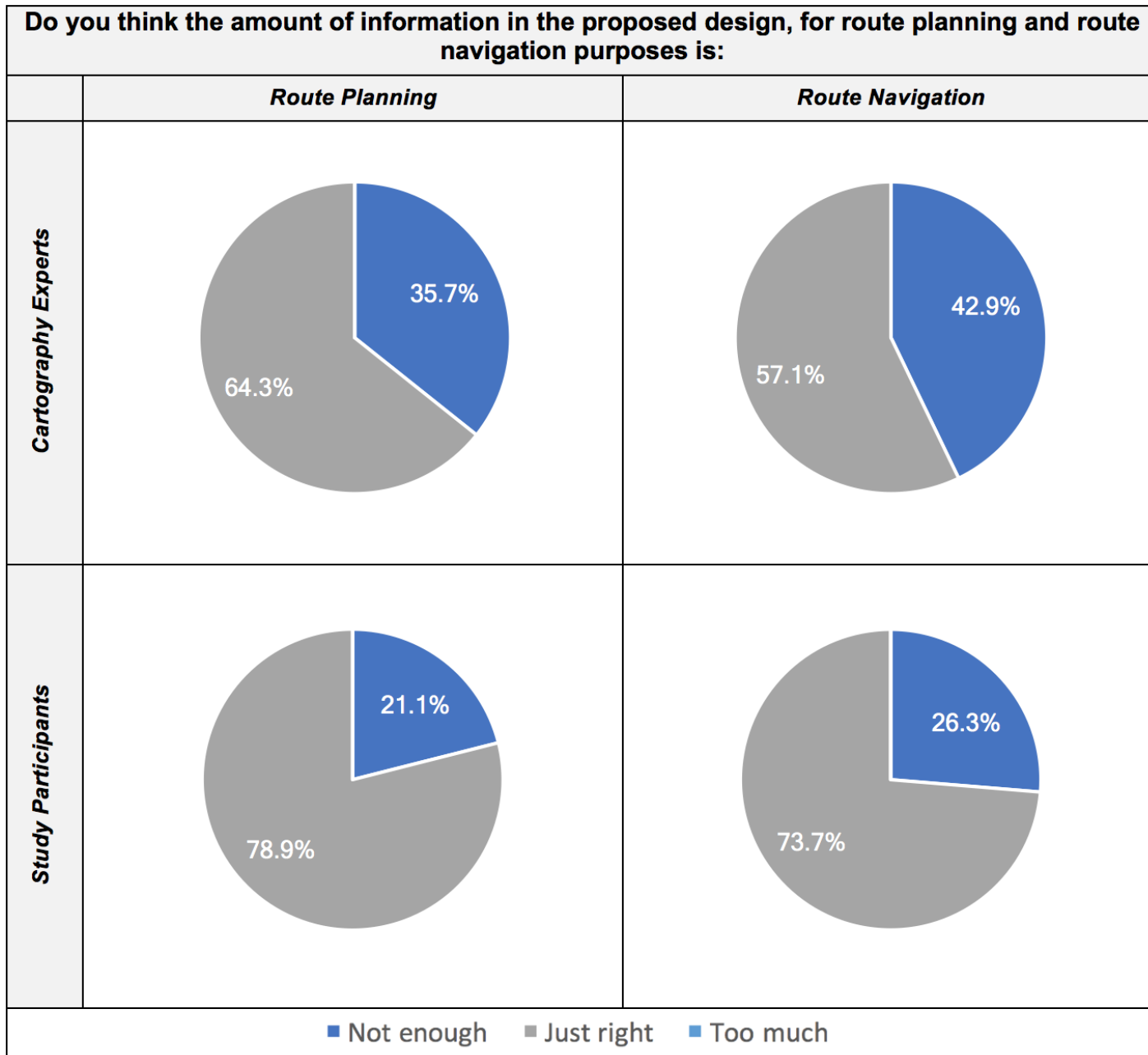
- Participants asked to compare three indoor map designs

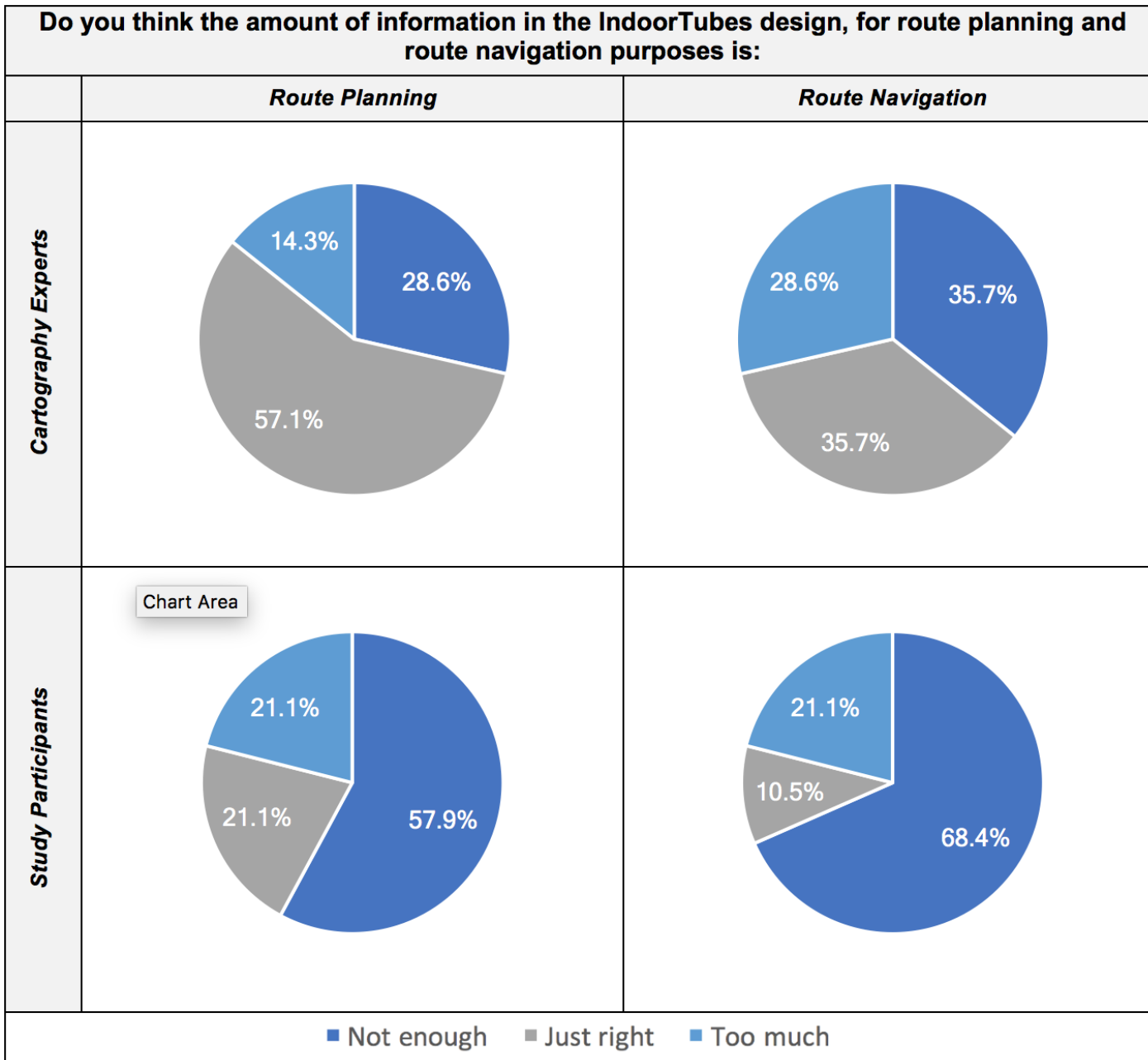


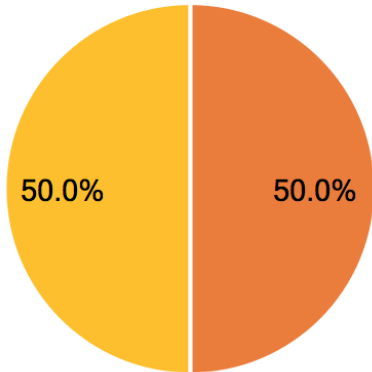
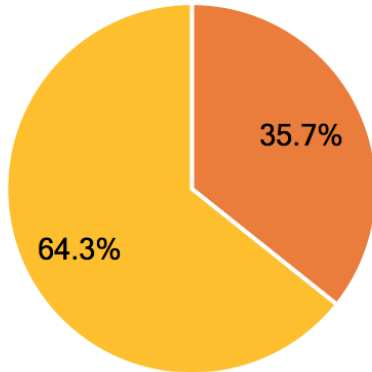
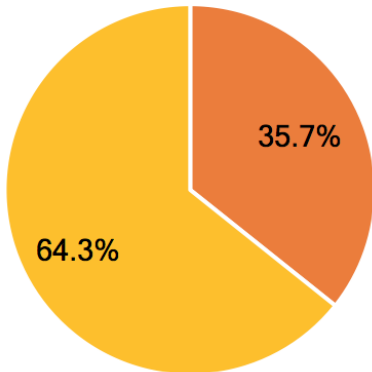
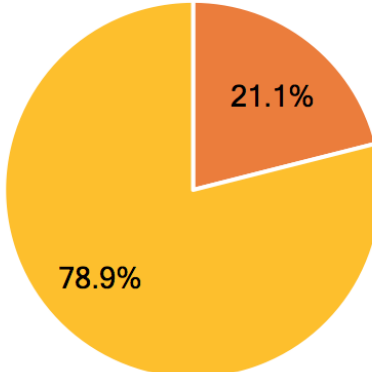
	Cartography Experts				Study Participants			
	Route planning		Route navigation		Route planning		Route navigation	
<i>In your opinion, which map design is better for route planning and navigation?</i>								
	Replies	%	Replies	%	Replies	%	Replies	%
Campus Navigator	4	28,6	6	42,9	5	26,3	8	42,1
Proposed design	8	57,1	7	50,0	13	68,4	11	57,9
IndoorTubes	2	14,3	1	7,1	1	5,3	0	0,0
<i>Do you think the amount of information in the Campus Navigator design for route planning and route navigation purposes is:</i>								
Not enough	1	7,1	1	7,1	0	0,0	0	0,0
Just right	1	7,1	4	28,6	5	26,3	9	47,4
Too much	12	85,7	9	64,3	14	73,7	10	52,6
<i>Do you think the amount of information in the Proposed design for route planning and route navigation purposes is:</i>								
Not enough	5	35,7	6	42,9	4	21,1	5	26,3
Just right	9	64,3	8	57,1	15	78,9	14	73,7
Too much	0	0,0	0	0,0	0	0,0	0	0,0
<i>Do you think the amount of information in the IndoorTubes design for route planning and route navigation purposes is:</i>								
Not enough	4	28,6	5	35,7	11	57,9	13	68,4
Just right	8	57,1	5	35,7	4	21,1	2	10,5
Too much	2	14,3	4	28,6	4	21,1	4	21,1
<i>In your opinion, depicting multiple floors in the same view of an indoor map assists or complicates route planning and route navigation?</i>								
Assists	7	50,0	5	35,7	6	31,6	4	21,1
Complicates	7	50,0	9	64,3	13	68,4	15	78,9

In your opinion, which map design is better for route planning and navigation?																		
	Route Planning	Route Navigation																
Cartography Experts	 <table><tr><th>Map Design</th><th>Percentage</th></tr><tr><td>Proposed design</td><td>57.1%</td></tr><tr><td>Campus Navigator</td><td>28.6%</td></tr><tr><td>IndoorTubes</td><td>14.3%</td></tr></table>	Map Design	Percentage	Proposed design	57.1%	Campus Navigator	28.6%	IndoorTubes	14.3%	 <table><tr><th>Map Design</th><th>Percentage</th></tr><tr><td>Proposed design</td><td>50.0%</td></tr><tr><td>Campus Navigator</td><td>42.9%</td></tr><tr><td>IndoorTubes</td><td>7.1%</td></tr></table>	Map Design	Percentage	Proposed design	50.0%	Campus Navigator	42.9%	IndoorTubes	7.1%
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Do you think the amount of information in the Campus Navigator design, for route planning and route navigation purposes is:																		
	Route Planning	Route Navigation																
Cartography Experts	 <table><tr><th>Response</th><th>Percentage</th></tr><tr><td>Not enough</td><td>7.1%</td></tr><tr><td>Just right</td><td>7.1%</td></tr><tr><td>Too much</td><td>85.7%</td></tr></table>	Response	Percentage	Not enough	7.1%	Just right	7.1%	Too much	85.7%	 <table><tr><th>Response</th><th>Percentage</th></tr><tr><td>Not enough</td><td>7.1%</td></tr><tr><td>Just right</td><td>28.6%</td></tr><tr><td>Too much</td><td>64.3%</td></tr></table>	Response	Percentage	Not enough	7.1%	Just right	28.6%	Too much	64.3%
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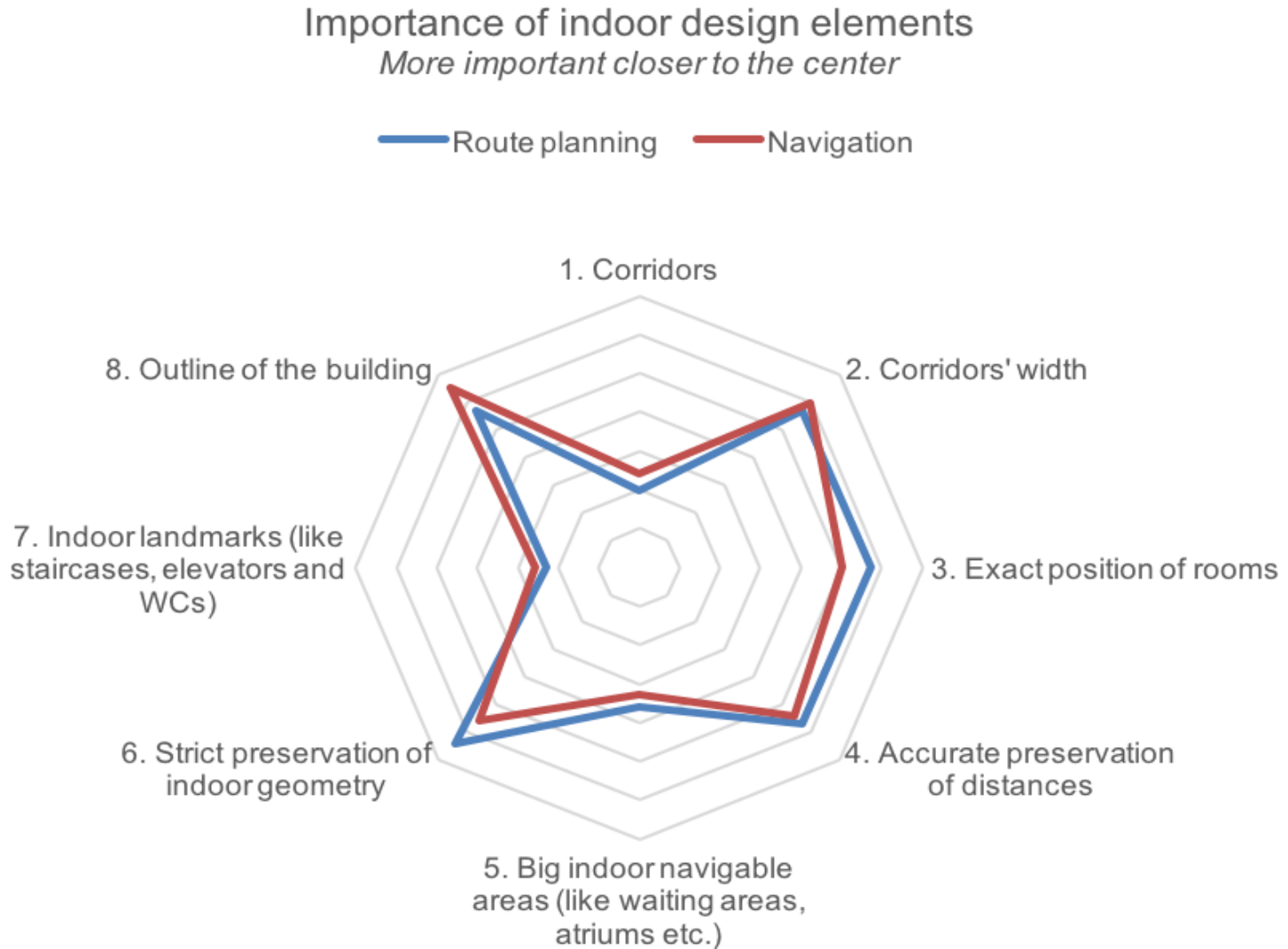


In your opinion, depicting multiple floors in the same view of an indoor map assists or complicates route planning and route navigation?														
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<div><div></div> Assists<div></div> Complicates</div>														

4.3 User surveys' results

Average importance of building elements				
On a scale of 1 (very important) to 5 (not important)	Cartography Experts		Study Participants	
	Planning	Navigation	Planning	Navigation
1. Corridors	1,00	1,21	1,16	1,11
2. Corridors' width	2,86	3,00	3,53	3,37
3. Exact position of rooms	2,86	2,50	2,05	1,95
4. Accurate preservation of distances	2,86	2,71	2,79	2,58
5. Big indoor navigable areas (waiting areas, atriums etc.)	1,79	1,64	1,74	1,95
6. Strict preservation of indoor geometry	3,21	2,79	2,79	2,79
7. Indoor landmarks (like staircases, elevators and WCs)	1,14	1,29	1,37	1,32
8. Outline of the building	2,86	3,29	3,11	3,05

Cartography experts

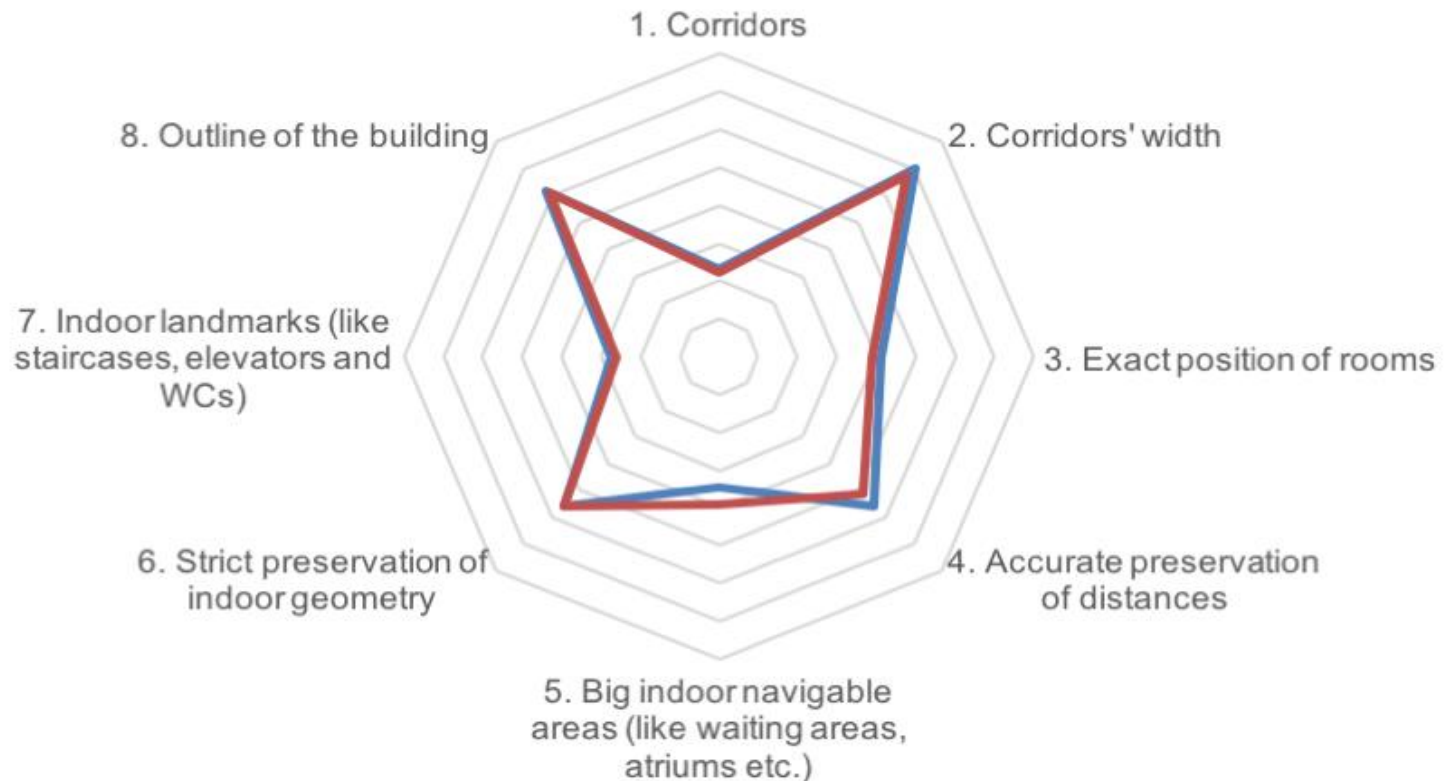


User study participants

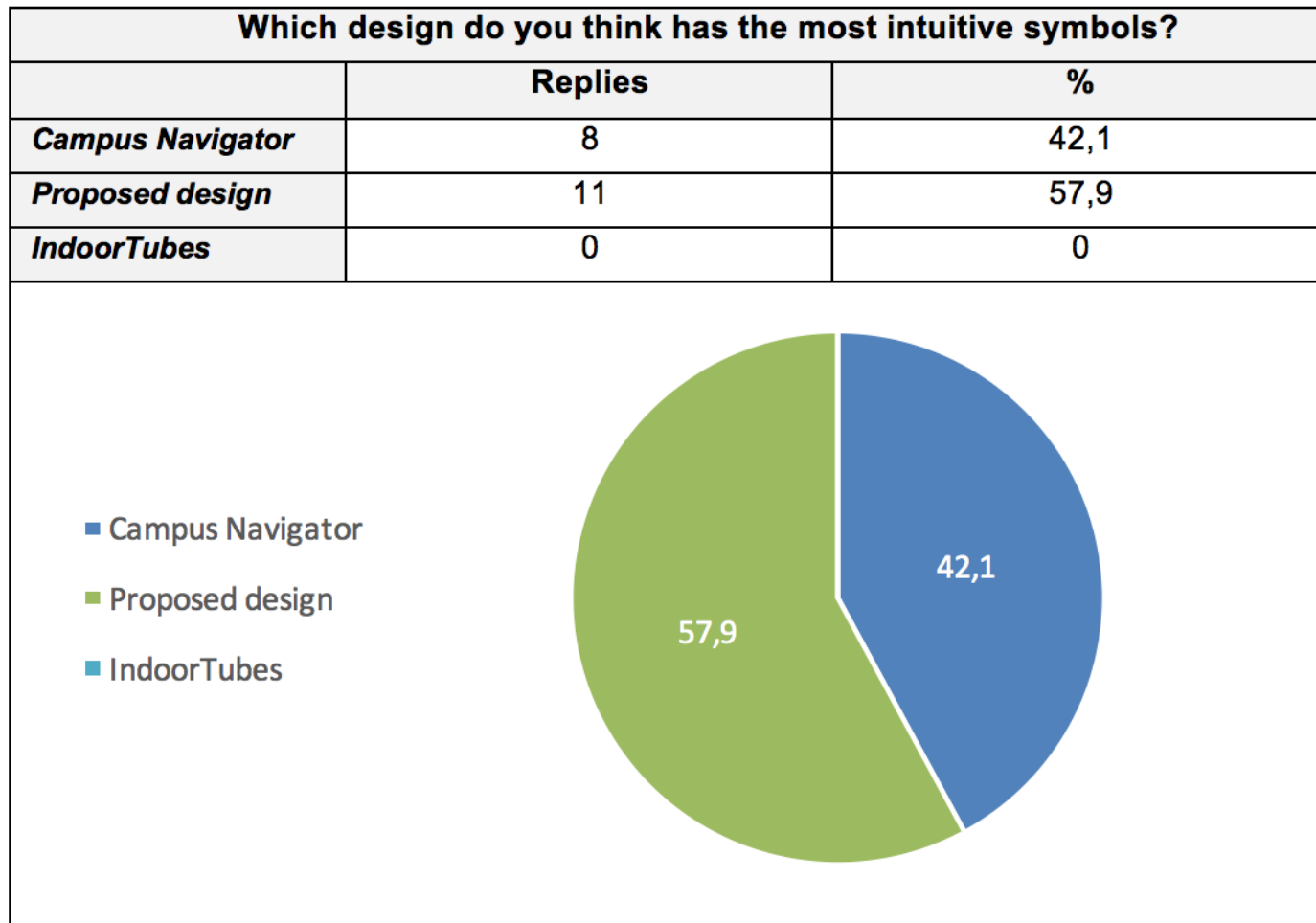
Importance of indoor design elements

More important closer to the center

— Route planning — Navigation



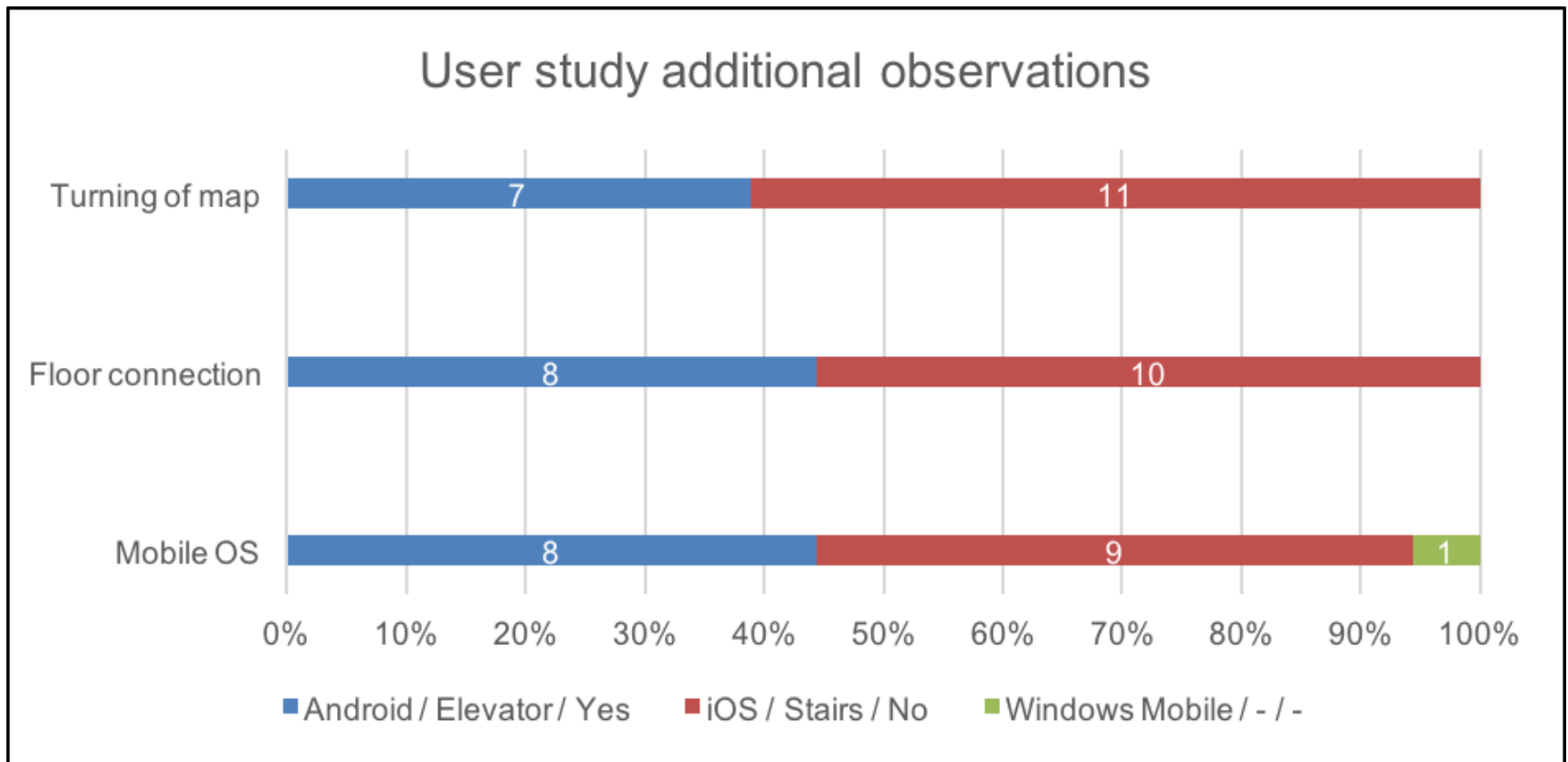
4.3 User surveys' results



4.4 Additional observations

- Additional findings
- Do not directly answer the research questions
- Still relevant and interesting

4.4 Additional observations



4.4 Additional observations

When you visit an unfamiliar big indoor space, how do you find your way (you can choose more than one)?					
	Replies		%		
<i>Use big, wall-mounted indoor maps</i>	19		86,4		
<i>Use signs and number plates on doors</i>	17		77,3		
<i>Use mobile phone applications</i>	3		13,6		
<i>Other (e.g. asking people)</i>	5		22,7		
Usage frequency per map type					
	Daily	Weekly	Monthly	Yearly	Never
<i>How often do you use maps (of any kind)?</i>	15 (68,2%)	7 (31,8%)	0	0	0
<i>How often do you use Indoor maps?</i>	1 (4,5%)	4 (18,2%)	10 (45,5%)	5 (22,7%)	2 (9,1%)

4.4 Additional observations

User experience with current commercial solutions				
	Yes		No	
	Replies	%	Replies	%
<i>Do you have experience using popular mobile map applications like: Google Maps, Here WeGo, Apple Maps etc.</i>	22	100,0	0	0
<i>Do you know that the above-mentioned commercial applications include indoor maps for select buildings?</i>	9	40,9	13	59,1
<i>If yes, have you ever used the indoor functionality of these commercial applications?</i>	3	33,3	6	66,6
Which mobile map application do you most often use?				
	Replies		%	
Google Maps	19		86,4	
Other	3		13,6	

5. Conclusions and future suggestions

5.1 Conclusion

The proposed design performed better in both:

- indoor route planning
- indoor navigation

and can be suggested as a better solution for indoor maps.

5.2 Proposed indoor map design guidelines

- Use colors to distinguish the corridors from the rest of the design and to highlight rooms of different functionality and floor connections
- The total number of colors should be relatively small
- Focus primarily on the corridors and try to preserve most of their geometry since they are the single most important element of a building when it comes to wayfinding

5.2 Proposed indoor map design guidelines

- Include big indoor areas (like atriums etc.) since they function as a kind of indoor landmark and help users orient themselves and check where they are on the map
- Include other important indoor landmarks like elevators, staircases and WCs. Apart from being useful, their location assists users in wayfinding and orientation
- Preserve the overall geometry and relative distances between the different building elements as much as possible

5.2 Proposed indoor map design guidelines

- Do not include rooms and the building's outline
- Use self-explanatory symbols and make sure their design fits the overall design language you are using
- Make symbols as simple as possible, but avoid abstract ones

5.3 Future suggestions

- Compare proposed design with simplified blueprints, since they are the most popular form of indoor maps
- Research how interactivity can affect the indoor wayfinding experience
- Create and test a solution with dynamic maps that change in style and abstraction level based on zoom level or building type
- Research ways to automate indoor map creation from architectural plans

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