# INDOOR NAVIGATION IN HOSPITALS

INTERACTION DESIGN PROJECT II
IN II - 90

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# Approval Sheet

The project titled 'Indoor Navigation in hospitals' by Labeeba K, is approved for partial fulfillment of the requirement for the degree of 'Master of Design' in Interaction Design.

Guide

Chairperson

Internal Examiner

External Examiner

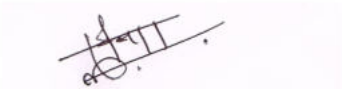
Date 18/07/2016

# Declaration

I declare that this written document represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources.

I also declare that I have adhered to all principles of academic honesty and integrity and have not misinterpreted or fabricated or falsified any idea/data/fact/source in my submission.

I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.



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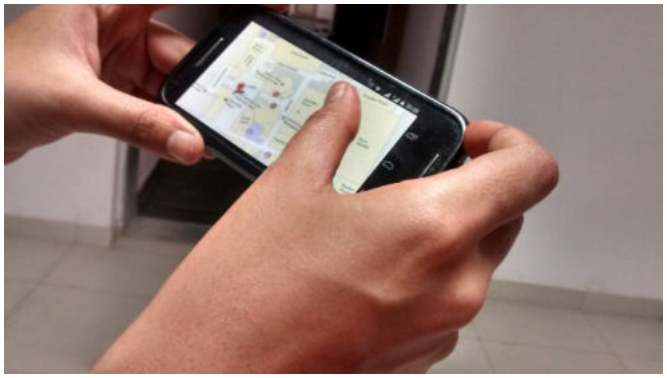
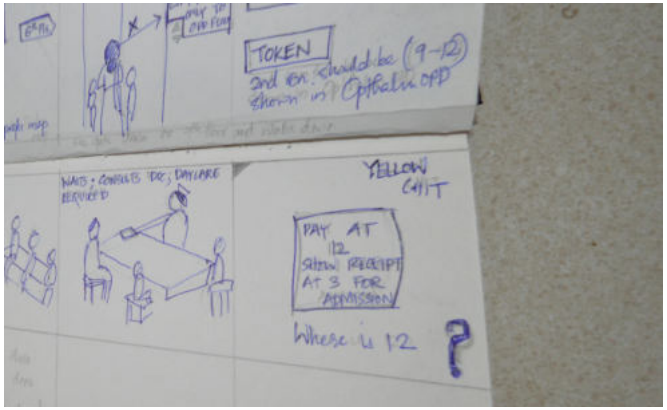
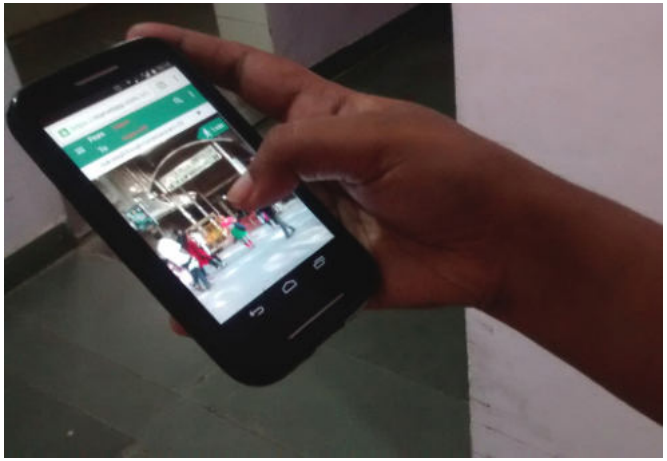




# Abstract

Public hospitals in India are a confusing maze even now for patients and bystanders during panic or not. The helpless patient being cared by the uninformed family member and bystanders running between queues is not a sight that can be missed at any public hospital in India. The lack of information, ineffective information and analysis and confusing layouts need to be accessed and catered to avoid the current situation.

With the advent of technology and smart gadgets, various solutions have been identified to technologically improve the navigation of people within hospitals mostly in abroad and even in India.

From studies in KEM Hospital and IMCH calicut, it was observed that, indoor spaces require a different set of navigation principles than outdoor spaces. Uncertainty in users to traverse between signage points without the required mental imagery and not knowing what to expect as destination reduces their confidence in signages. Even though asking around was observed as a well sought solution, users where not satisfied by the clarity of information conveyed by the office staff or the strangers. Common colloquial terms used within the hospital were unknown to certain users. A good experience depends on timely and effective communication to the fast and slow user and the reduction in confusion.

Photo and video based hand-held navigation application with emphasis on landmark data was found to be a easier and less complex solution for the target user. This concept was developed with further studies on how indoor landmark images can be used in navigation and what are the complexities in different indoor spaces.

The prototype created with these concepts was tested in comparison with the signage at KEM Hospital, Parel. Two sets of users are taken and one set was asked to follow the signage and other were instructed to reach the destination using the prototype.
It was found that even though both sets took relatively same time, users with the application seemed to be more confident of the route.This photo based navigation of the application definitely has an edge over other systems, when it comes to taking the right turns at junctions and identifying the correct floors and doctor rooms.

*Source : www.hospitalreview.com*

# Introduction

## Problem Context

In a [hospital] facility of some 800 beds, no less than 8,000 hours of professional time are lost in redirecting patients and visitors to their destinations. (Arthur and Passini, 1992)

Similar was my experience when I was doing a study for my bachelor thesis 'Redesign and redevelopment of Institute of maternal and child health, Calicut medical college. As I concentrated more on architecture and interior design, I couldn't go into details about the problems of way finding. This was the initial motivation for the topic and I would be able to put in my best of Bachelors in Architecture and studies from interaction design.

The advent of technology has not infiltrated the public hospital scenario in India much. Hospital information system digitizes all records and information. Signages are the mostly researched and designed way finding solution in India, with symbols replacing language and cognitive barriers. Interior design and giving character to spaces, colored guiding bands etc have also found place .Too often solution is assumed to be more signs. Signs will always be mainstay, but they should be supplemented or made effective. Display maps and zone plans of hospitals are used extensively with minimal results. Even though smart phones have penetrated even the lower sector of the society, hand-held navigation application applications have not found track yet, due to technical and functional issues in positioning and tracking movements.

Now talking about the terminology, usually we tend to talk about navigation and way finding as the same and use it regardless of its differences in all context. Hassan Karimi, a computer scientist in his book says that although these terms overlap semantically, there is an important but subtle difference between them, namely, that way finding involves finding routes between pairs of locations whereas navigation involves traveling and receiving continuous real-time guidance while on a chosen route.

If we look in the conceptual manner, then way finding and navigation in outdoor and indoor environments comprises of similar activities, but there are differences when looked from the physical elements in it and the functions they are used for. For example, the physical space (or environment) for pedestrian way finding and navigation outdoors generally

involves sidewalk networks consisting of sidewalk segments and intersections, regardless of the city or the neighborhood in which way finding and navigation activities are needed. This is different from the physical space (or environment) for way finding and navigation indoors, where building structures are not uniform (e.g., different floor plans for different floors of a building and single-story vs. multistory buildings).

One major difference in indoor and outdoor space regarding the physical elements is that ,it is possible to provide way finding and navigation to user moving outdoor through 2D map data but in buildings 3D map data should be provided as there is transition between floors. An example of difference with respect to functionality that Passini suggests is that that unlike way finding and navigation systems and services outdoors, which are predominantly based on GPS as the sole positioning sensor, there is no single positioning sensor suitable for navigation in all buildings. In short, way finding and navigation differences indoors pose unique challenges that are not present in way finding and navigation outdoors. (Karimi 2015, 9–25)

## Initial Objective

The initial objective was kept broad and was narrowed down in a later stage after the actual problems were identified.

Design to improve user experience while navigating through hospitals.

## Target User

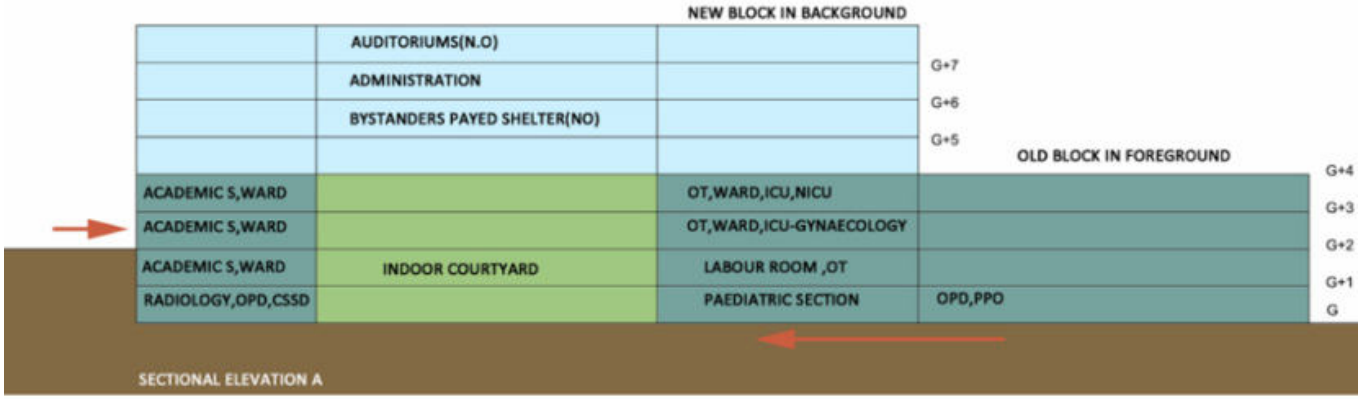
Patient : Patients who come alone to the O P and later might get admitted to the I P. Here the first time visitor patients are given more importance. In a city with a large migrant,student and working population, this situation is becoming common like in the western scenario.

Patient and bystander: The concept of bystander is so common in India that in public hospitals you can see bystander hostels for them to stay. The number of bystanders can range from 1 to 10 surprisingly.

During the study I have found an entire family of 7-9 members rushing into the EMS department with the patient and the authorities letting them in.

Visitor : New visitors who rush in to the IP section during the 4-6 visiting hours who can be distant relative or a colleague or a random person.

Other stakeholders involved are the hospital and the staff mainly the receptionists and security staff kept to guide the people to right direction. In both complexes i studied in KEM , there was a normal old man who was not a security or staff sitting in a chair in the entrance to the hospital guiding people towards the lift, warding of random people standing idle in the corridors etc.




*Multiple entrances at different levels and the number of stories of IMCH Hospital Calicut adds to the confusion in way finding.*
*Section through the courtyard and main entrances.*
*Source : Author*

## Design Process

Initially while looking at hospital as a whole ecosystem, navigation of all elements were considered, such as medicine, records, doctors, staff apart from patients and visitors. Later a deviation into navigation while emergency handling was looked into. But at the end of first stage scope was again redirected to indoor navigation of people in the entire hospital so that I can reach a executable solution.

### Scope and limitations

Design for indoor navigation starts from architectural planning to signages and applications. As my scope is to provide an interactive solution with minimum effect on the current infrastructure, i will not be considering the layout, interior design and signages existing in the scenario.

Initial pilot study was conducted in IMCH and Narayana Hospital in Bangalore

### User studies and Analysis

Primary studies were conducted to understand peoples navigation behavior, how people use existing solutions and conditions under which these have failed. Its concentrated on Indian context. Few problem scenarios where identified to cater to

### Prior Work

Study and literature review of work so far in the areas of indoor navigation and usage of 3d models and images for navigation. The modern solutions using augmented and virtual reality and various methods of localization were studied.

The initial objectives were restated at this point.

### Ideation and Final Design

5 ideas using different technologies were studied. Finally took up the simplest and comfortable idea for prototyping. As the idea called for more studies on how photos and videos can be effectively used for navigation, a brief study was done. A prototype using photos and videos as navigating clues were created.


# Primary research

User studies for the project was conducted in two parts. The initial study consisted mainly of interviews and a survey among a wide variety of users who have used hospitals in their life not particularly public hospitals. This was conducted in order to study the broader picture and scope down the project to a particular user segment and type of hospitals. The study didn't focus on navigation as the major problem and no particular user criteria was followed.

The second phase was more focused on factors that matter while first time patients and visitors orient, find and navigate within a selected public hospital. This mostly involved shadowing the users from their entry to them reaching the destination.

## User Criteria

The user criteria for the second phase of study : The users chosen for shadowing mostly were lesser educated bystanders and visitors coming first time to the hospital. Few were bystanders in the emergency department running for various errands send by the staff in order to study the difference in requirement of a urgent user. Apart from that 2 regular visitors were also studied.

In total, 10 people were shadowed. They were all in the age group of 35 and above, comprising of 4 women.2 of them comprised of family with 2-3 people.8 out of 10 had smart phones.

*Source : Author*

## Ecosystem - KEM Hospital, Parel

King Edward Memorial Hospital, Parel is one of the oldest and best public cum teaching hospitals in Mumbai with a strength of 2288 beds, 390 staff physicians and 550 resident doctors. Treats about 1.8 million out-patients and 85,000 in-patients annually.

Funded mainly by the Municipal Corporation of Greater Mumbai , these institutions render yeomen service – virtually free of cost .( KEM 2015 )

It has almost 48 departments in the medical college section. Like most other government medical college teaching hospitals, patients come from the surrounding places that comes in the hospital area and also as referrals from other low tier hospitals like district hospitals, public health centers. Emergency department takes all cases that comes in as casualty. During major emergencies and accidents also, KEM plays an important role in caring for the injured patients.

It is situated in the midst of many hospitals in the parel region which includes TATA memorial hospital, Wadia hospital for children etc. The hospital and the medical college buildings are in the same campus itself. The old complex of the hospital is made of stone and mortar in 1926 is still the major functional building element that accommodates most of the wards. Due to high demand for more space, the hospital has expanded in many directions for Emergency medicine department, new OP facilities, canteen, hostels etc.

Most of the OP facilities are situated in the multi-storied new complex build recently. But this complex is located very far from the main entrance with another small entrance to itself. The old block is designed in typical hospital ward layout with long wards parting from a central corridor.

The major navigations happening in the entire hospital is between main gate and OP Departments in new complex, between emergency department and old complex, between main gate to wards in old complex.


*1. The hospital complexes in Parel in and around KEM Hospital*
*Source : www.kem.edu*

*2. The new OP complex, KEM campus*
*Source : Author*


## Signage and way finding

Due to lower infrastructure and maintenance compared to the IP and OP intake, KEM lacks proper signage which are up to date with the current distribution of functions and expansions in the hospital complex.

Outdoor signage comprised of sign boards in english at very few junctions with the upcoming major buildings.

While old block somehow runs with the signage system designed by IDC, it is very low effective due to the lack of lighting in most places and changes and addition to the dilapidated infrastructure. The administrative block had very effective and new signages. To my surprise the new and redesigned complexes like emergency department and the new OP block lacked proper signage. The new building had a floor wise department chart in a corner in the ground floor, which can be surely missed. Rest of the signages in the entire block were lettered on walls and door frames in red paint. Important instructions were also displayed in the same manner and others as print outs on papers stuck to the wall.

*1. Signage in old block.*
*2.Signage and numbering at new block*
*3. Other awareness sign boardings are seen everywhere in the campus.*

The newly expanded emergency departments provided signages only in Marathi which was very difficult for me to comprehend.

But there were some speedy and effective decisions adopted out of necessity that helped the hospital to function. The use of number system for facilities turned out to be very effective solving some of these sign issues. Asking around was a major phenomenon and the hospital has sort of formalized it. There were security desks at prominent  locations which catered to the lost patients and visitors. And in both complexes there were random guards not in security or hospital clothes who gave answers to other peoples doubts. They were not part of the authority but, are more familiar to the place due to their long stay.

# Initial Insights

### Public hospitals

Public sector healthcare shall continue having its relevance for a long time in order to reach out healthcare to vast sections of under-served populations in developing countries like India. Even though many users considered public hospitals to have better doctors and facilities, they consider best to not go there for treatment due to apprehensions that some mistakes might happen in treatment. This might be due to the bad experiences people have in the hospitals due to service failures and infrastructure conditions.

### User experience

User experience in hospital navigation consists of 3 main factors as understood from interviews.

**Way finding**

**Service**

**Information**

Navigation is intertwined with experiences during service and while dealing with various informations. As catering to all these problems is not part of my scope, I decided to focus on technology interference in way finding and augmenting it with required information and service .

### User Behavior

Users were very unique when they deal with way finding based on their age, gender, literacy. Each user has his or her own level of knowing. First time visitor is totally confused. Few visitors who are aware of their ignorance do not want to know how to navigate , but they want an escort to their destination. Few who lack knowledge are too embarrassed to ask questions, so they will try to navigate on their own.

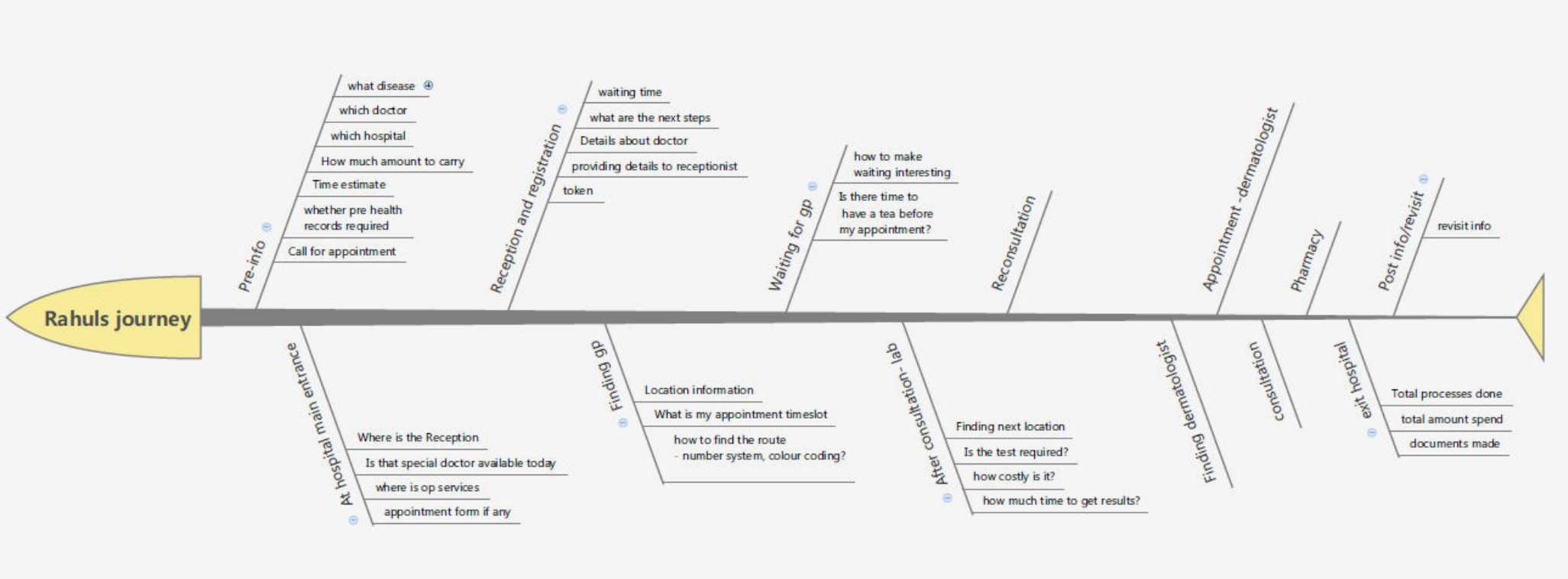
### User statements

I take one day leave when various illnesses are reported in the family. Hospital leave. As one whole day will be anyway lost roaming around it is better to treat me and my 2 kids together in the same day.

Lot of green yellow and blue chits. Who knows whether all these are actual costs.

Hand painted signages are difficult to understand at times.

I believe in what people like me give as instructions, hospital authorities might lie about the timings.




*User journey of a patient coming for checkup in OP in a public hospital.*

## User journey

Journey of a typical person who comes to the OP for treatment was studied and analyzed to come up with certain problem scenarios. I found that even though user experience is a service in the entire journey, indoor navigation can be broken down as a small process in this journey. Following steps are identified in navigating from one node to the next in the above diagram.

Knowing where he/she is

Knowing his/her destination

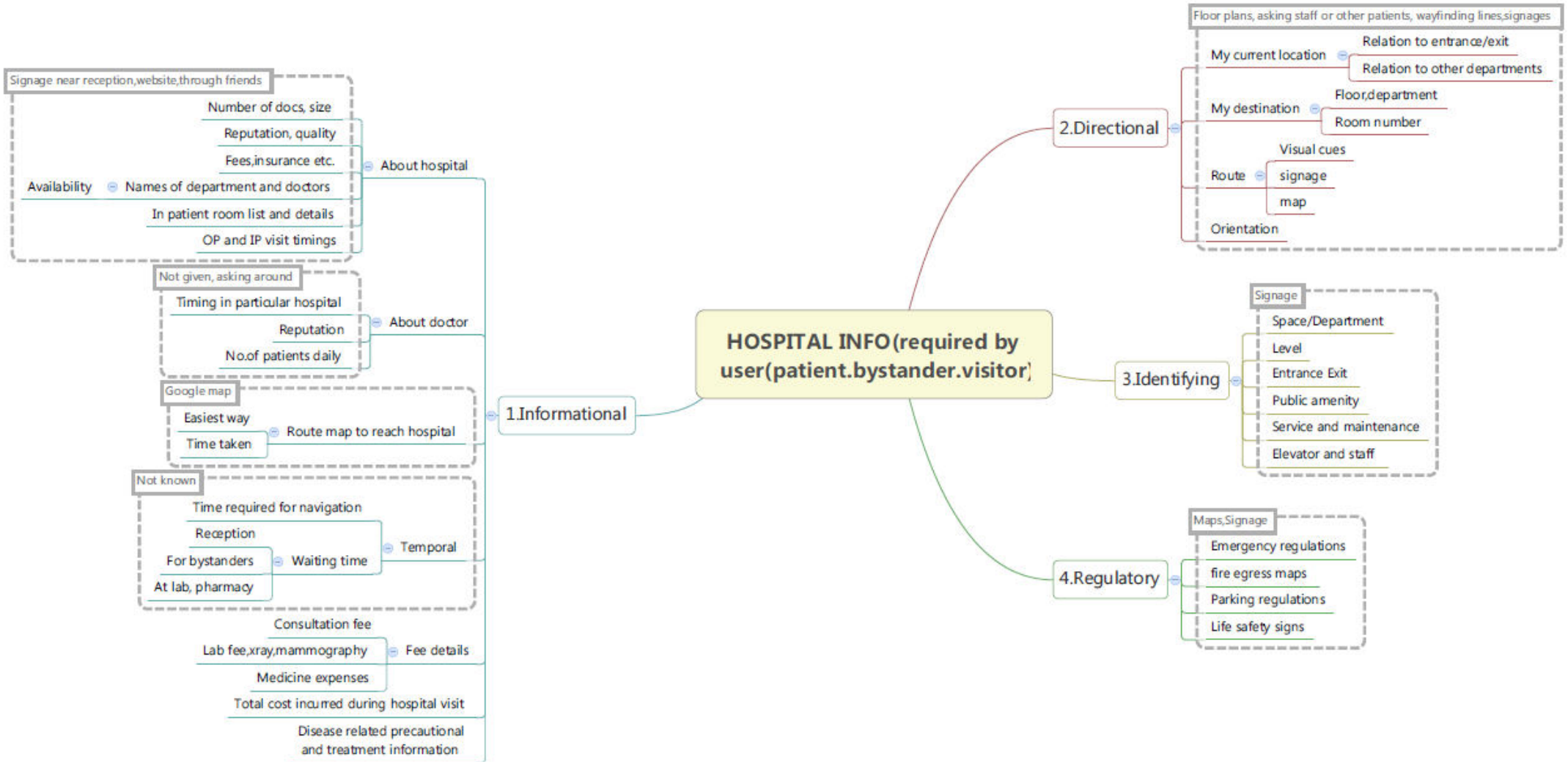
Knowing which route gets him/her to destination

Ability to follow route

Knowing when he/she has reached destination

If apart from catering to these 5 steps if one with a product can augment or improve other information services as well, then it can support a part of overall user experience.

From the study, I learn that getting timely information while navigating about the next step, can be a bonus for the user experience.




*Various kinds of information the user requires in various degrees while traversing through the hospitals*
*Source : Author*

## Information study

First, the existing information provided by a public hospital was jotted down and categorized into different categories, namely Directional, Identifying, Regulatory, Informational. Later, the information that the user actually required while using a hospital service were found and added to the mind map. Interview user statements were mainly about how the users didn't receive the required information at the right time or the wrong information. After this, the chart was compared to the current scenario in KEM hospital and whatever is lacking is marked out, so that those can be implemented in any future product.

For example, a user complained about how the doctors OP schedule got changed just before her reaching the hospital and how she had to wait till the afternoon.

## Findings

Following were the findings from shadowing users in KEM Parel.

### Way finding preference of users

Few visitors and patients who are aware that they are new to the place and do not know where to go actually did not want to know how to navigate, but they wanted to be escorted to their destination. Women mainly felt this way. Some of them were too embarrassed to ask questions and clear their doubts, and they try rigorously to study the maps and navigate on their own. These people seemed like they were not in an urgency and took more time. Few users can seemed to stare at the map kept outside, but didn't seem to infer anything out of it and preferred easier methods.

There was a reduction in magnitude of problems from first time patient to frequent visitor. While first time visitor need continuous support, frequent visitor needs recall of certain images from past to find the right route.

7 of the users I studied started navigating using intuition and signage, but later switched to asking others.

### Variety in choice of routes to the destination

In current scenario, there is no way to know the best routes based on patient requirements. They have to stand in a long queue to clarify their doubts and the receptionists do not have enough time to give them the right directions. For example, one patient did not prefer the usage of staircase due to medical reasons, but as they couldn't find the lift to the odd number of floors they had to take stairs to go one level up.

In urgent cases, most users preferred the fastest route, even if it they had to use staircases instead of lifts.

Hence, giving the user facility to choose most friendly path is an option.  Giving the users multiple option of routes like in Google map is good but might have a detrimental effect due to added confusion and cognitive load. One can see that in google map itself, we do not use this option very effectively. Small inputs from user regarding their preference and urgency can facilitate constructive input for example whether they need a wheelchair or they need to use stairs etc. While there is rush in the hospital during visiting hours, visitors can be channeled through a specific route without hindering other patient movement.

### Pace of navigation

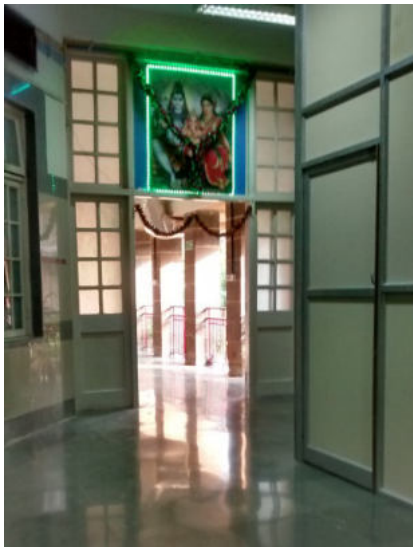
Many users complained of losing a lot of time in the hospital, especially those who were working. They are prompted to come on weekdays as some doctors are not available on weekends and there will be  huge crowd on weekends. Navigation in hospitals with specific visiting hours had rush then, thus reducing the users pace. Users wanted to know 'how long will it take' and 'when the wait will be over'.

Urgent users made more errors. They get irritated with minute details and tend to avoid them in signboards. Only very relaxed users preferred the maps and kiosks available, otherwise they were left unused. Hence design should cater for both fast and slow paced users

### Incongruity in directions and instructions given

This is the most evident issue found in both the hospitals. Maybe this is an issue for all large government hospitals. There are 2 manifestations for this problem. One related to instructions obtained when asked.

Users preferred asking around to confirm their directions. This is mostly to receptionists or security or to a person who looked like part of the authority. Women preferred asking women itself. But 2 users had bad experiences after following the route described by the security. One person told that



1. *A corridor without any character at IMCH Calicut*
2. *A destination with a temporary character at KEM*

the security mostly shows direction by action and thus he misinterpreted the action. Incidents during asking around in KEM, that created trouble. Assurance of the route reduced stress might be the reason for a lot of people preferring to ask other people. But, most users were not convinced with the inputs given.

According to a user the best directions are provided by other users who are familiar with the space not hospitalwalas, as they explained it in a visual language he understood. It seems the direction giver told picked certain elements from nature like cricket ground, badam tree etc that were relatable to the user and he told approx. how many minutes to the final destination. Activity based instructions are preferred as directions from staff.

One user pointed out that he asks multiple people and at all junctions because in the hurry, he usually forgets the entire directions given or feels that his decisions are not right. This might be because he has a low memory but people generally prefer progressively getting the information. As this system is followed in less stressful areas like airports and malls, it is a must in hospitals. Hospital signages usually do this by dividing the plan into meaningful blocks. In that signage guides the user only with the information necessary to get to the next decision-making point.

The second case where misinterpretation of information occurred was when the first time user and the old hospital staff were on different platforms regarding terms of spaces and equipments.

At reception and security Eg : Chit system
Signages. Eg.: lift signs

**Users mental model**

Mental model of the route in case of indoor spaces are not in the form of 2d maps or routes but as 3d experiences, distinctive landmarks, condition of the space around etc. People prefer faster reaching the destination over new, detailed or unpredictable information .

**Inadequacy to establish landmarks**

During interview, users remembered their experience as major junctions with distinct character. Lack of unique character for spaces lead to confusion in certain locations. Landmarks should be used as effective feedback systems

Complexity of the route is a major issue in hospital indoors especially, number and names of departments, floor change, lift. Change in floors and departments are major areas of disorientation. Special measures to enforce these changes on the user so that it is retained in his memory.

# Secondary Research

A secondary study was done in various aspects related to 'Indoor navigation in public hospitals' and prior research work happening in this field is documented. It can be summarized into the following headings.

Public healthcare scenario in India

Navigation and healthcare

Way finding and design thinking

Current trends in indoor navigation

- Comprehensive interior design for navigation
- Future of way finding
- Beacons (i beacon and qualcomm)
- Ultrasonic waves, RFID, wireless network
- Startups (Bespoon, Sensus labs)
- Dead reckoning
- Continuous localization & sparse localization
- Augmented reality and mixed reality solutions
- Google indoors

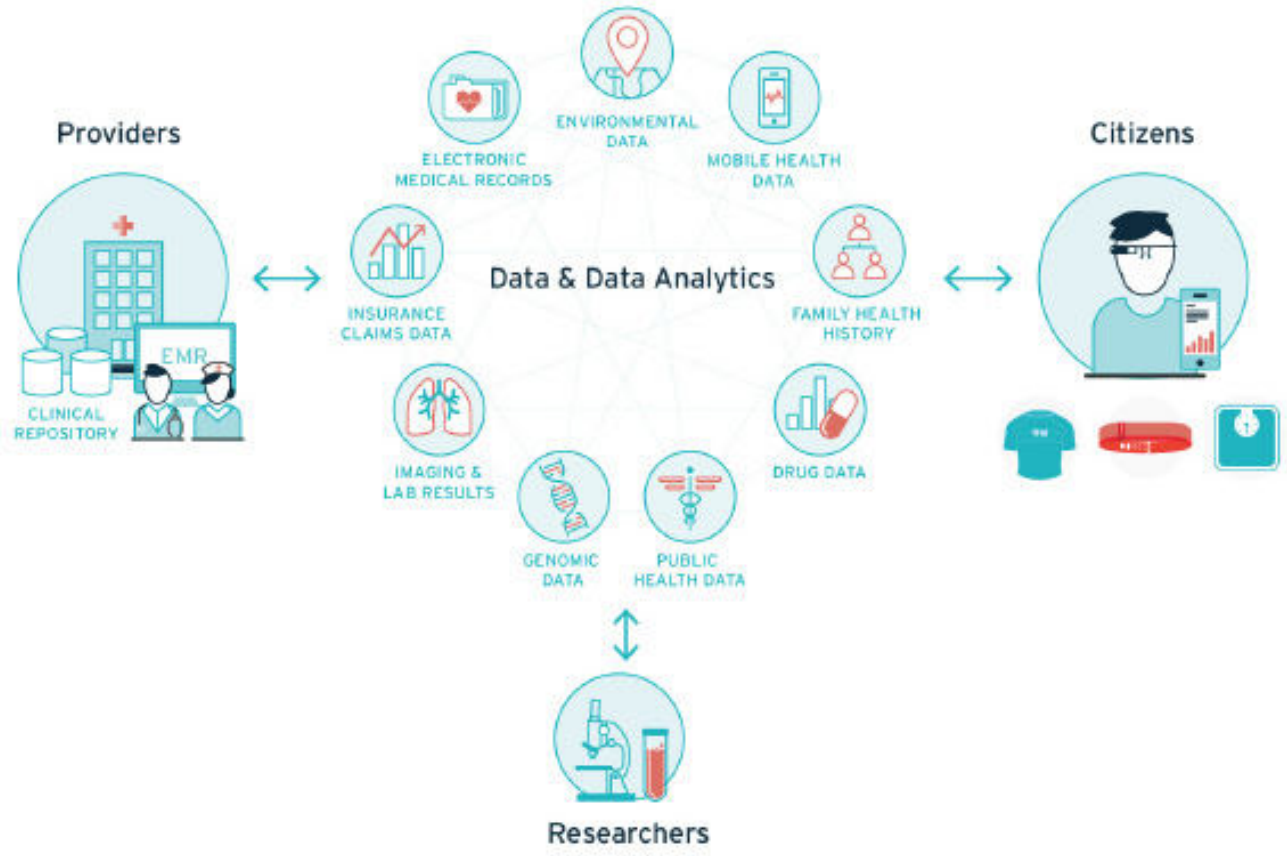
Current researches in the field

## Public healthcare scenario in India

" The healthcare ecosystem in India is at an inflection point. While the outlook for the healthcare industry is optimistic, there is a need to move towards an integrated healthcare delivery system, which leverages technology and has the patient at its center " says Nilaya Varma, Partner, Health & Public Services of accenture. ( e-health, 2015)

The Indian healthcare industry is all set to grow to over USD 280 billion by 2020, which is a growth of over ten times from 2005. Out-of-pocket spending remains the mainstay of healthcare expenditure.

With advent of information technology, a propaganda called the connected health ecosystem have emerged. This approach to healthcare delivery leverages the systematic application of healthcare information technology to facilitate the accessing and sharing of information, as well as to allow subsequent analysis of health data across systems. The idea of connected health is to connect all parts of a healthcare delivery system, seamlessly, through inter-operable health information processes and technologies so whole health information critical is available to all stakeholders. This is where indoor navigation systems can become integral part of hospitals.




*The connected healthcare ecosystem*
*Source : MaRS Market Intelligence 2014, e-Health, 2015*

# Way finding and Patient wellbeing


*Source : LH signs*

Healthcare environments are complex places with multiple processes. Patients and caregivers may need to go to several locations within a facility in a single visit.  Although way finding appears to be a simple  exercise, it is a complex activity with significant and measurable impact on users.

When Patients and caregivers arrive at a facility they are most often in a vulnerable state. Studies indicate that unclear signage can have an overwhelming impact on patients and further heighten their existing state of anxiety.

The relation between way finding and stress or anxiety was studied. He identifies the psychological and practical issues of spatial cognition, fear of death, noise/sound perception, boredom, dependency on others for life support, fear of abandonment, isolation, worries about family, job, money, staff access to patient, and hospitalization psychosis for male and female patients. Patients reaching hospital will have one or more of these symptoms. (Malkin, 1982)

According to Lawton, wayfinding anxiety is treated as a trait characteristic that depends on the wayfinding situation. The ability to maintain orientation in an environment varies between individuals. In one study, she examined way finding anxiety, gender, and cultural differences in American and Hungarian Universities. Participants were given a navigational task and a questionnaire to assess way finding strategies, way finding anxiety, and trait anxiety. Results of the study showed that men reported greater preference for a strategy of orienting using global reference points (i.e., North, South, East, West), whereas women reported greater preference for strategy based on route information (i.e., use of landmarks). As for anxiety, women reported higher levels of way finding anxiety than did men.(Paul, 2013)

# Prior research work

### Place Legibility and Way finding in general

Place Legibility talks about how people find their ways. Various studies are done based on collecting individuals' perceptions of distances, angles, and locations. An example for a typical experiment is the pairwise judgment of distance between points. Such experiments help in describing features of the cognitive map.

All studies on way finding in general starts with Kevin Lynch's The Image of the City (1960). He envisions to develop a method for the evaluation of city form based on the concept of image-ability, which is defined as the quality in a physical object which gives it a high probability of evoking a strong image to any given observer (Lynch, 1960).

Lynch identified and divided the contents of the city images into paths, edges, districts, nodes, and landmarks. These elements were described as the building blocks in the process of making firm, differentiated structures at the urban scale and have provided the basis for later research on 'place legibility' and way finding. For Lynch, urban environments are a complex system of interactions between people (users) and various surrounding objects. According to him users are "moving elements in the environment and in particular, the people and their activities are as important as the stationary physical parts." Hence indoor environments especially hospitals are a complex space which needs to be analyzed in this manner.

These thoughts can be applicable in Indoor scenario as well. Lynch described two things important for a subsequent explanation of the whole theory: first, physical elements of the city and second, the psychological, mental image of the city. Similarly, in interiors also there is physical and mental elements.

Through a study conducted by Weisman (1981) four classes of environmental variables are identified that influence way finding performance within built environments:

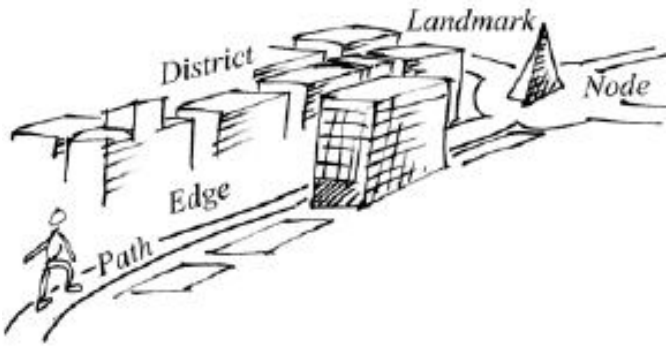
1. Visual access

2. The degree of architectural differentiation

3. The use of signs and room numbers to provide identification or directional information

4. Plan configuration

(Weisman, 1981)




He also found that asking people to estimate directions to indoor locations was greatly facilitated by visual access between locations but, after they had 4 or five tours around the location they didnot show any difference due to visibility

Along with Weisman's four classes of environmental variables, people's familiarity with the environment plays a major part in way finding performance: The number of times of using the space had a big facilitating effect in successfully navigating through an unfamiliar environment (Seidel 1982).

Studies or research on indoor navigation started almost 3 decades before now. It is important that in secondary research, one has to examine the cognitive aspect of indoor navigation.

Findings from the studies on prior work are described below. Spatial information acquired from maps are totally different from patient knowledge acquired from walking through indoor spaces. This was based on a study done by Thorndyke and Hayes Roth on comparing knowledge of large indoor space ( Rand corporation headquarters) as gained from maps or from navigation. From a map people acquire survey knowledge encoding global spatial and this resides in memory in images that can be scanned and measured like a physical map. Whereas from navigation they get procedural knowledge of routes connecting diverse locations. (Thorndyke and Hayes Roth, 1982)

Another surprising finding from a study done by Moeser is that in a complex indoor structure like a hospital, it is very difficult to learn from navigation. In a study student nurses found it difficult to sense any sort of survey knowledge of a 5 storied hospital even after 2 years of working at the hospital while , other new participants could. (Moeser, 1988)

Holscher et al. identified seven hot spots with navigational difficulty with an example of multi storied conference center. The hotspots he identified are entrance halls, survey places, floors, dead ends, interior building structures, public and private spaces, and stairways.

Looking at how individuals respond to cues upon leaving a subway station, Ishikawa and Yamazaki (2009) found that participants responded faster and more accurately to photographs that highlight subway exits rather than the same information presented on a map. Wang and Yan (2012) were able to implement an image-based app for indoor navigation based on this principle with an accuracy of 95% recognition by participants using the system. (Ishikawa and Yamazaki, 2009)

Color also had a major role in navigation. It helped a lot in recalling of locations through both navigation and pointing when the interior walls of a four-story building were painted with different wall colors. (Evans et al., 1980)

Recent work by Allen (1999) groups people's spatial abilities according to their function that is, to the tasks and situations in which they are applied. This classification is based on previous research in the psychometric, information-processing, developmental, and neuropsychology traditions. It consists of interactions between

1. A stationary observer and small manipulable objects.

2. An observer and moving objects.

3. A mobile observer and large stationary objects.

Although there are encounters with moving people and objects, way finding in a building is mainly concerned with the third group because people move through an environment that contains large immobile objects. The foundation for this group of spatial abilities is sensitivity to available perceptual information, visual, auditory, vestibular, or tactile. Examples are obstacle avoidance and path integration.(Paul, 2013)

As mentioned earlier cognitive abilities are crucial to way finding. Finding one's way in a city with entangled street networks uses a different set of cognitive abilities than navigating from one room to another in a hospital (Timpf, 2003). If people have weak spatial skills, they use verbal skills to navigate when they become lost, and they prefer asking around for assistance.

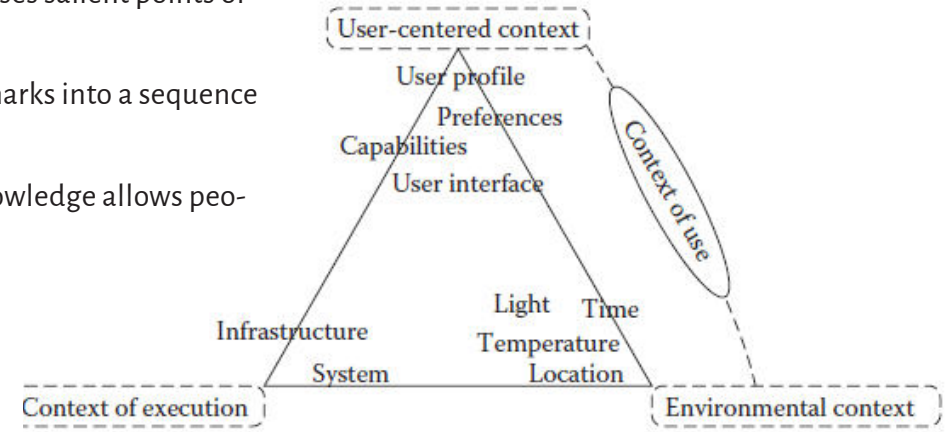
Human spatial knowledge of geographic space is assumed to develop in three successive stages (Siegel and White, 1975):

1. Landmark knowledge comprises salient points of reference in the environment,

2. Route knowledge puts landmarks into a sequence (e.g., navigation paths), and

3. Survey or configurational knowledge allows people to locate landmarks and routes within a general frame of reference

But in todays world, development of context aware, adaptive navigation be it autonomous robots or human travelers in new environment, is on the forefront of development. Figure shows that environmental cues, infrastructure issues and user preferences work together to bring a good navigation system.




*Classification of contextual dimensions for indoor navigation*

*Source : Karimi, 2015*

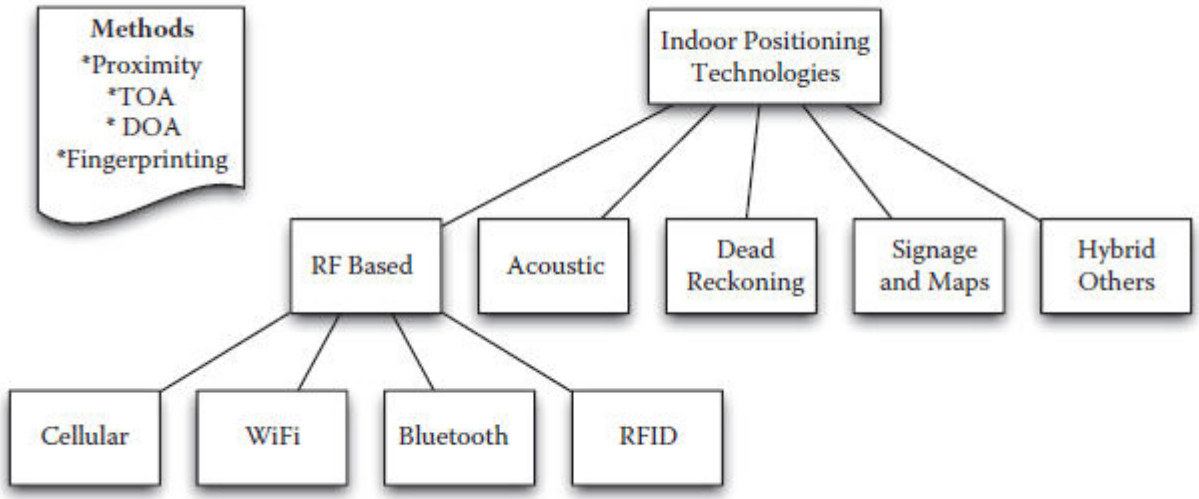



Figure shows some popular indoor positioning technologies and how they are classified. They can be classified into RF based and non RF based. In RF based, wi-fi is preferred as the technology of choice even though others are also used in many cases. Among non RF based technologies, acoustic based that use sound for localization are in the limelight. Dead reckoning and signages are the only choice in indoor spaces without proper infrastructure. (Karimi, 2015)

*Methods of Indoor positioning system*
*Source : Karimi, 2015*

# Current trends in Indoor Navigation

Signages are the most common media which hold way finding information, which are encoded, read and decoded by the person navigating a particular destination.

Some of the government hospitals like KEM, still uses the traditional method of hand painted signages. They are used indoor and outdoor  and can range for all functions like Identification, Directional, Orientation and regulatory. It is because they are the easiest, cheapest and instantaneous solution to lot of situations.

With availability of new modern materials, accessibility of  new techniques like laser cutting and fabrication, innovative and better way finding systems have emerged.

Colored lines on the floor form a continuous path to be followed by a person when he/she intends to go to desired destination. These lines are based on progressive disclosure method. Initially only a few colored bands will be there to reach the department. Once in the department, a single band diverges into other colors. The bands can be on the floor or on walls.


*Coloured directional bands on the floor for navigation.*

*Wall paints and wall papers give character to a space adding legibility.*


*Kiosk showing floorwise details in an hospital abroad.*

Floor mounted and electronically lit plates that will guide people. Similar kind of system was found in Kokilaben hospital in Mumbai too and worked very well for the users. This can additionally have some texture to help for way finding for visually impaired people.

Very huge and evident directional signs as part of the wallpaper itself

Self service kiosks have become very common in abroad and in Indian private hospitals. They are preferred because they require lesser maintenance. But they donot give users point of view in all locations.

Hand held applications are becoming very popular in malls, airports etc and also in hospitals with the advent of indoor positioning technology. For example, google indoors, Wifarer, navstar etc.

# Prior work on new solutions

Navigation instructions are formulated in terms of a series of user activities e.g., “walk 10 steps north” and then “walk 2 floors down”. Like in turn-by-turn navigation, the instructions are user-centric, and the results of a user study show that it is a viable solution to help users navigate in a building, in the absence of continuous localization. However, their solution is not robust against users’ deviations from the pre-defined path, due to the complete lack of localization.(Brush, 2010)

Different types of sensing infrastructure have been used as a basis for indoor localization. For example, the Cyberguide project uses an array of infrared beacons, the BAT system uses ultrasonic waves

## Photo based navigation

Anirudh joshi et al.,in their exploration of designing landmark based interface for less educated users developed a method were the user was directed towards his destination using series of photographs of landmarks along the route.(Joshi, 2012)

## AR based navigation

A novel design of an augmented reality interface to support indoor navigation combine activity-based instructions with sparse 3D localization at selected info points in the building. Based on localization accuracy and the users’ activities, such as walking or standing still, the interface adapts the visualization by changing the density and quality of information shown.(Mulloni, 2011)

## Conclusion

So, following areas are covered with the findings in the secondary study.

Factors are to be considered to reduce errors in navigation in complex environments like hospitals

Visual access

Individual spatial ability

Navigation aids

Mental maps users construct

Spatial learning

Reasoning strategy

Physical environment and structure of built space.

# Restated objectives

**Primary**

Provide confidence to the hospital users that they can reach their destination with minimum errors.

<Problems> Preconceived notions, uncertainty in manual instructions, Urgency, More areas of confusion, Non distinguishable landmarks.

**Secondary**

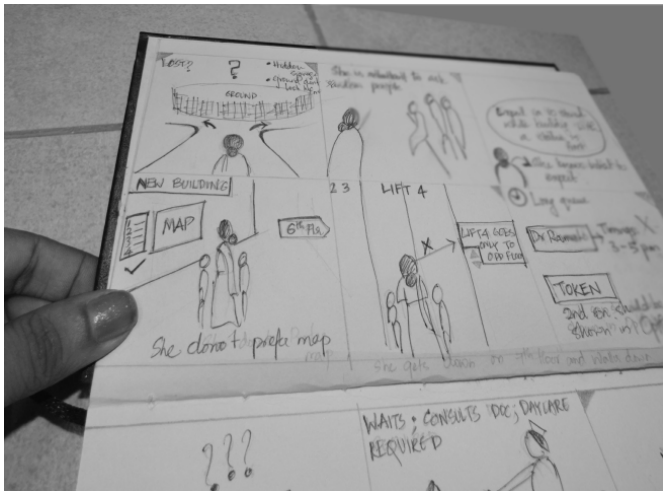
Reduce the complexity of system by giving adequate information and reducing number of processes if possible.

Integrating solution for first time visitor and frequent visitor / fast and slow visitor

Easy adaptation to the product

Low cost on infrastructure

# Ideation





Ideas were based on the formulated objectives and also had roots in some of the findings. Initially there was confusion that whether triangulating the current position of the user without intervention will be a problem and whether to go for complete localization or sparse localization. Hence ideas that had all levels of localization were studied.

Following were the parameters that lead to the following ideas

- Reduce complexity of current scenario
- Activity based instruction
- Ease of adaptation
- Progressive disclosure
- Error correction

While studying about users mental model, it was revealed that users connected to spaces with images, events and not paths. But there are instances where the user was not able to connect with any image due to lack of character of space. Whether to provide a continuous virtual view of the space or a broken view is to be decided.

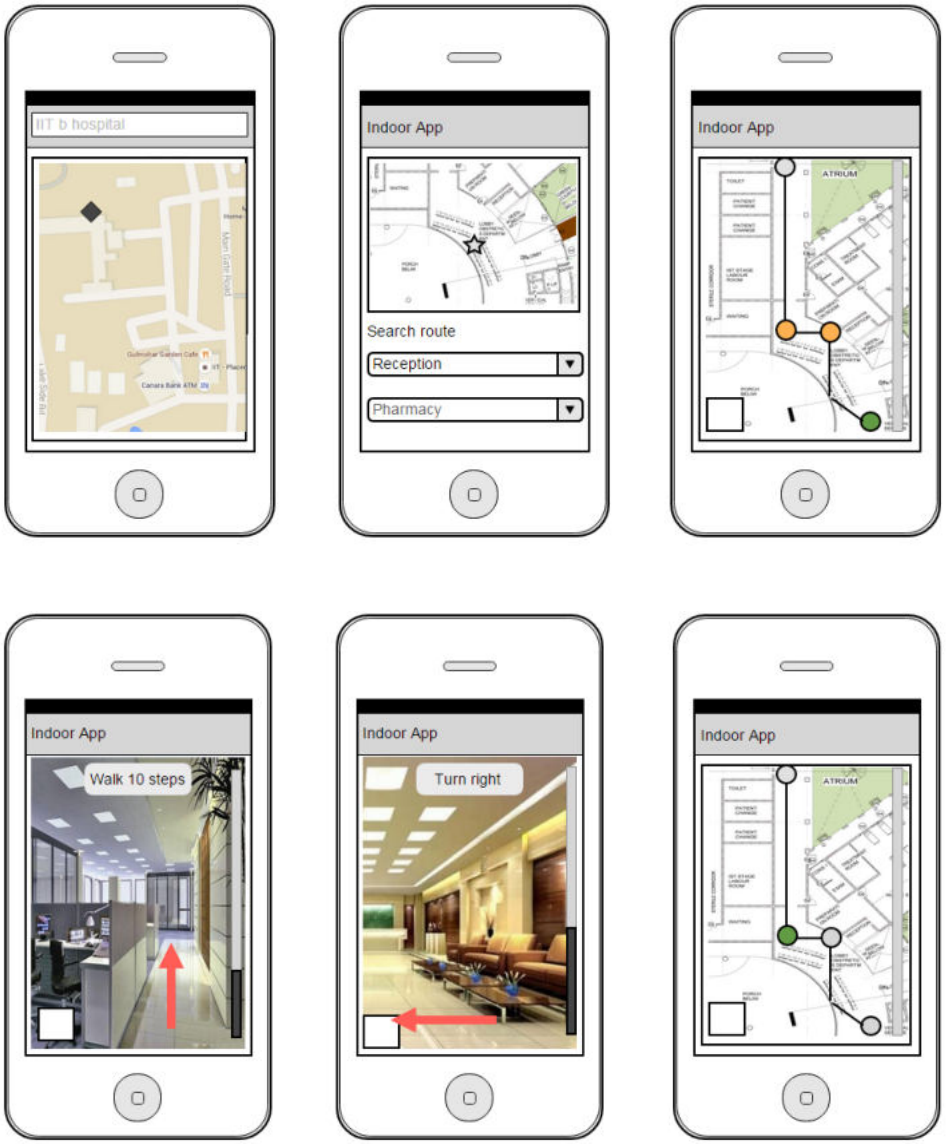
# Concept 1

In this concept, an existing map based application is augmented with indoor model view in real time but in a more simplified way reducing the complexities. In this continuous positioning and localization is used. The concept is similar to google indoors, but emphasis is shifted from floor plan to 3D.

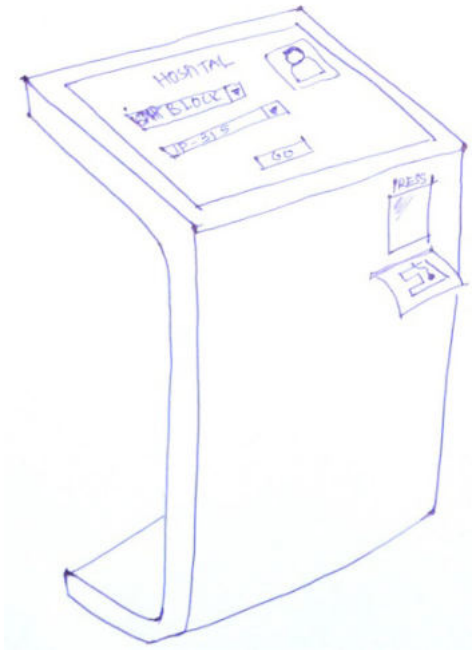
Indoor plan and model of any number of hospitals can be updated in the application. As infinite zoom levels and complex details will mislead the hospital user, only two zoom levels are used for the map. One is the entire map with the start and end point and other is more closer view with activity halt nodes visible. In this concept, infrastructure should be properly mapped for user positioning in all details.

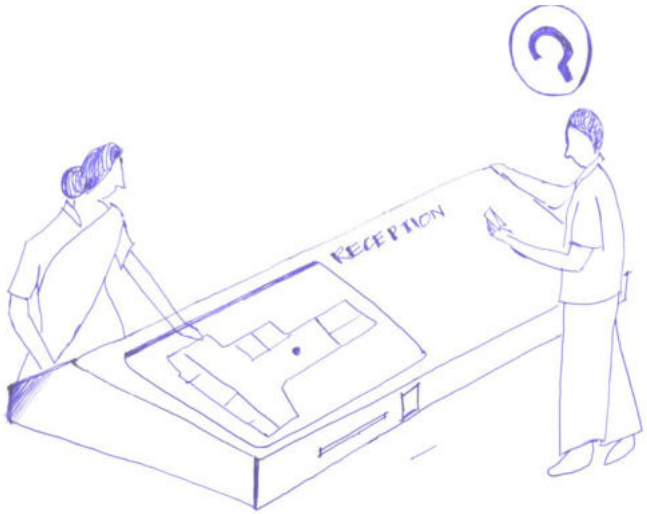
### Limitations

Whether this detail and accuracy is required in a hospital setup and will it lead to confusion was a feedback. And also the cost of setting up the virtual model and the beacons also forms issues.




*Starting from top left, various tasks with the two major navigation option are seen*




*1. Self service kiosk with personalised route print out option. The ID no/ card can activate the machine.*

*2. Receptionist equipped with a table mounted way finding kiosk to help patients.*

## Concept 2

This concept comes from the insight that certain locations in hospitals are prone to way finding confusion especially large open spaces, lobbies, junctions that deviate into 3-4 paths and entry to a new level.

Another scenario is when the busy receptionist glued to a place finding it difficult to direct the patients to a destination without any visual imagery to compare to.

So the solution is self service kiosks at landmarks with a set of services personalized to the user. In this case only sparse localization is required at the area were kiosk is installed.

**Limitations**

But various issues can be identified like the users prefer progressively getting instructions and pace of navigation is not considered here.

This solution is very effective to be augmented to a continuous solution in case of lost route.


*Starting from top left to right, screens for the kiosk showing activation, profile and navigation instructions*

## Concept 3

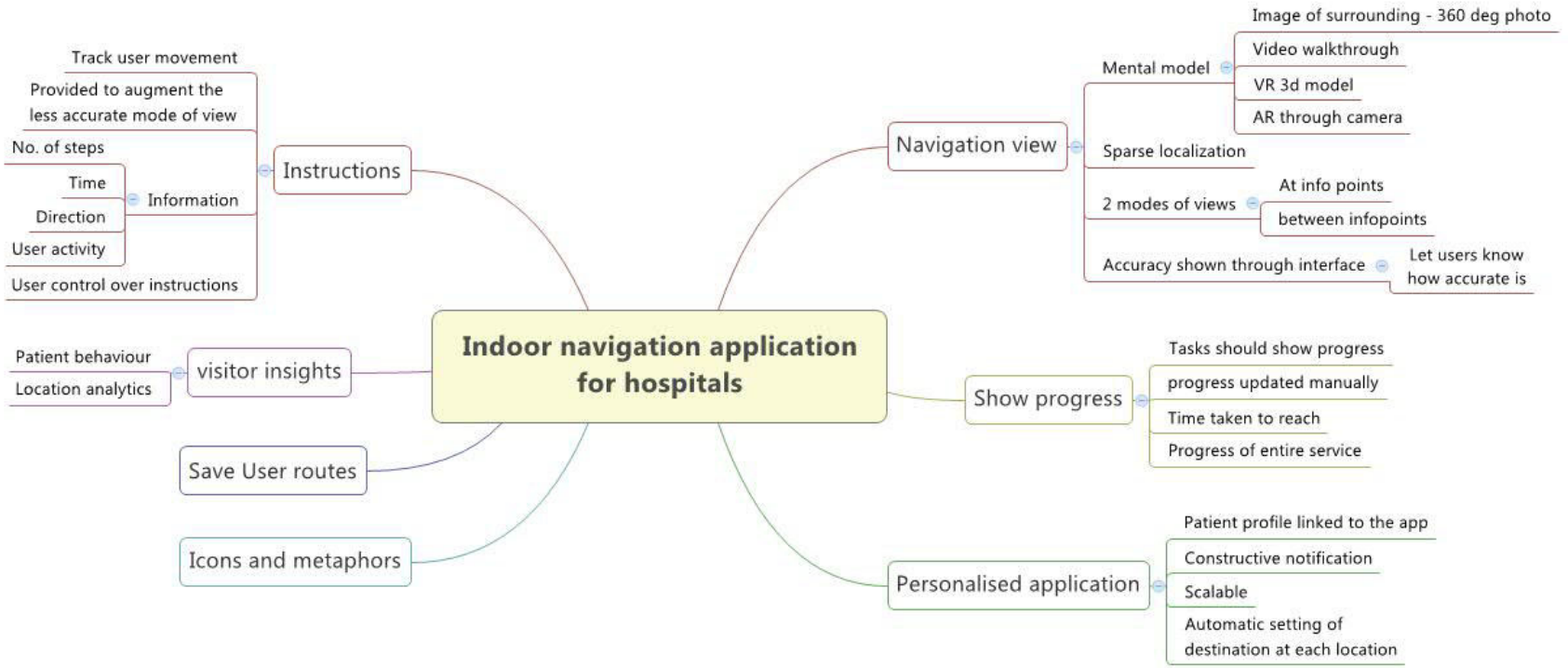
In order to sparsely localize the space augmented and virtual reality is used to provide the navigation interface. The concept here is to use augmented reality at specific landmark locations within the hospital to localize and instructions with virtual images in the remaining locations.

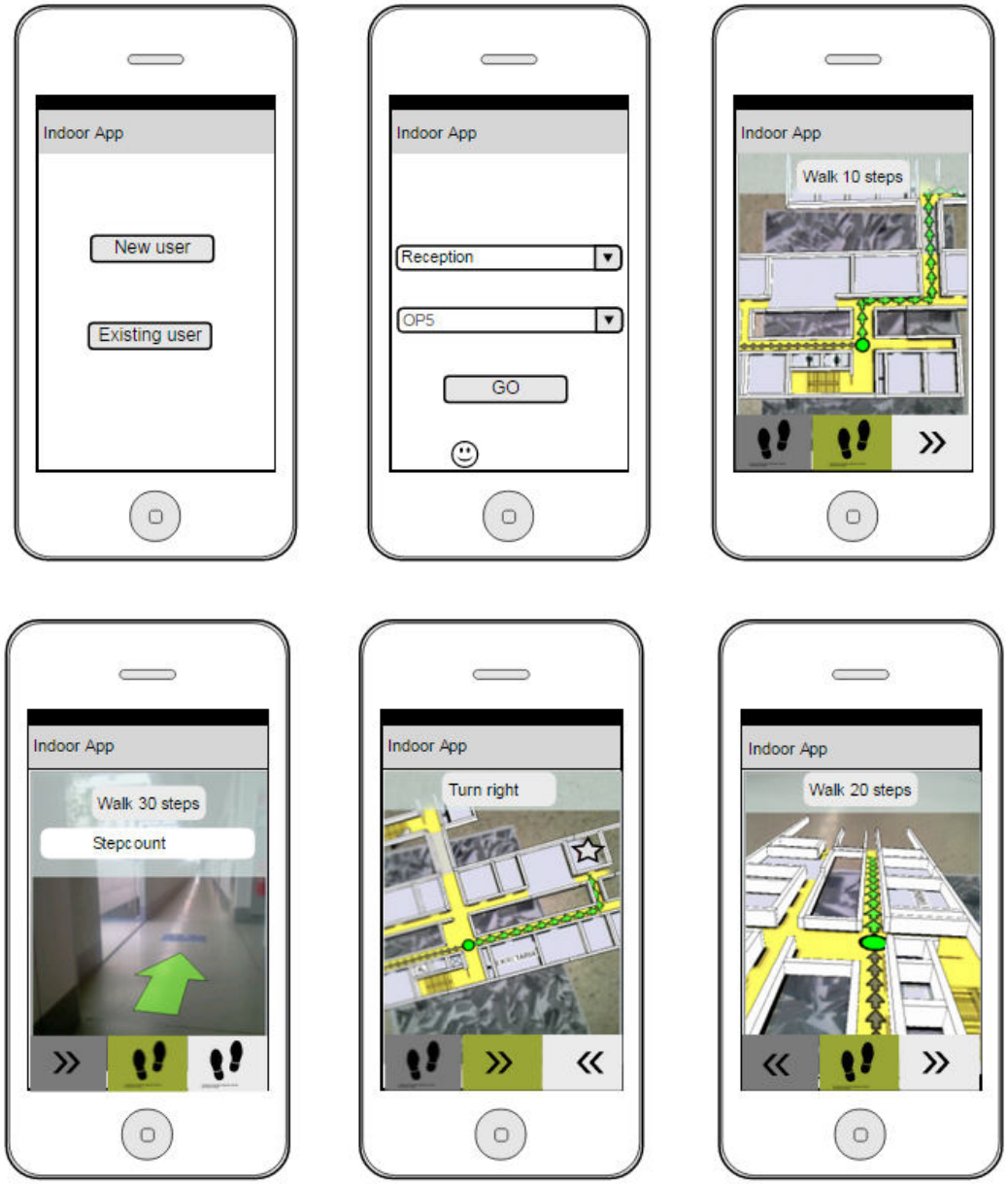
Firstly, major confusing junctions are identified as info points were information will be shared to the user through AR. Detailed route is available in the application at these info points through AR.

The idea is to outsource  work to the user while navigating between the info points by using vr or AR or 360 deg images.

This idea as it is interesting was explored in detail through research work done in this field.

*Mind map detailing main elements of this idea starting from various functions that can be provided if the application is made.*






*Starting from top left to bottom right, screens show idea in which activity based instructions are provided on top of augmented 3d model.*

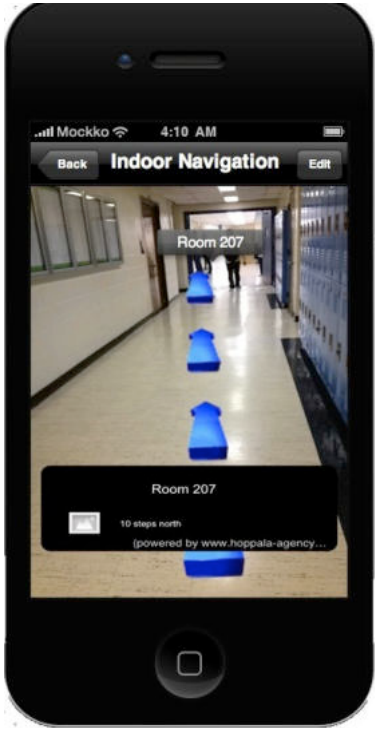
## Concept 4

Using augmented reality and instructions with continuous localization. Through this concept, the view through the phone's camera will be augmented with activity based instructions for user. But with a user segment who are trying to hide their ignorance and at a crowded location, this is very difficult to be practical.

## Concept 5

The final idea is one of the most feasible and commonly studied navigation idea which uses photos or a set of walk through images to navigate. First step is to prepare walkthroughs/set of images for prominent routes.

Initially, the idea was to go with the mixed reality concept for development. But finally owing to the ecosystem and the fact that there can may not be smooth flow in that case the much simpler concept 5 using images and videos have been selected.


*2 methods of mixed reality based applications in market.*
*1. V irtual reality based indoor navigation (G. Schroth/TUM)*
*2. Augment instruction on view through camera*

# Final Design

## Concept

Photo and Video based navigation system with junctions as guiding nodes and activity based instructions.

**Why?**

This idea was chosen above the others because it is very important that the common man adapt to the application. So one should start fr

Hence the product consists of a smart phone application for the patients and visitors  which has a back end where the authority uploads and updates the photos and videos at decided landmarks.The application also connect to the hospital information system.

## Design Development

The design decisions were made based on the studies done previously and connecting the dots from various ideations. (Fig)

From the primary studies, it was revealed that users need one to one attention, hence personalization was included in the design. From the literature study, it was understood that visual access, complexity of the mental model, elements in the landmark etc plays an important role for legibility of the location. Hence, while designing, importance was given mainly to the following aspects, that is the navigation interface, how well photos can portray the directions, personalization of the application, how to help users who are lost, how to provide notifications.

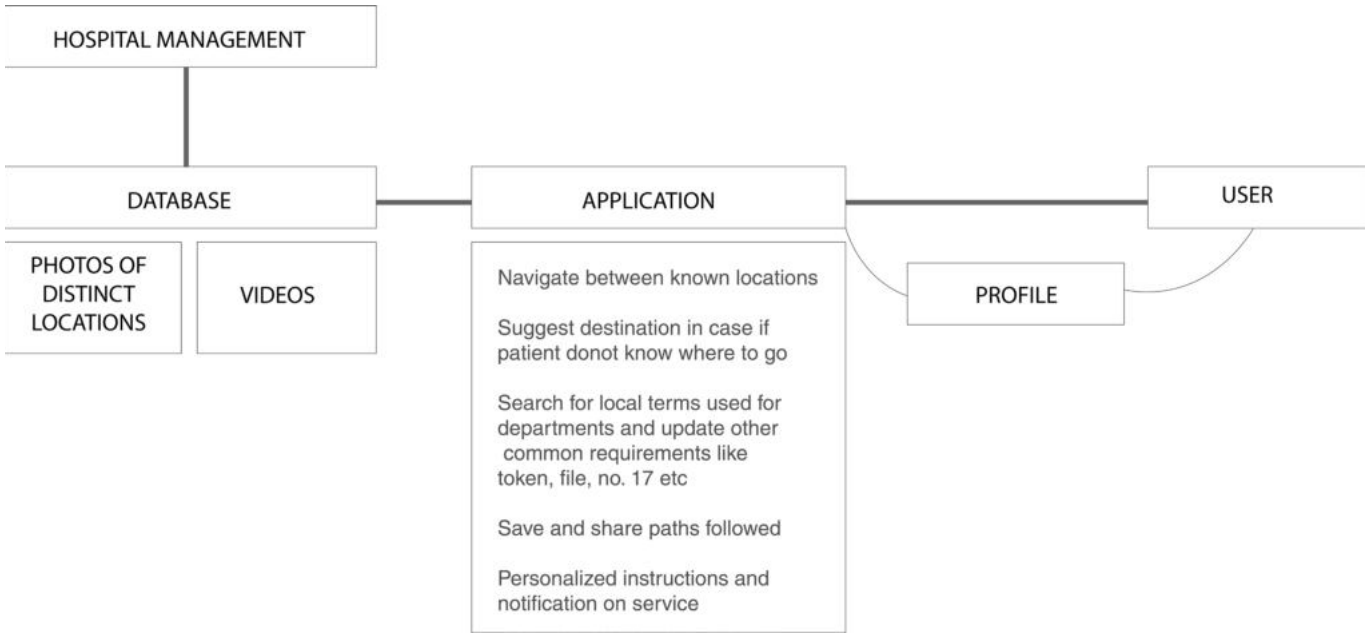
The wire framing was done in marvel app for demonstration and prototype was made using phone gap.

# Conceptual Model

The entire ecosystem comprises of three major elements - the hospital image database, the independent application and the user.

The user can access the application either by creating the profile or without doing so. There is added benefit of additional information, record keeping if a profile is created. User also can have a cash register at the end of the visit. And he can save the routes, so that it can be shared with a relative or stored for second visit.

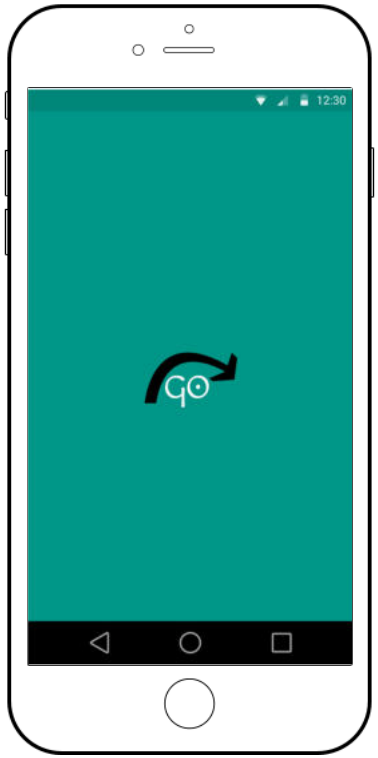
The application gets information regarding doctors timings, lab records etc from the hospital information system.

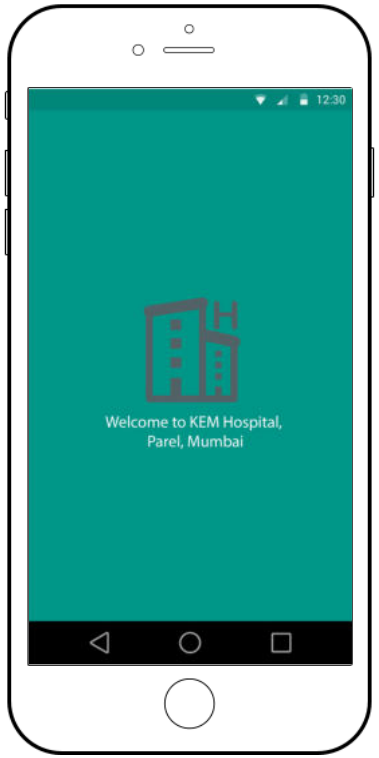


# Scenario 1

First time user receives the application at registration, creates profile, navigates between known locations.

## Initiating the app



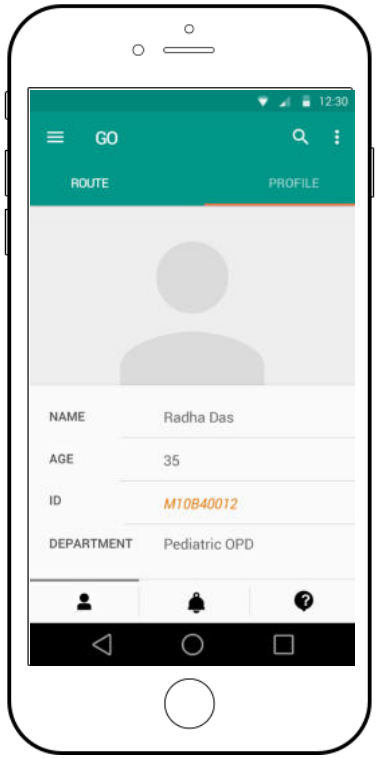

*Radha was registering for OP treatment at the reception when the receptionist says to please register into Go application which will be very helpful for navigating the hospital at difficult times.*

*Radha receives a message as she is registered and the app is installed. It takes her to the KEM home page.*

*She is directed to the hospital app. This application is solely for a particular hospital but can be replicated for other hospitals in similar fashion very easily.*

# Profile creation for new user



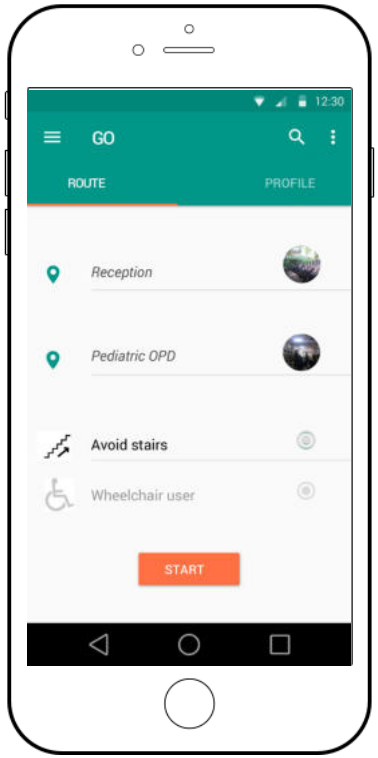



*As Radha is just registered, the profile page opens up and the ID is immediately updated from the database. If not she can also manually input the id/ name. If she donot wants to register and is in a hurry, then she would skip the step and directly move to the route tab.*

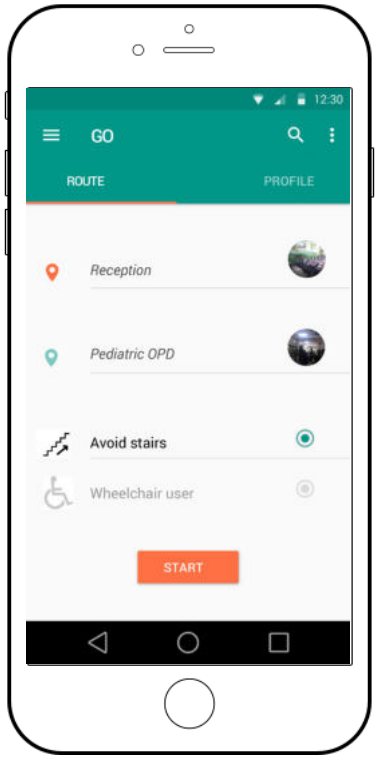
*She is directed to a unique profile page. The receptionist confirms her destination details and it is updated in the profile automatically. Within profile there is an option to see notifications about timings and help in case person is lost.*

# Finding the right route

## Method 1

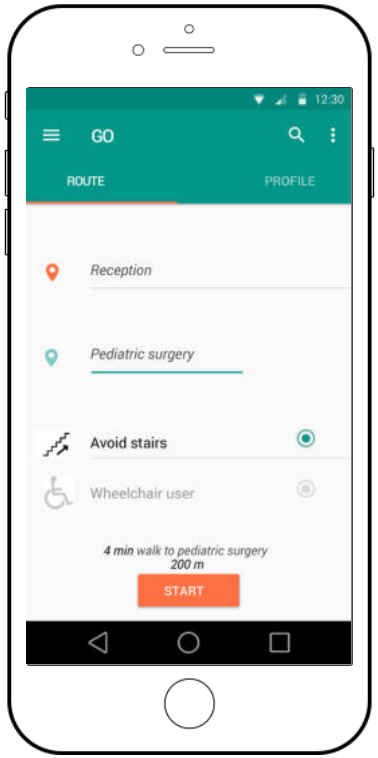



*As Radha is a registered user, her route details are updated. Otherwise beacons can be installed at limited locations, especially at reception, entrance and major departments to update the location information.*




*Within this interface, there are 2 parts. From and to locations and particular choices about stairs and wheelchairs.*

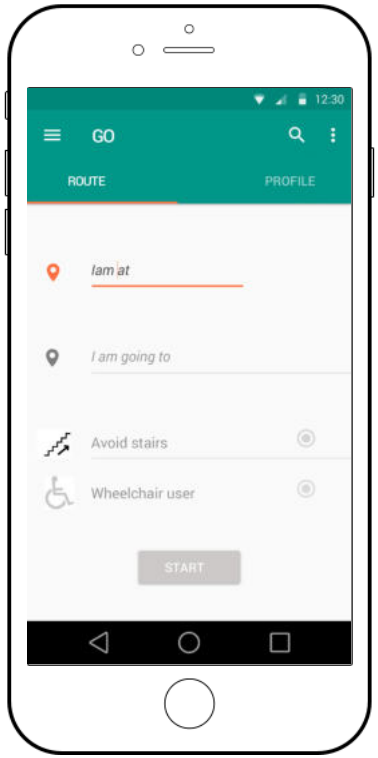
*Inorder to easily relate to the locations, images of the locations are provided along side as the user can expect hoe his end destination looks like.*

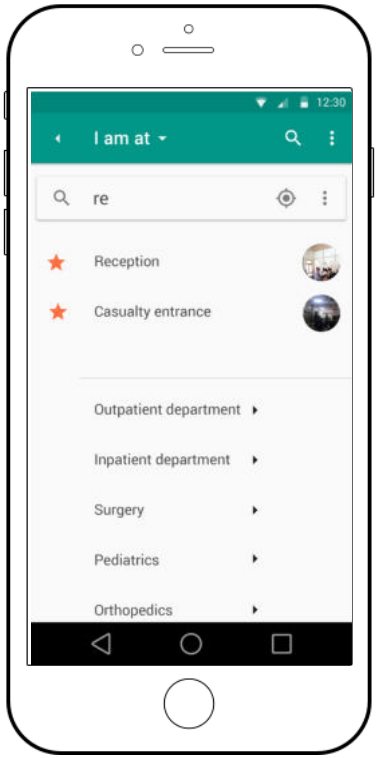



*Once the user select required choices, then a feedback is provided regarding the time and distance to the particular destination.*

# Finding the right route

## Method 2



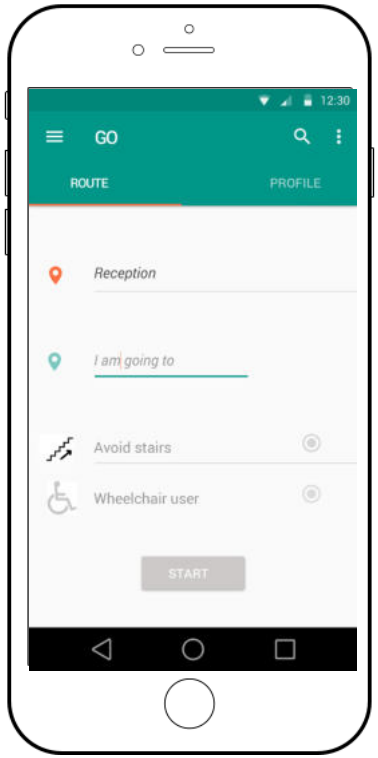



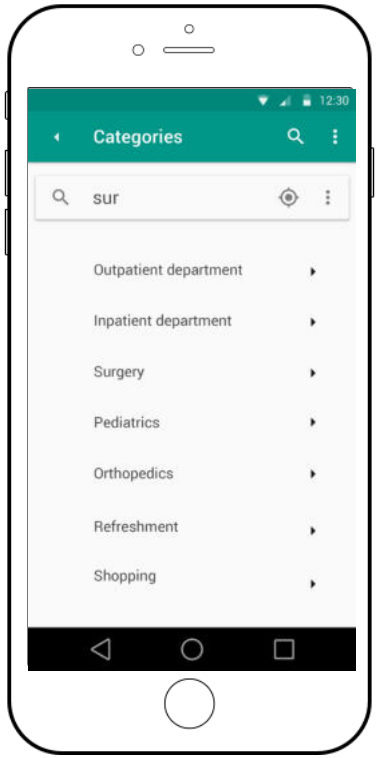


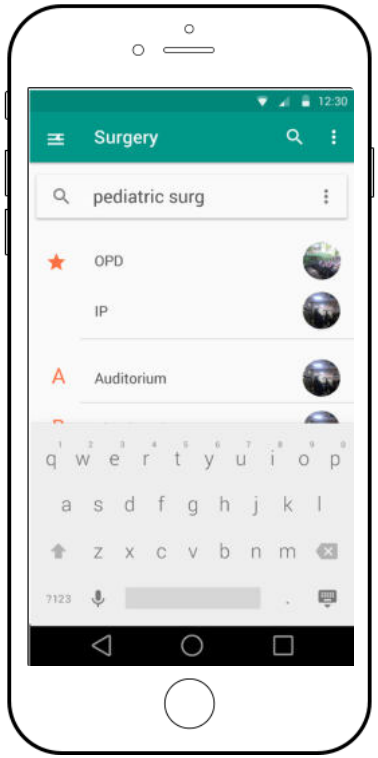
*This is the case, if Radha receives the app from the entrance or from a friend. Especially in case of visitors, they don't have to register before entering the hospital. In such cases, the person has to input the from and to location by referring to the various categories and images along side.*

*If the user click on the thumbnail of the location an image showing the details will be displayed. This is very helpful in case were users don't understand some complex terms used by docs or security for example, token machine, eye clinic. All these colloquial terms are updated in the database.*

# Finding the right route



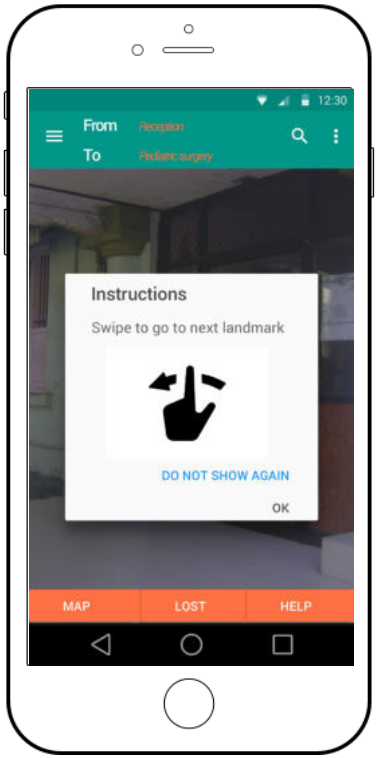



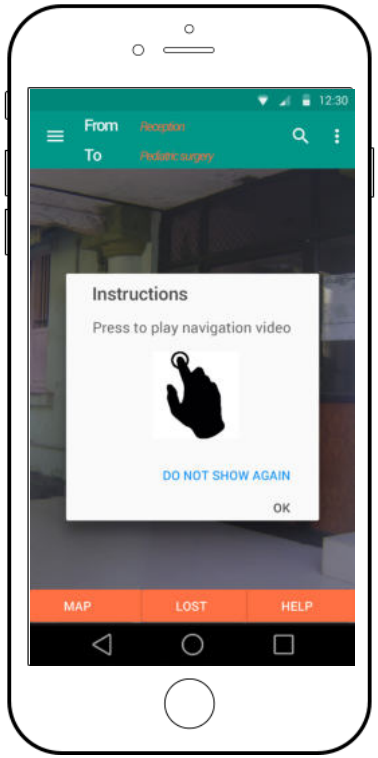




*The various spaces can be accessed through search as well as going through departments. A system similar to phone contacts are followed in case of search. A miscellaneous set with common terminologies like yellow chit, toilet, file etc are also provided. Frequently used items will come on the top of list.*

# Navigation Interface

## Educating first time user




*In order to make the users adapt to the various gestures in the navigating through photos, instructions are provided. The navigation interface starts from this screen.*

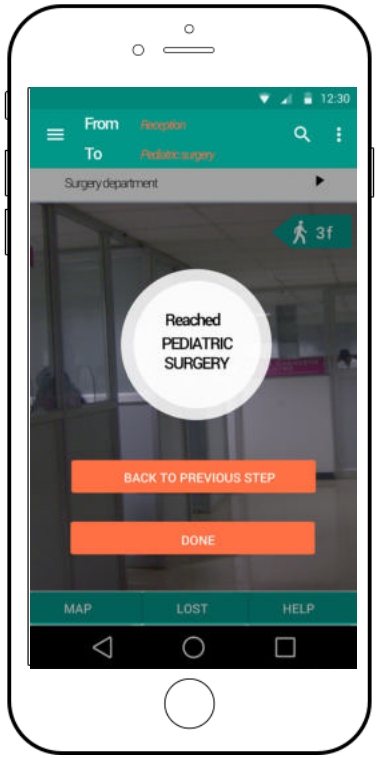
# Navigation Interface
# Idea 1


*This was the initial navigation idea. This interface had two parts. The landmark image and the instructions embedded on top. The landmark image was taken from users eye point. And arrows were used to show direction on the images. The instruction tab displayed activity based instructions with number of steps involved.*


*User has overall control over the navigation. She can view the series of images at a stretch or can view in a progressive manner. One important aspect was the lighting of the area while navigating. Spaces will look different in different climatic conditions.*


*At important locations, for example , in near a lift or operation theatre, special attention is required and hence the icon blinks to tell the user.*

# Navigation Interface
# Idea 2




*Once the steps are over, user reaches the end screen and she can start a new navigation with the existing location as the starting point.*



*As the previous navigation concept had a static effect altogether, in the next idea i decided to provide directions through animations. For example if the user has to go to the entrance in above case, the image will slowly zoom in to the entrance. Or to move left, the image will slowly pan from left to right.*

# Evaluation Plan

The main evaluation was done with the help of prototype of the final design. Even before that a dummy evaluation was conducted to test the idea with just photos and IDC as ecosystem which will be discussed later.

## User Criteria

As project was conceptualized for a range of first time and less frequent users who find difficulty to navigate in a public hospital ( KEM Hospital, Parel), a minimum proficient user group should be chosen for testing.

Education Level : 12th std educated

Age : 30 years and above

English proficiency : Fair

Smart phone usage : beginner

Total number of users : 6

Testing ecosystem : KEM Hospital, Parel

Routes : From the main entrance to pediatric OPD in new block

## Goals of evaluation

To find issues involved in using photos and videos as mediums of indoor navigation

Whether the proposed product helped in reducing the uncertainty patients had while navigating the route using signage's and improved their confidence to navigate.

## Method

### Task

6 First time users are selected. 3 of the users are asked to traverse the route using signages and rest three are given the application to navigate.

### Introduction

The participants will be given a brief of the application. The participants will receive an overview of the test procedure. Their actions would be recorded and studied to find where they are getting stuck. And they will also complete a post-test information questionnaire.

## Evaluation Criteria:

The evaluation criteria is based on three aspects.

1. Whether the user reaches the final destination or upto what junction is the user able to navigate without asking around.

2. Time required to complete the task.

3. Analysis based on likert scale output about experience and confidence.

## Testing the idea

In the initial stage of the design phase, a study was done to test how effective photo based navigation is for way finding

**Space : IDC**

### Scenarios

Navigation using existing signage

Navigation using landmark photos

Navigation using landmark photos with instructions

### User

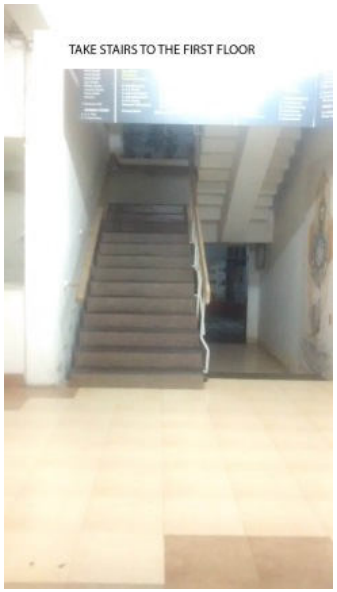
3 m tech students visiting IDC for the first time.

### Tasks given

Navigate from entrance to prof. shilpa ranade's room

Navigate from entrance to Shenoy innovation studio

Evaluation was based on performance between subjects.





*The photos used for testing the ideas for 3rd scenario : Images with instructions.*

## Insights

Efficiency ranking of way finding was found according to speed of navigation – photos with instructions came first followed by video and photo, only photos, signage.

In first scenario using signages alone, finding out particular room from main signboard and searching for the room signboards took a lot of time for users.

None of them searched or enquired for a lift facility.

In the second scenario(landmark photos) Instructions were found to be important even if photos of landmark is provided

Even in Photos with instructions, orientation of the user tend to make confusion. Videos might help here.

Junctions with 2 or more similar looking paths to navigate. Instructions and orientation might not work.

Major confusion was at the lobby to which users alight from staircase in 2nd floor with multiple optional steps next.Special effort is to be taken in taking error free photos

# References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