Navigation & Wayfinding

Using Schematic Maps and Landmark Data for Less-Educated Users

Semester IV Project Report

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Approval Sheet

The project titled *Navigation and Wayfinding - Using Schematic Maps and Landmark Data for Less-Educated Users* by Naveed Ahmed, is approved for partial fulfilment of the requirement for the degree of 'Master of Design' in Interaction Design.

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Naveed Ahmed

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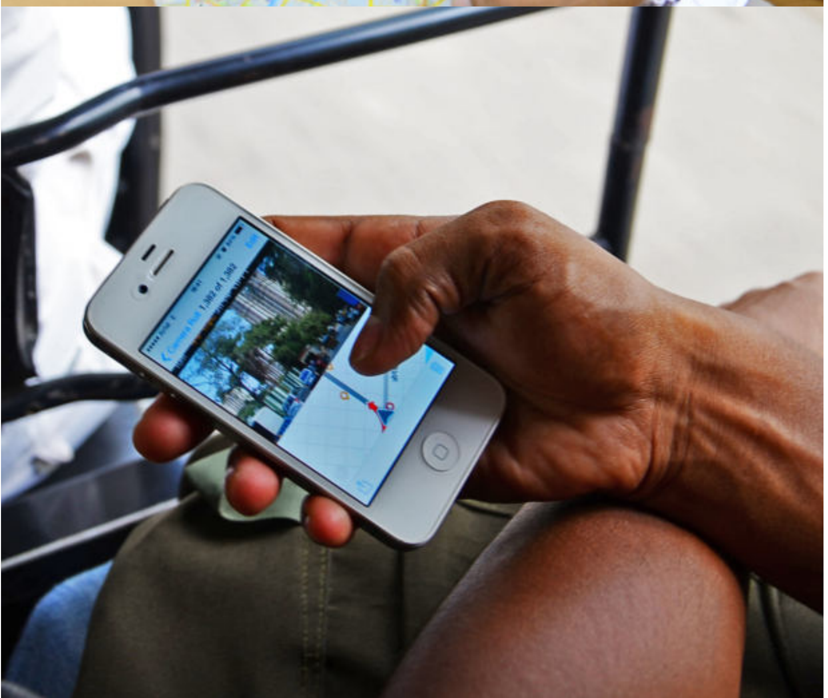


Abstract

In India, where usage of printed maps is less and the reliance on asking around is higher, adaptation to existing online solutions is low. Asking around is influenced by several socio-cultural factors and in turn affects how wayfinding systems are designed. These include micro factors like the time of the day to macro factors like gender and personal biases.

Using the hypothesis that a combination of schematic maps and landmark information will be an effective way of navigation, a prototype that uses these concepts was created.

A combination of schematic maps that are widely used in transit networks and photographs of landmarks on the route can result in a new wayfinding system. Schematic maps are created using generalization techniques to make a map more usable and closer to users' mental models. With the map showing the direction of travel, landmarks along the route can be used to move further and reach the intended destination.

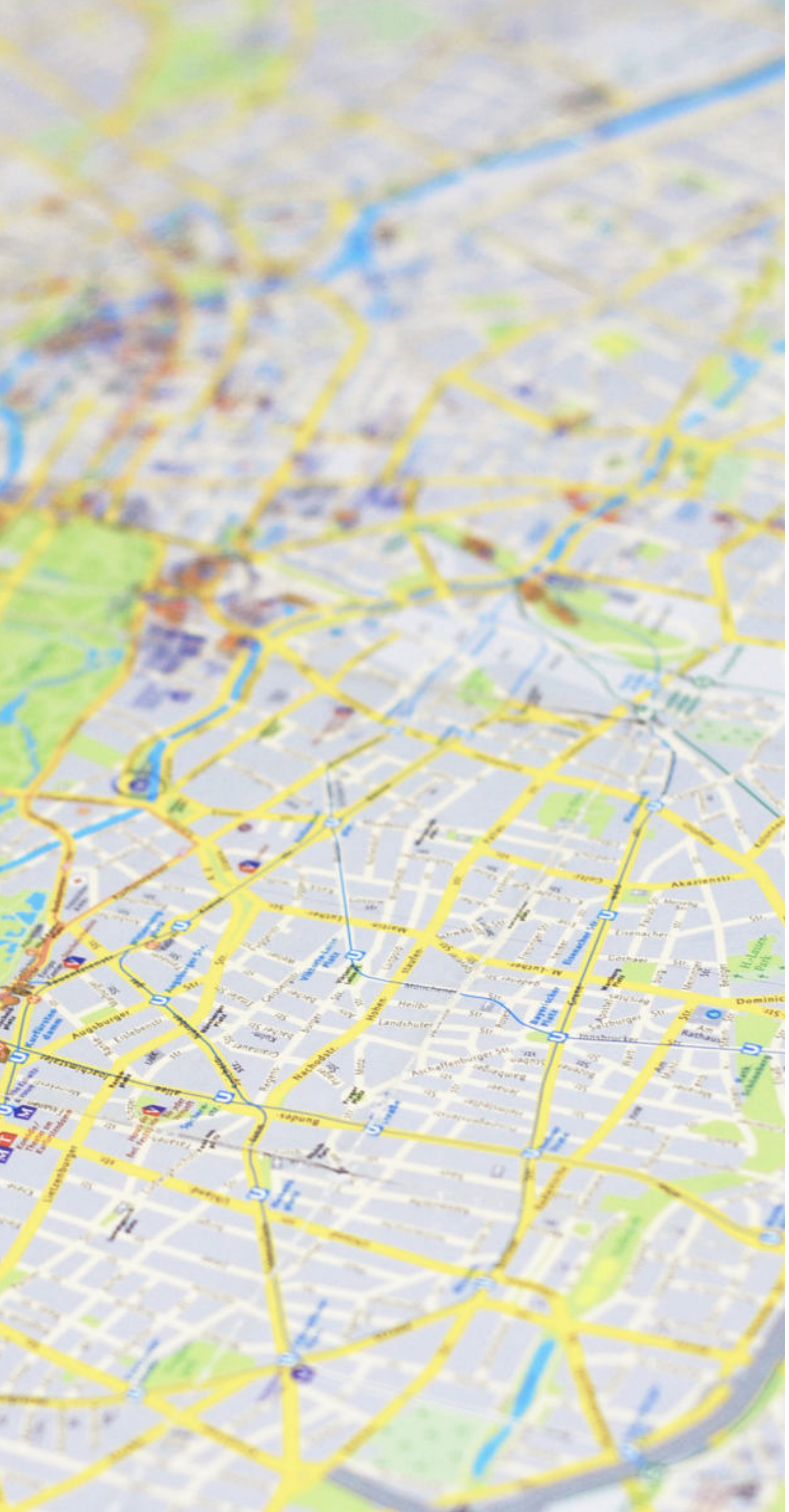
Here, landmarks along the route are used as checkpoints and nodal points. Checkpoints are intermediate milestones which the user has to achieve and nodal points are locations on the route where the user takes a turn from his current direction of travel. These are shown as points on the map and each of these have corresponding landmark photographs associated with them. Hence, the route is divided into segments that are completed in a sequential manner. Nodal points with several intersecting roads are provided with details of other routes to guide the users accordingly.

The prototype created using the above concepts was tested in comparison with an existing solution (Google Maps) with users with less education. Some of these users were first-time map users.

Two randomized sets of users—one using an existing solution and one using the current concept—were asked to reach a destination using the prototypes. A/B Testing was also conducted to avoid bias.

During evaluation, users could use the application successfully with most of them being able to identify landmarks and reach the final destination without much hassle. Comparative studies showed that landmark-based navigation definitely has an edge over other systems, especially when it comes to taking the correct turn.

Future work lies in creating a scalable model for generating data that will be required to make the application usable and keep it up-to-date with the changing environment.



Introduction

Navigation and wayfinding are an integral part of modern lives. Wayfinding is the process of gathering required information, making decisions about a direction of travel and then traversing the route to get from one location to another. This includes determining one's location in comparison to the destination or a nearby location.

Ideally, information wayfinding design is based on cognitive research and environmental psychology, but in the absence of good architecture, avenues must be created to facilitate easy and successful wayfinding (Hunter, 2008). Good wayfinding strategies increase user satisfaction by reducing frustration, stress, danger and hazard to the users and thereby increasing productivity (Hunter, 2010).

For people who commute to new places regularly or need to search newer locations on a daily basis, wayfinding becomes an essential part of their daily routine. Incorrect and confusing wayfinding systems lead to lost staff time, lost business due to frustration, missed and delayed appointments, amongst other consequences. (Arthur, et al., 2002)

Wayfinding in India happens by asking around and people usually point to landmarks as nodal points. In a map, landmarks like buildings, trees, statues, etc. and topographical features like hills, elevations, etc. act as referential points to know one's position or to orient oneself. And these are sometimes marked on a physical map to aid in navigation. But in India, where very few people use printed maps, landmarks are obtained from info-givers[1] whom people ask around during their journeys. Added to these are many cultural influences of when, where and how people provide instructions to these info-seekers that affects the process of wayfinding.

Traditional GPS devices evolved based on aerial perspective of locations. But in India where usage of traditional maps itself is low, digital solutions based on planimetric maps[2] don't always work.

The project started with exploring how design in urban space influences the way people perceived cities and the way they moved around. A study into available literature on navigation and wayfinding opened up interesting opportunities. This included a

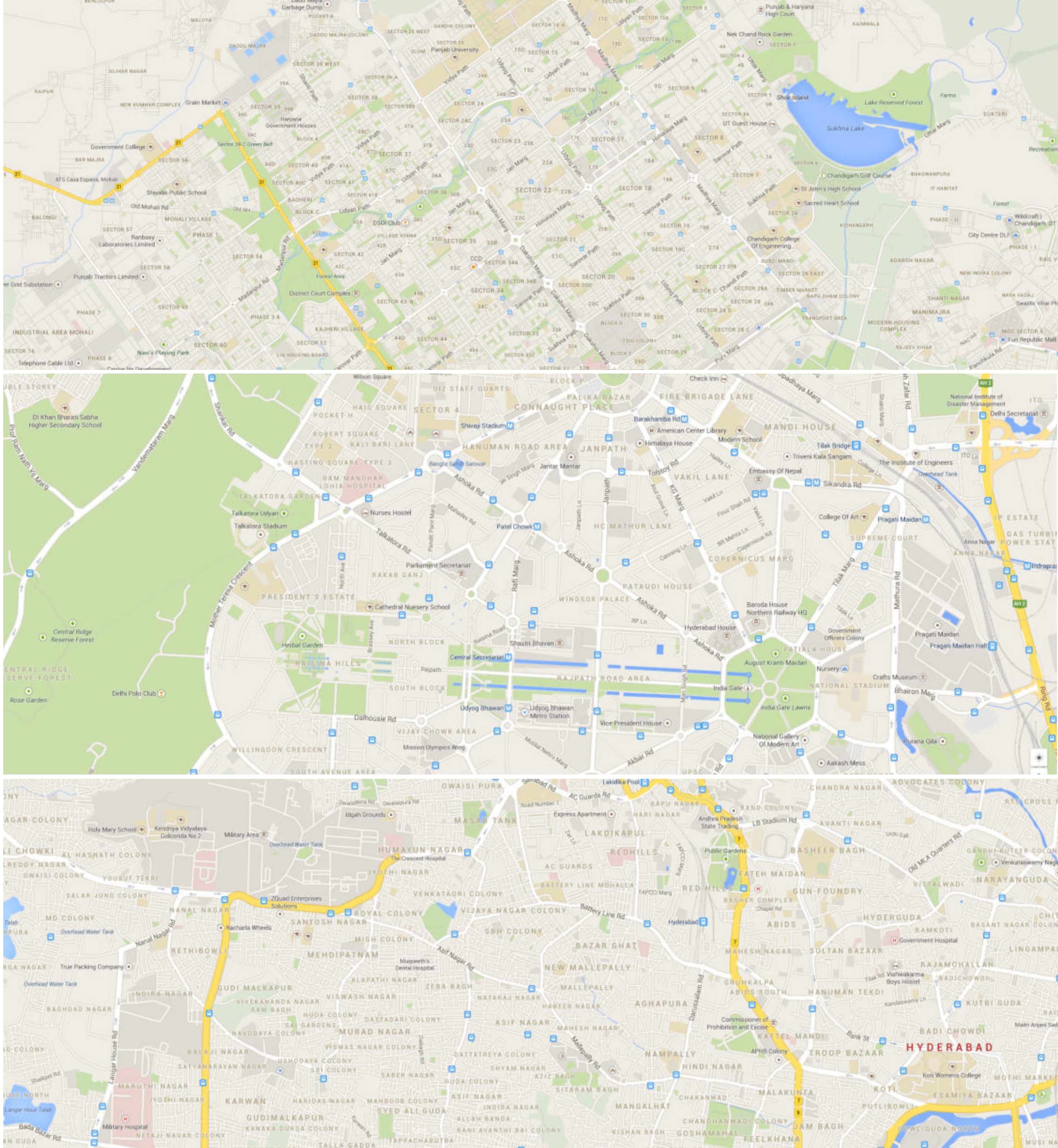
1 Info-givers are information providers whom a traveller might ask while travelling on a route. Similarly, those who are seeking for information are info-seekers. These terms are specific to this report and are not a standard.

2 Planimetric maps are maps that include features of those items that can be seen on the ground from an aerial perspective and are represented on a map. These maps do not show any terrain (relief) information. (Wikipedia, 2014)

review of cartographic techniques, navigation for the visually impaired and indoor navigation.

The book, The Image of the City by Kevin Lynch, was a major influencer in shaping the project (Lynch, 1960). In the book, Lynch talks about how people perceive, inhabit and move around in the urban landscape. He talks about how landmarks should be created in a city so that people can create easy mental maps of the city they live in and of the routes they traverse (known as *imageability* and *visibility*). These mental models also change based on the layout the city.

For example, cities like Chandigarh follow a grid (also called gridiron) structure, while New Delhi has a radial structure and places like Hyderabad which have evolved with time do not follow any fixed structure. As grid cities are organized in a rectilinear roads, people find their way through cross-streets which is easier than finding routes in an organic or a grid structure. Similarly, the amount the distance to be covered is also higher in grid cities (Walker, 2010).



Cities have varied layouts that affect wayfinding.

Top: Chandigarh with a grid layout
Center: New Delhi, radial layout
Bottom: Hyderabad, organic layout

Source: Google Maps

Newfound Professions and Lesser-Educated Users

In the recent times, India has seen the emergence of new professions like delivery, courier, cab and related door-to-door services. These require searching and finding new addresses on a daily basis. Most of these professions do not require very high educational levels and hence people employed in these are not highly educated. Here, low education level does not mean low literacy.

However, people in these professions possess smart phones that they generally use for applications like camera, gallery, Whatsapp, SMS, etc. But these phones are not used to their full capabilities. Even slightly advanced applications like online maps and internet browsers are something that are never or rarely used. Some of these people carry smart phones with them all the time to support the profession they are involved in but never use anything beyond the company-specified application.

These professions need applications like navigation maps to reduce their turnaround and service times, but as the apps are not made for these people, they usually stop using them or not use them at all.

This cohort of users hence became the main focus during this project—users with low education levels and those who need to find addresses frequently. Similar users were interviewed to find the right information and insights that aided in the design process.

The cultural aspects of wayfinding and the navigation behaviour of people in various situations supported the development of the final landmark-based navigation system which has been discussed further in this report.

Design Process

During the project, the hypothesis formulated on the basis of user studies and prior work was tested with users for its standing. Comparative evaluation was done using existing products and a prototype of the proposed concept.

The SemWay Project refers to the method of creating wayfinding solutions through a user-centric process as 'Semantic Wayfinding.' (Rehrl, et al., 2007)

The steps involved in the project are mentioned below.

User Studies

Primary studies were conducted to understand people's wayfinding behaviour, how people use existing solutions and conditions under which these have failed. The studies concentrated on the Indian context. Insights generated in this step were used further in the design.

Ideation

Exploration of multiple concepts and ideas based on the data & insights generated from user studies. Of the ideas, the one based on schematic maps and landmark information was selected and taken forward for further detailing.

Prior Work

Study and literature review of work so far in the areas of navigation and usage of schematic maps and landmarks for navigation. With the exception of two that were done on users with less education, most of the studies were around tourists, pedestrians and older generations. Studies on computational models for automating schematization of maps were also looked into.

A hypothesis was proposed at this stage which guided the process henceforth.

Final Design

A detailed prototype combining schematic maps and landmark data was created. This prototype was then used to validate the proposed hypothesis.

Evaluation & Findings

The prototype was evaluated with the users and the findings were used to improve the concept and the final prototype. Multiple iterations of the design and prototype were used during the evaluation process.

The report follows the same sequence as the process mentioned above.

User Studies

User studies were conducted to understand navigation and people's wayfinding behaviour.

India as a country is highly heterogeneous in the way cities are laid out, the way people use landmarks in the absence of road names and how certain cultural aspects affect the way wayfinding instructions are given and received. Factors like these affect the way maps and navigation systems are designed. These studies were an attempt to explore such implications and find design opportunities.

Some of the users that were interviewed during user studies

User Criteria

To understand the process of navigation and wayfinding, users who did this on a regular basis were interviewed. The users chosen for interviews were primarily delivery personnel, intra- and inter-city drivers and repair technicians. People who use existing solutions on a regular basis were also interviewed to understand their usage behaviour.

In all, 15 people were interviewed and most of the users were in the age group of 25-35 and have lived in city suburbs most of their lives. Users with low familiarity with using a computer and used a phone with smart features were chosen for the user studies.

Due to differences in the structure of Indian cities, two users were chosen from Rajasthan to get diverse inputs and the rest of the interviewees were from Mumbai.

Findings

Following were findings from the user interviews.

People do not prefer online maps

Users mentioned that online maps do not contain adequate information that can be used while wayfinding. People in India usually find their way by asking around. Being a society that relies less on maps for wayfinding, online aerial maps were something that users found difficult to adapt to. Few users even mentioned that landmark information was something they wanted maps to provide, so that they can remember the route even if they are not using maps while travelling.

Some users were not comfortable using a software for navigation as they could not operate them easily. Anxiety during travel and unfamiliarity with use of maps and software may contribute to this behaviour from users.

Users felt that landmark information was currently not available clearly. They could not locate landmarks while using online maps while travelling. A solution must hence seamlessly provide landmark information along the route that is being traversed.

Some users were not very keen on continuously using mobile phones for maps as it was perceived as 'talking on the phone' by others. A user was once booked by traffic police for using mobile phone while his vehicle was waiting at the traffic signal.

People look for a seemingly-trustable person to ask for directions than asking a random person

Whom to ask?

Though people rely heavily on asking around to find the address right, they are often not sure whom to ask for directions. People solved this problem by relying on 'seemingly-trusted' persons and possible providers of information.

Well-dressed and older people are presumed to be more trustworthy than others. *Autowallahs* and *panwallahs* are considered more reliable as they are local to an area and might know the place better. But *autowallahs* often refused or provided wrong information.

A user also mentioned a case where school kids misguided him and he had to find his route all over again.

Women ask other women. This striking aspect has been noticed in our studies and would have a major influence on how wayfinding systems are developed. Women are more anxious about wayfinding than men as they feel insecure and more vulnerable than men, especially in unfamiliar and seemingly unsafe areas. Studies have also shown that, in other countries, women use different strategies than men for wayfinding. (Lawton, et al., 2002)

People also ask multiple sources to verify and validate the information they have been provided with. But this may sometimes be an issue as people have their own perceptions and understanding of the route and excessive verification by the info-seeker might lead him astray.

The issues mentioned above have a single concern—trust. People seek trustable sources and this should be a prime feature in the final solution. Creating trust into a non-human entity is something that can make or break the final solution.

Some frequently used landmarks by people

Top: Religious structures like Nishan Saheb (Source: Wikimedia)
Center: Malls like these are prominent landmarks (Source: Google Plus)
Bottom: An overflowing garbage bin (Source: The Hindu Newspaper)

Landmark Info

As India is not a very map-savvy culture, landmarks have always played an important role in wayfinding. In our studies, even users of online maps mentioned that they checked major landmarks on their route before starting the journey.

Prominent physical structures like buildings and trees were used as landmarks commonly. Sometimes the colour of buildings was more important than the building itself. But this was mainly in case of large roads. In smaller streets, the choice of landmarks changed completely. People used garbage bins, broken walls, *nullahs* and even volatile entities like road-side vendors, people sitting on street corners and cows as reference points. Here, religious structures like minaret and *nishan saheb* which are specific to an area were also used.

Landmarks should hence be an important feature in the final solution. Instead of an aerial view, the solution must be completely landmark-based that shows ground-level view to the user. This data can be collected off the ground directly. But in India, where topographical changes are very frequent, landmark data might become unreliable with time. Hence, the final solution must ensure regular validation and verification of the available landmarks. This will also help in increasing the trust factor in the system.

Progressive Discovery

People find their way through progressive discovery. Progressive discovery is something like progressive disclosure which is an interaction design technique where only the important and primary information is disclosed initially and the rest of it is provided on demand (Nielsen, 2006). Similarly, users divided their journey into shorter milestones and once they reached each of these, they inquired for further directions.

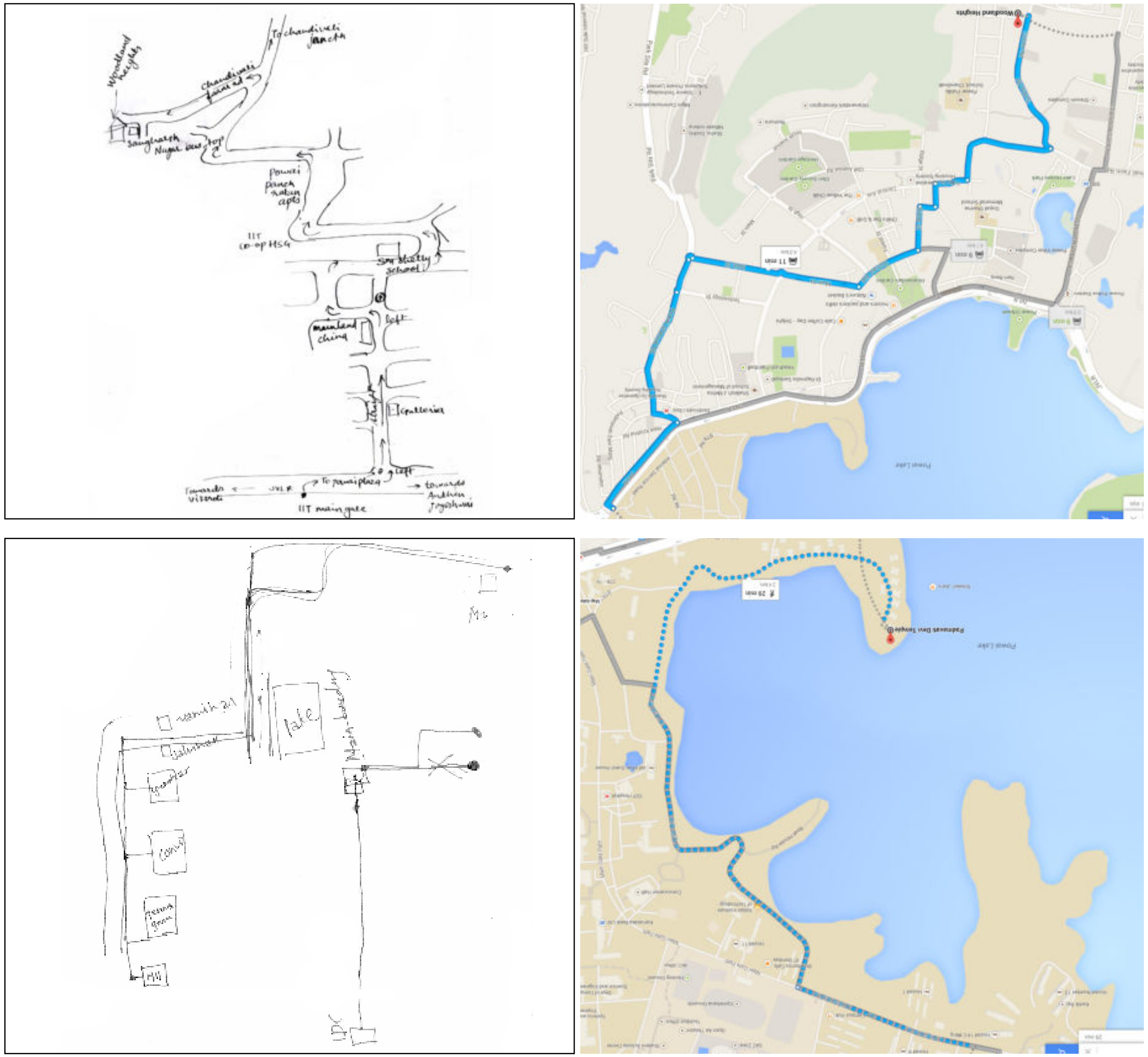
Depending upon proximity to the destination, people provided directions in the same manner. They asked the seekers to reach a certain point ahead and inquire further. Certain seekers and even providers felt that verbal directions were complex and confusing. Hence, they followed progressive disclosure of information intuitively. In short, both information seekers and providers first searched for larger information and got into finer details only when they were closer to the destination. This was true even in case of some Google Map users who obtained the approximate route to their destination online and got into micro details of the destination by asking around.

Hence, it is not required that complete information is provided to the user in one go. Necessary information can be provided to the user to take him to the next intermediate point in his journey and he can take further decisions thereafter. The solution can have smaller milestones for people to achieve, like a game, leading to the final destination. This will help the user to be assured that he is on the right path and also as a feeling of accomplishment.

Measuring distance

People used indigenous and ingenious methods to measure distances. Locally available data such as the number of buildings, telephone poles, traffic signals and trees were mainly used. In some cases, the distance was measured by the amount of fare charged by the bus or the available mode of transport. In rural areas, people used the number of villages between the starting point and the destination as a measure of distance.

The number of route options to reach the destination depended directly on the distance between the source and the destination. The layout of the city also affected the number of routes available. A grid structure has lesser route options to complete a journey compared to a radial or organic layout (Walker, 2010). One user mentioned that grid means more travel and also that it was easier for him to find shortcuts in a city with a non-grid layout.



Comparison of routes made by users during interviews. On the left are sketches made by users and on the right are the corresponding routes from Google Maps. The heavy generalization and simplification by the users can be clearly seen. (See Appendix)

Mental Models

People create mental models and have perceptions in navigation and wayfinding too. Users construed a route without any turns as a straight road. They did not perceive a curve unless it was at a sharp angle. Users subconsciously performed rectilinear correction of the path by ignoring the minor bends and curves.

When asked to draw the route between two points they travel regularly, users usually did a correction in the path. If the route had no major turns and streets, it was assumed to be a straight road. People mentioned finer details only when the path involved too many turns. High-speed parts of the road were drawn straighter than the low-speed ones. A comparison of the route drawn by the users and the actual route can be seen on the left.

As the human mind ignores minor bends and curves, the map provided to the user must have the simplest of information. Major turns and prominent topological features can be reproduced for guidance. Users can concentrate on the path they have to travel instead of the minor details if they are provided with minimal and only the necessary information. Schematic maps can therefore be used for this purpose.

Roads also look different at different times of the day. Landmarks do not appear same because of traffic and light conditions which vary greatly depending on the time of the day. An opportunity here is to create solutions which cater to different times of the day, mainly lighting conditions and hence provide a seamless experience.

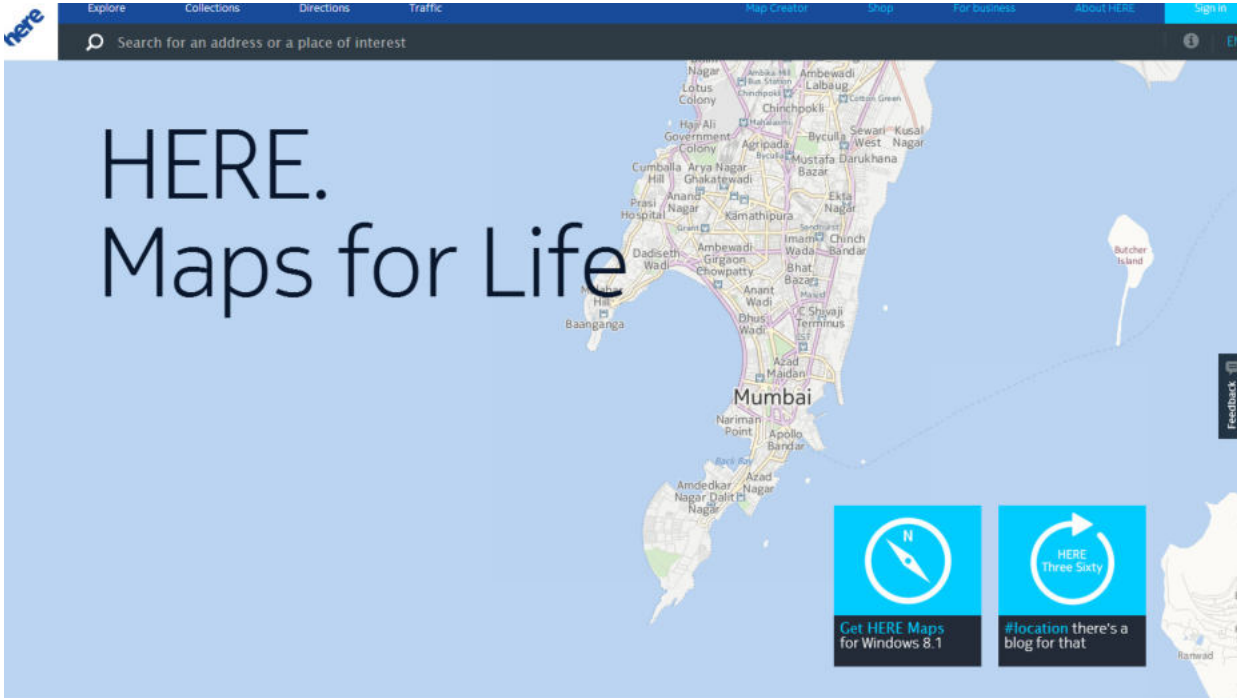
Usage of existing solutions

Of the users interviewed, five of them used print maps and popular online solutions like Google Maps and Nokia HERE on a regular basis.

One of the users (a European) who used print maps extensively found it difficult to use them in India as they were not very detailed and finding street names was not easy. This was mainly due to improper and insufficient signage. He had later resorted to asking around.

A user felt that Google Maps provided information that was not necessary. He used the application primarily to know his current position and if the taxi was taking him on the correct route. There was no direct way to know how much journey was left. He also mentioned, that once he started driving on his own, he might find the other features of the software application more useful.

One user was gifted with a dashboard console of MayMyIndia a year back, but had stopped using it in a month. He did not find it useful as most of the travel was intra-city and it was too cumbersome to input data to find a route.



Nokia HERE Maps, one of the latest introductions to the map market.

In the above the context, the profile of the users was different, so were their requirements. It must be noted that they used existing solutions but these failed due to some internal and external issues. These were either interface issues, infrastructure issues or specific requirements by users.

Size of the road

People felt it was easier to ask for directions on larger roads than in inner streets. This may be because of progressive discovery (See earlier section on Progressive Discovery). People seek major landmarks while on the larger roads and get into intricate details only when they get closer to their destination. Intricate details mean more specificity and finding them might be more difficult. Also, info-providers would know the bigger picture better than the finer details.

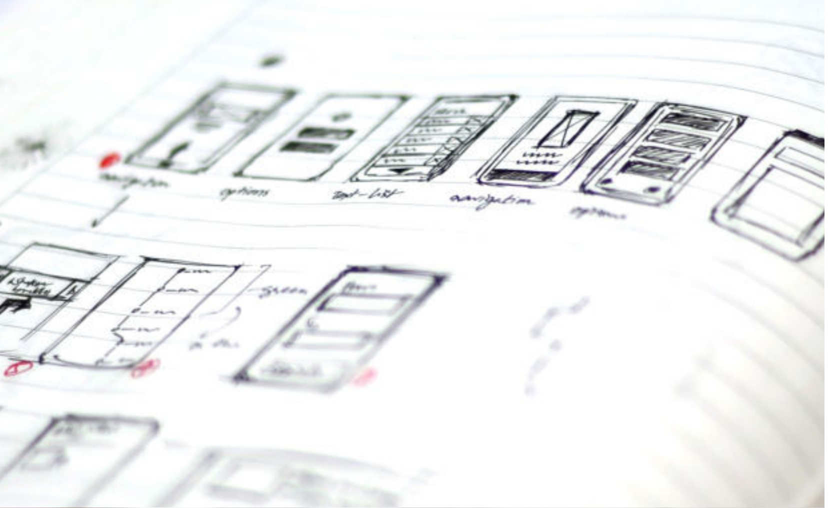
This would have a design implication in the way data is collected for the final solution. It would be easier to find data in the bigger context than the intricate details that will be necessary as the user gets closer to his destination.

Error Prevention

Maps do not have an error prevention mechanism. If a user has gone too far on their route, there is no way to quickly know and rectify the mistake. This also happens when users ask multiple sources to verify and validate the information they have been provided with. Info-providers might perceive the route differently and direct the user with varied instructions to the info-seeker leading him off the right path.

Users had used maps in the past and missing diversions on highways cost them heavily. There should be a strong system in place that when a user goes too far he must be alerted well in advance that he can change his course in time.

In a country, where people are trusted more than a computer for wayfinding, even a small error will deem the software unreliable. Building trust through a perfect error prevention mechanism can go a long way in creating overall confidence in the system.



Ideation

Taking cues from Lynch's ideas of designing landmarks for easy mental models (Lynch, 1960), a reverse engineered technique of making easy mental models out of existing landmarks had to be developed. A way of navigation that would bring in the cultural aspects of wayfinding (as in User Studies) to suit the traditional mindset and at the same time be as efficient as, if not more than, physical planimetric maps.

An area other than navigation, where maps are used extensively are for transportation networks. In most cases across the world, transit routes are represented using schematic maps. These are maps of fixed routes of a bus or a train. The most famous example of a schematic map is the London Tube map designed by Harry Beck in 1931. Schematic maps are built-up from sketches that usually have close resemblance to verbal descriptions about spatial features.

Schematic maps are used in situations where existing geographical maps perform poorly and provide insufficient information to the user due to overwhelming visual information. Map designers overcome this problem by applying various cartographic generalizations to convey the most important information on the designated route. This is done by adding or removing data on the route. They hence become conceptual representations of the actual map. (Avelar, et al., 2006)

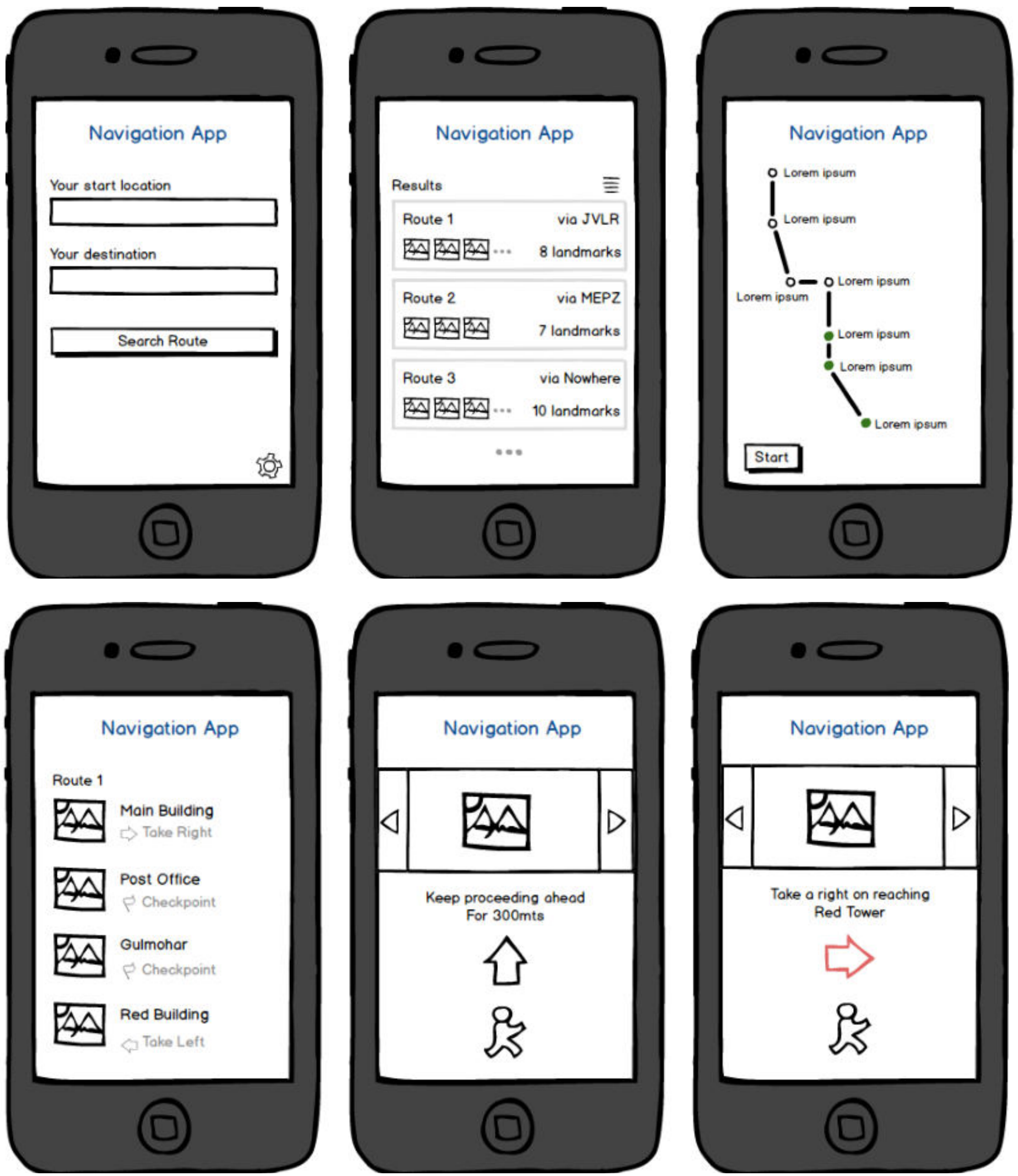
Studies have shown that user were able to solve problems faster and more accurately using schematic maps (Agrawala, et al., 2001), but there are certain practical instances these maps have failed. For example, even with minimization of geographical features, the maps are still cluttered with a lot of information for the users to search and find a location. Due to generalization, the maps lose the scale of distance between two points. This sometimes leads to confusion in choosing the right drop locations.

Based on the studies so far, the project will now involve creation of more usable and easily accessible navigation solutions. The aim is to create a solution that can be used by those who search for new addresses on a regular basis and by those who are not adept with other wayfinding solutions.

The application would make use of concepts like progressive discovery (as in Findings) and tightly couple it with landmark information to make wayfinding easier. Cultural factors and trust have to be introduced into the system, so that the solution becomes acceptable.

The classic London Tube map designed by Harry Beck in 1931. It was the first time that geographic features were eliminated from a Tube map and concentrated only on where and how to catch the right train. Over the century, the idea has been adopted by various organizations world-wide.

The Mumbai Railmap by Prof. Mandar Rane of IIT Bombay. This is a work in progress to develop a schematic map for the various lines for the Mumbai local train network.



Navigation Concept 1

In this concept, the existing method of online maps is accentuated with schematic maps and landmark-based navigation. Instead of just giving instructions of navigation, visuals of the various landmarks are provided to the user. This helps in easy recognition of the location.

Also, checkpoints between two landmarks help the user keep track of his progress and to ensure that he is moving in the right direction.

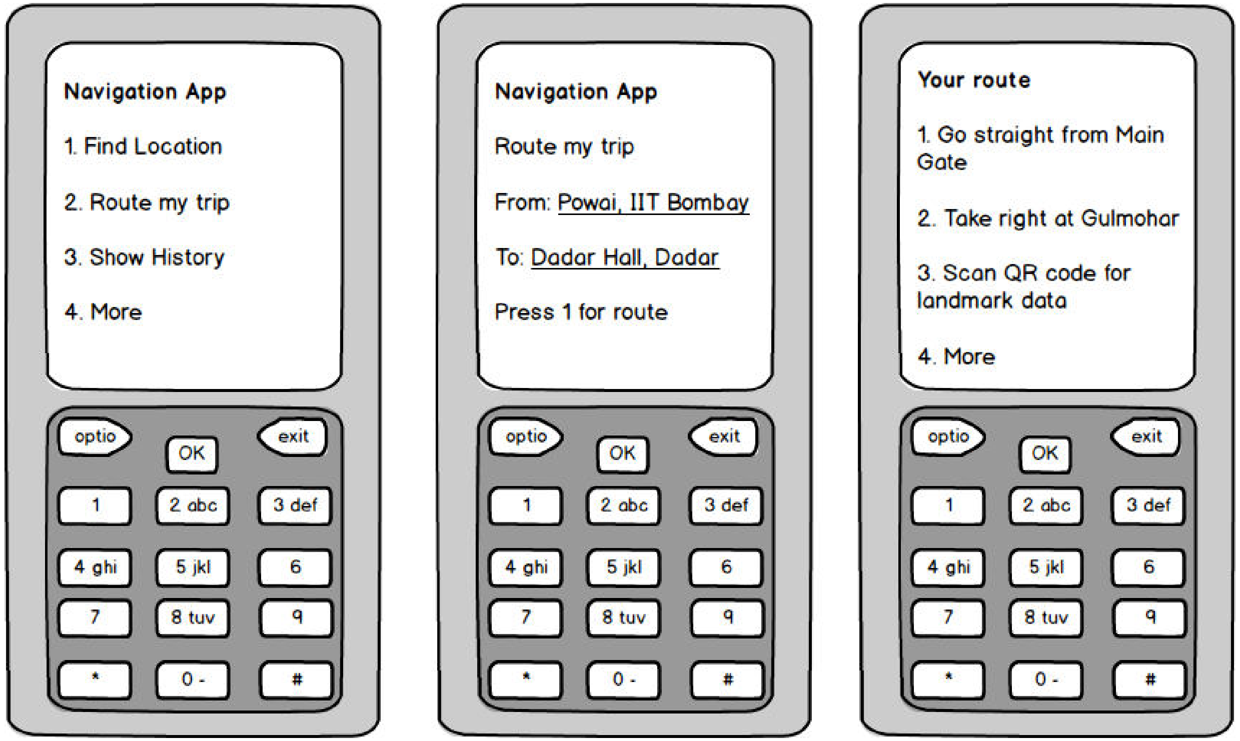
Starting top-left, various tasks involved in searching for a location to finding way using the application, can be seen.

Navigation Concept 2

In this concept, the user interface of the map can be accessed using a text-based interface. The interaction can be in the form of simple text messages that are sent to the server to receive navigation information.

Entities like QR-codes can be placed at regular intervals along the route that can help the user keep track of his current location and progress. With the help of QR-codes this concept will work even on feature phones and there may not be a need for GPS-enabled devices.

Alternatively, the navigation system can also be coupled with services like Whatsapp, where the user chats with a server to receive relevant information.



On top is a simple text-based interface that a user can use for navigation by sending SMS.

Users can use QR-codes or similar markers to know their current location.

This view gets activated when the user gets closer to his destination.

It acts like a compass showing the direction of travel (red cross-hair) and direction of destination (blue dot) so that the user can orient themselves in intricate street networks.

Navigation Concept 3

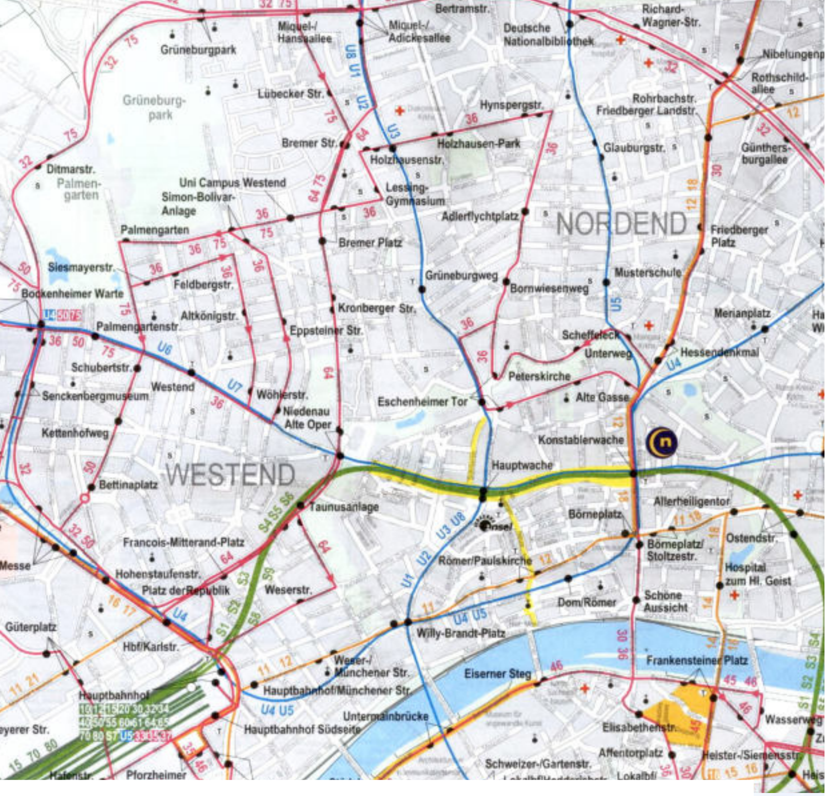
In this concept, the view through the phone's camera is overlaid with navigation information to guide the user towards his next landmark. This will not be a full-fledged app but overlays will be available when the user reaches a checkpoint (as in Concept 1).

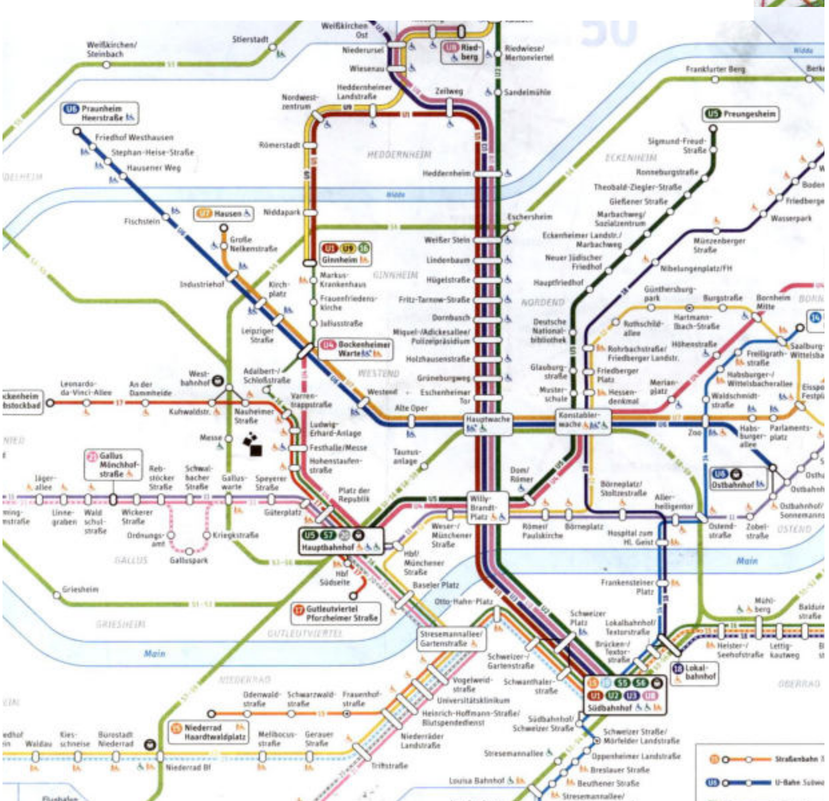
User studies have shown that the final leg of the destination is the most difficult one. This feature hence would appear during the final part of the journey to guide the user to the final destination.

As seen in the images on the left, there is a bar on top that shows the direction of the final destination. The bar acts like a compass where the central cross hair is the heading[1] and the blue dot is the final destination. The distance between the two points is the angle subtended, with the user as vertex.

Based on the ideation so far, the concept of using schematic maps and landmark information was taken forward. Further in the process, prior work related to these ideas was also explored.

1 Heading is the current direction where the phone is pointed towards. It can also be the direction in which the user is currently facing. The term is derived from general geometry (Wikipedia, 2014) and aircraft navigation (Wikipedia, 2014).





Prior Work on the use of Schematic Maps and Landmark Data for Navigation

Wayfinding Design as a concept has been part of architecture for a long time. With the advent of new technologies, the concept of spatial planning has now moved into information systems design using various geographic information systems (GIS).

According to Golledge, wayfinding is concerned principally with how the route is structured rather than the environment through which the path passes (Golledge, 1999), but in a modern city where life is affected by factors like traffic, multitasking, etc., the path and the environment both have become important, if not primarily.

Wayfinding involves three basic stages (Bogen, et al., 2010):

- Situate: determine one's location with respect to a nearby point or the destination
- Orient: determine the direction/route to take to reach the destination
- Navigate: monitoring and finding the way during the journey

The process of wayfinding is affected by a person's physical and intellectual abilities, socio-cultural background, gender, etc. (Arthur, et al., 2002) (Lawton, et al., 2002). These directly and adversely affect design. And in India, where people rely primarily on asking around the above factors even determine if the information conveyed is right or wrong. Studies at IDC have revealed people's preferences and apprehensions in asking around. People take time to decide whom to ask, when to ask and how often to ask.

Along with these, mental models and perceptions of a particular place determine how people store information about routes and how they are conveyed to people around. As navigation is a spatiotemporal process, these perceptions may change based on the stimuli the user receives at the moment (Montello, et al., 2003). This results in creation of new routes and wayfinding strategies on the fly. (Hunter, 2010)

In the absence of maps, people communicate via verbal directions or through sketches. These sketches are people's interpretation and understanding of the route. The mental model determines how people make and convey routes through their sketches (Tversky, 2002). Schematic maps are closest to mental models in terms of simplicity and representation of reality (MacEachren, et al., 1987).

Images: On top is the geographic map of Frankfurt, Germany showing various subway lines. Bottom is the schematic version of the same. (Source: TraffiQ.de)

Existing Navigation Solutions

Currently used solutions for wayfinding and navigation include dashboard consoles, online maps, printed maps and even asking around.

Online Maps

Google Maps, Bing Maps and Nokia HERE are the most widely used and up-to-date maps available online. Though they have mapped most of the country, problems persist in the form of less topographic information, inaccuracy in highly networked streets and misguided routes. For example, Google Maps currently does not know one-ways, flyovers and dead-ends. Users sometimes find relating the aerial view with the actual view difficult, leading to confusion.

Dashboard Consoles

Dashboard consoles like MapMyIndia (similar to TomTom) have been in India for about a decade now, but even with the high cost of installation the amount of details in the maps is low and it renders them unusable in most of the cases.

Top: Google Maps (Source: Google.com)

Bottom: MapMyIndia Console (Source: MapMyIndia.com)

Printed Maps

Printed maps are one of the most tried-and-tested method of wayfinding for advanced users, but they fail when it comes to scalability and intricate street networks of unplanned city areas.

There are solutions in the print media that have integrated landmark information with maps. But these are mostly legend-based and the number of landmark options a user has is limited. As print is static, the amount of information that can be included into the map is also restricted. Also, users find it difficult to find a location on map and refer to legends simultaneously.

For example, in the adjacent map of IIT Bombay, photographs of only 9 locations could be included. While this may work in a small areas like IIT Bombay, scaling it to the size of a city would be difficult

Some existing solutions that use landmark data in maps.

On top, Map of Darmstadt, Germany that uses landmark information on maps (Source: Darmstadt Info Centre)

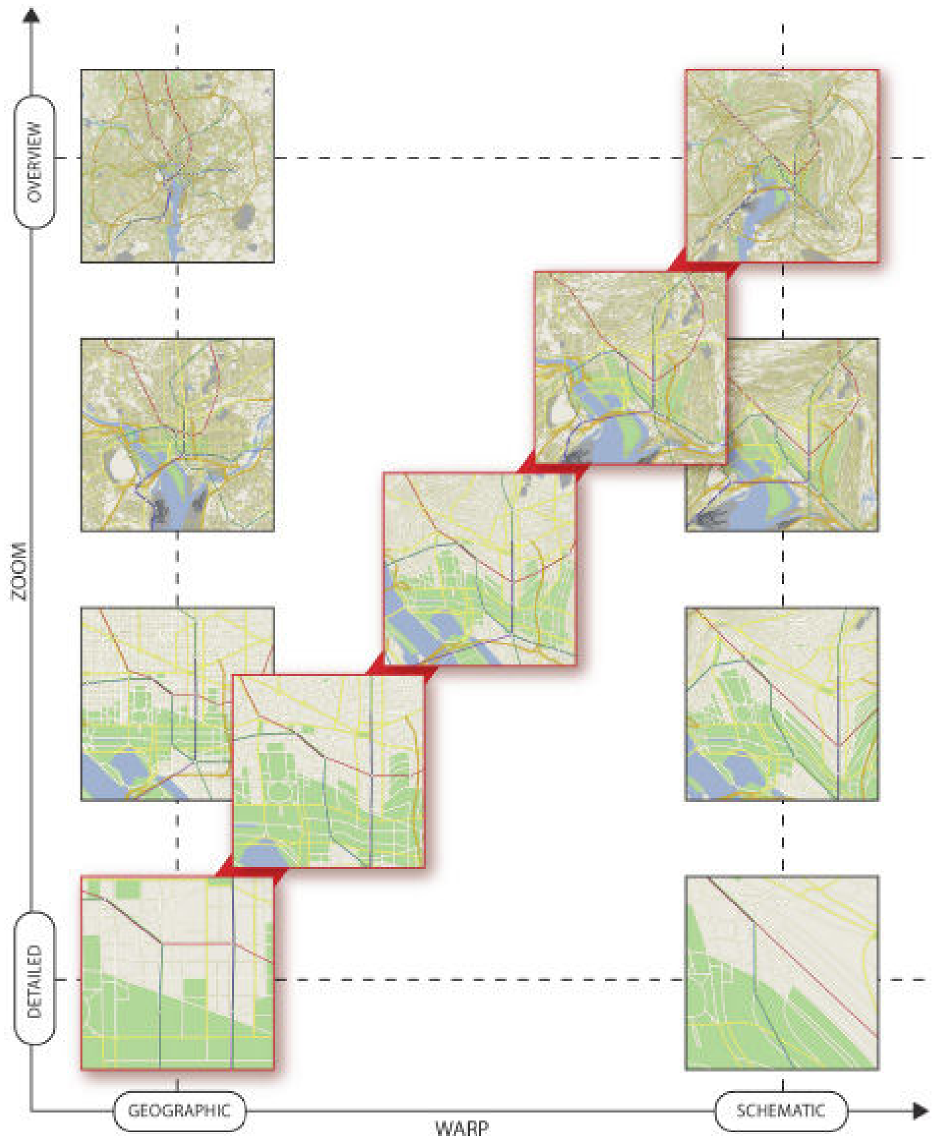
At bottom are maps of IIT Bombay by Prof. Mandar Rane using landmark data

Information from Secondary Data

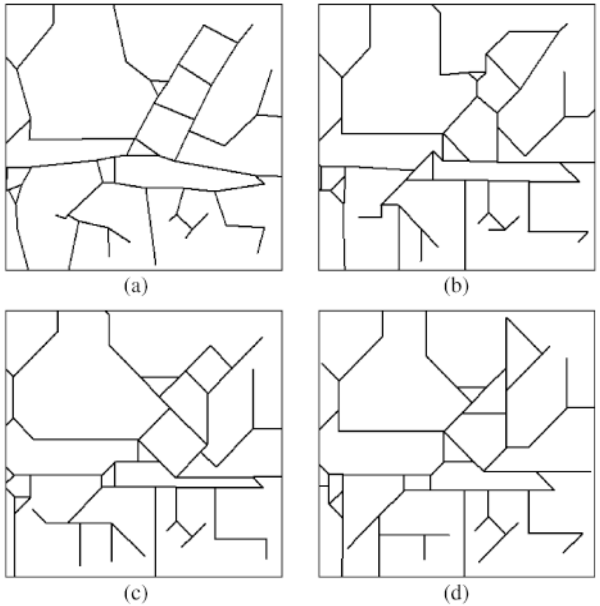
Simplification of Routes

Schematic maps are representations based on highly generalized lines and contain lesser details of adjoining areas than geographic maps, are easier to follow and understand than actual maps. These maps are widely used and accepted across the world to depict transit networks.

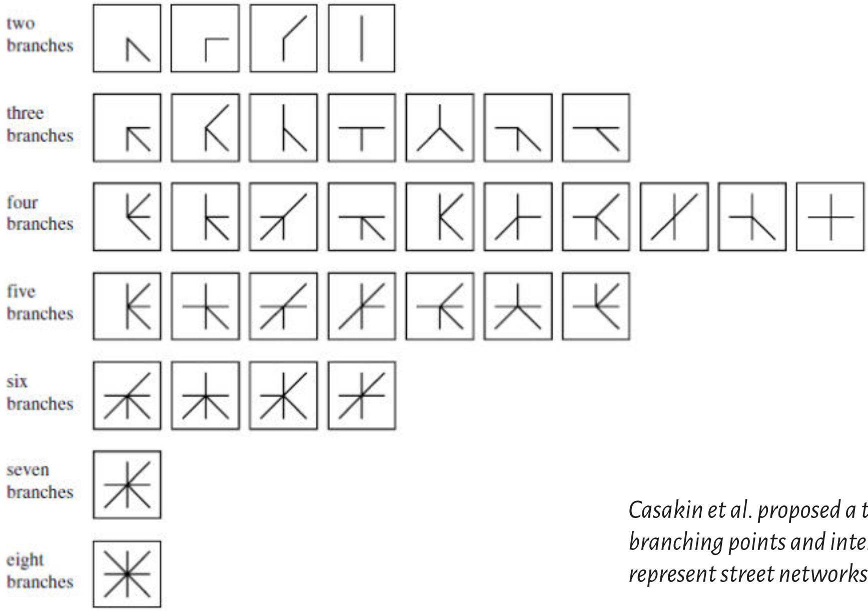
Schematic maps with sufficient amount of generalization and reduction have been proved as good wayfinding aids. This is mainly because of their abstract representation of the route by eliminating the finer and functionally not-so-necessary details (Casakin, et al., 2000) (Ware, et al., 2006).



Bogen et al suggested the 'Warping Zoom' method where the level of detail of the map and the kind of map changes depending upon the speed of the user.



Ware et al. through their algorithm of automatically creating schematic maps show the various stages. More the time spent in the process, more accurate the map would be.



Casakin et al. proposed a taxonomy to represent branching points and intersections. These can be used to represent street networks in organic cities easily.

Schematic maps have been used extensively in case of transit networks, but rarely in case of navigation and wayfinding. Generalization and abstraction - the advantage of schematic maps becomes an issue when it comes to scalability. Manual production of schematic maps is labour intensive, while automation of the process calls for a wide variety of strict pre-set rules.

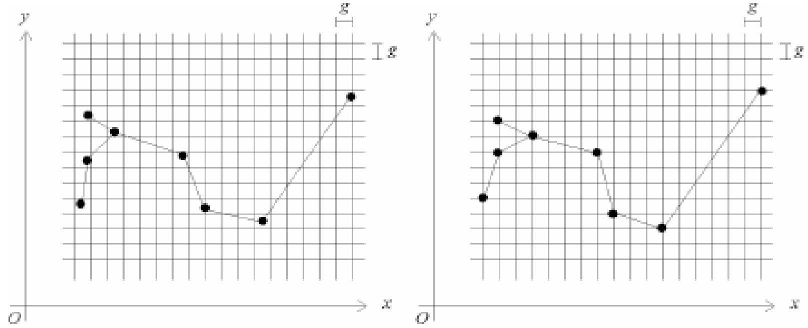
Dealing with branching points and relationships between various details of the map is a major issue while creating schematic maps. The map will work only when the right details are preserved and/or eliminated.

To simplify the process, Casakin et al. proposed a taxonomy for classifying and representing branching points (left bottom). This technique was tested and most of the branching points reproduced using the taxonomy were comprehensible to users. In the generalization process, main roads were simplified first and then the inner secondary roads. The road simplification followed a hierarchical process (Casakin, et al., 2000).

Simplification of curves is not easy either. As most of the routes are depicted by straight lines, change in direction is shown commonly at an angle of 45 or 90 degrees, sometimes 30, 60 and 90 degrees. After a study of existing approaches, Weihua et al. developed a square grid model, where the nodes are approximated to the nearest vertex of the grid (See next page) (Weihua, et al., 2008). Breaks and changes in line direction are sometimes added to provide better visualization and sense of original geometry. (Avelar, et al., 2006)

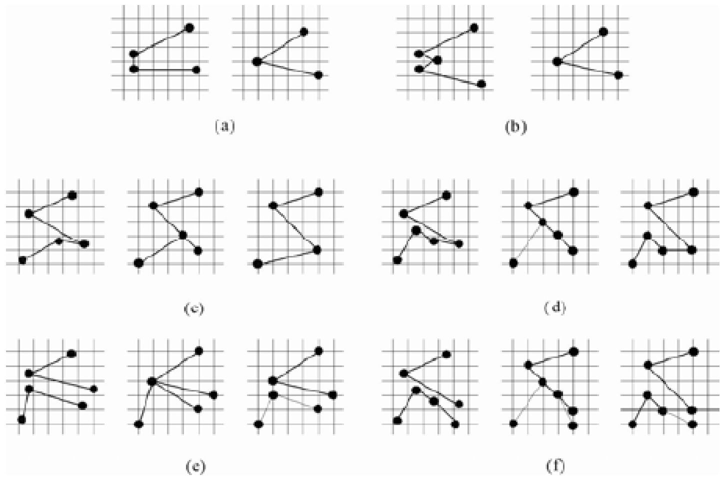
Things get complicated when multiple nodes or features are nearby on the map. For example, difference in densities of downtown and city fringes. Congested areas are increased to scale at the expense of scale in areas with lesser density (Ware, et al., 2006). Sometimes maps are supported with textual data to supplement the loss of proximity and scale.

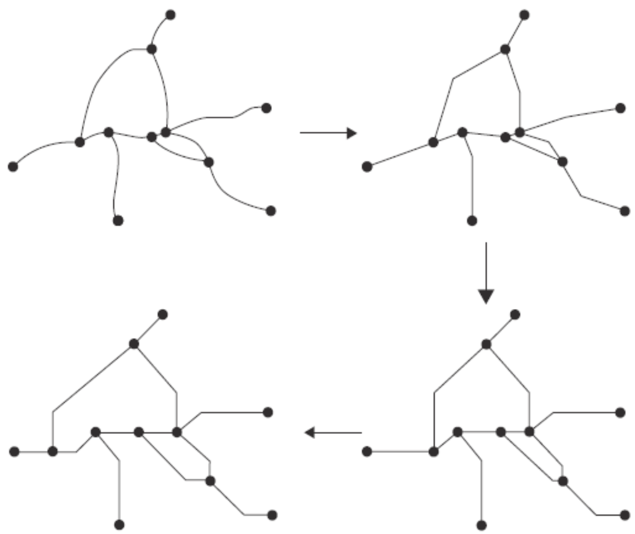
Weihua et al.'s square grid model to approximate nodes to the nearest vertex of the grid



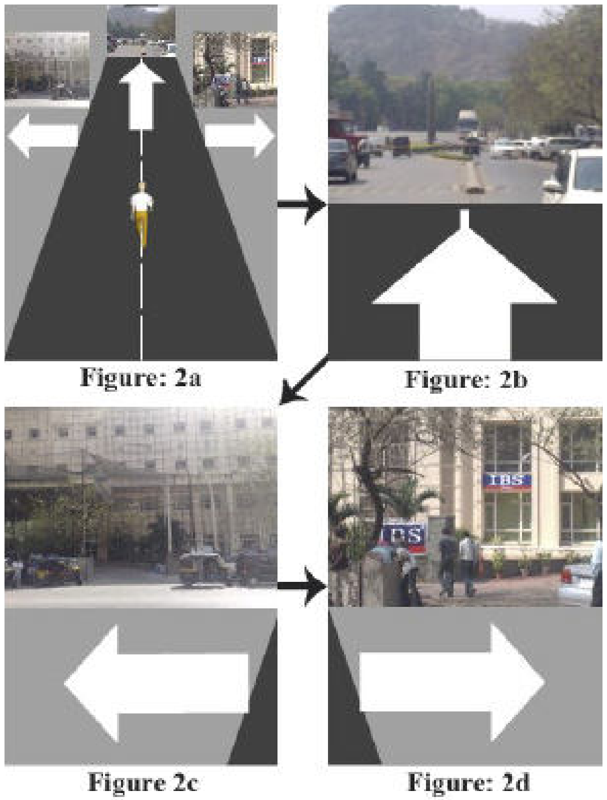
Weihua's examples of various nodes getting approximated to nearest vertices.

Here, we can see examples of multiple nodes being approximate to a single vertex and how they are being simplified.

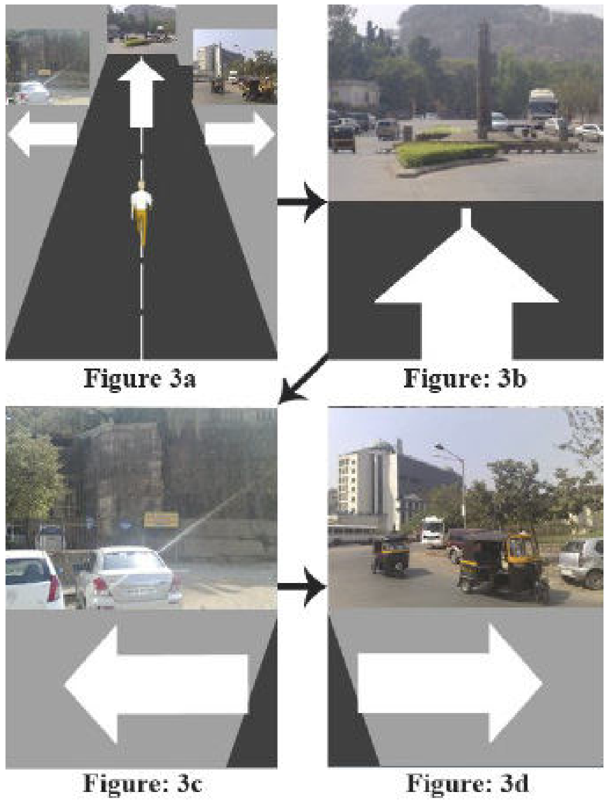




Ware et al.'s computational model converting a geographic route into a schematic. The order starts top left, then top right, bottom right and then bottom left. Note that congested nodes were freed up by providing more space between the nodes, in the third and fourth iterations.



Audio-visual interface used by Joshi et al. to guide the user using landmark photographs. The user is shown multiple photographs on reaching an intermediate location and then proceeds further.



The user inputs his confirmation by pressing 1 or 2 on the mobile keypad. The position of the landmarks is shown by the directional arrows

Landmark-based Navigation

Studies have shown landmark-based wayfinding applications to be more effective than those which don't support them.

Anirudha Joshi et al, in their explorations of designing landmark-based interfaces for less-educated users developed a method where the user was directed towards his destination using series of photographs of landmarks along the route. (Joshi, et al., 2012)

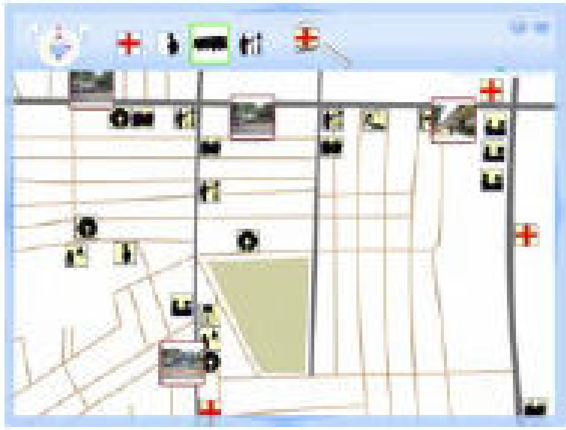
On a mobile interface, the user was provided with landmarks (photographs) which he has to reach and confirm by pressing a button on phone. The audio-visual application then provided further navigation instructions. Landmarks here were nodal points where the user must take a turn from the current direction of travel. The idea was tested on a fixed path. As the concept was designed for and tested with low-literate users, the application gave positive results.

As the concept worked on the premise of non-GPS enabled devices, triangulating the current position of the user without intervention is a problem. Viability of the chosen landmarks is usually based on people's perceptions. This is a problem in any landmark-based navigation system. Also, there are chances that this may not work if the distance between two landmarks is high or in low-light conditions where structures may not be clearly visible.

Indrani Medhi et al, in their work on text-free user interfaces created a navigation interface that used a simple planimetric map overlaid with icons and images (Medhi, et al., 2005). Though the experiment was not on wayfinding, the fact that almost-illiterate users could use this interface successfully is a proof that visuals work better than instructions even in wayfinding.

Anahid Basiri et al, explored a similar concept where a landmark-based navigation for pedestrians was developed for a controlled environment of a university campus. They relied on the fact that people in an unfamiliar location notice prominent structures to find their way around. These objects are unique and it would be easier to remember and recollect them from memory (Basiri, et al., 2013). However, pedestrian navigation is different from car navigation as there is more freedom for movement and a higher tolerance for error. (Corona, et al., 2005)

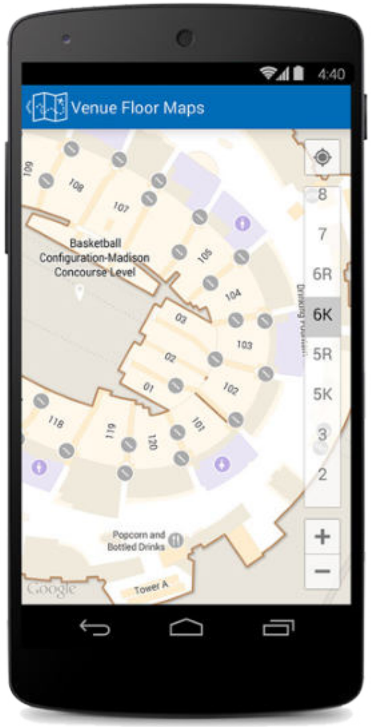
Usage of wireless infrastructure has often been tried to track the location of the user (Cheverst, et al., 2000) (Ledlie, et al., 2011), but this may not be scalable except for indoor navigation.



Map overlaid with icons and thumbnails of landmarks and important buildings on the route

Users using Google's Indoor Maps use known indoor locations like shops to reach an unknown destination within a building/mall.

Nokia City Lens overlays data over live camera images to through AR



Indoor Navigation

In indoor navigation, usage of sensors (like Apple's iBeacon and Qualcomm's Gimbal) to track and communicate with the user is now being adapted widely. Some of the systems use indoor dead-reckoning to determine the position of the user. Markers like QR-codes and vendor-specific markers have also been used. Though these have been successful to a certain extent, they can only be implemented in locations like malls or universities but not scalable for a city (Chandgadkar, 2013).

The recent introduction of Google Indoor Maps has taken the concept of indoor navigation impressively ahead but this feature is available only for very few locations and needs extensive manual mapping of the location. (Google, 2014)

Another popular software Nokia City Lens uses augmented-reality to give dynamic information about user's surroundings through the camera (Windows, 2014).

Walther-Franks in his study on AR-based see-through navigation solutions considered such solutions costly for mobile devices and instead suggested using incremental guidance augmented with photos (Walther-Franks, 2007). This is similar to what Anirudha Joshi et al. (Joshi, et al., 2012) had done with their application.

Hypothesis

With the information so far, the following hypothesis was formulated.

"If local landmark data is integrated with schematic maps, they can be an effective way of navigation and will facilitate faster retracing of the route, than using a planimetrics-based map."

The basis of the hypothesis were studies where schematic maps have been seen to be more effective than planimetric maps or written descriptions. By using schematic maps people will have lesser information to process, leading to an easier understanding of the information provided. When these maps are overlapped with landmark information in the form of visuals from the view of the user, making sense of the location becomes easier. This will also help in faster recognition and recall of the route during subsequent travels.

Landmarks here will be nodal points that will be used to change the direction of travel or act as checkpoints along the route which the user needs to pass during his journey. The checkpoints will be intermediate points which will help user know that he is on the right path. A landmark can be any monument or prominent structure on the assigned route.

A structure can be classified as a landmark along the route if it has the following characteristics:

1. Visually prominent and identifiable compared to the surrounding environment
2. Large enough to be easily recognizable even when the user is moving (travelling in a vehicle)
3. Landmarks must act as nodes where the traveller needs to turn the direction of travel and as intermediate checkpoints between the nodes.

Landmarks may be naturally occurring (like trees, hillocks, etc.) or man-made (like stores and buildings). Some of the landmarks which people use on a regular basis are mentioned below

General landmarks

Banks, ATMs, schools, malls, movie theatres, post offices, traffic signals, intersections, bus stops, railway stations, statues, hospitals, bridges, fountains, religious places of worship, elevation in the road, parks, hoardings, and other prominent locations.

Landmarks from user studies (specific to India)

Mother dairy outlets, trees, colour of buildings, slums, electric poles, banyan trees, fish markets, post-boxes, tiny temples and *dargahs* under trees, rickshaw stands, road side shops (like ironing store, cobblers, cycle shop, *pan* & cigarette shops), street vendors, drainages, broken walls, garbage bins, *chabutras*, political party offices, police outposts, policemen, gated communities (like *chawls*), minarets, electric transformers, religious flagpoles (e.g. *Naksha Sahib*), prominent cultural residences (*pol*), public toilets, names of grocery stores, flyover pier numbers and other prominent locations.

Final Design

The ideas generated in this section utilize the concepts of landmark-based navigation along with schematic maps to create a new navigation system. The main emphasis is on how landmark images are conveyed to the user and to make the last leg of the journey easier.

The user will be able to navigate and find his way through the help of schematic maps that uses landmark photographs. The schematic map will contain nodes and checkpoints. Checkpoints will help the user know that he is on the right path. Nodes are points where the user need to take a turn from his current direction of travel. These are clearly displayed the map.

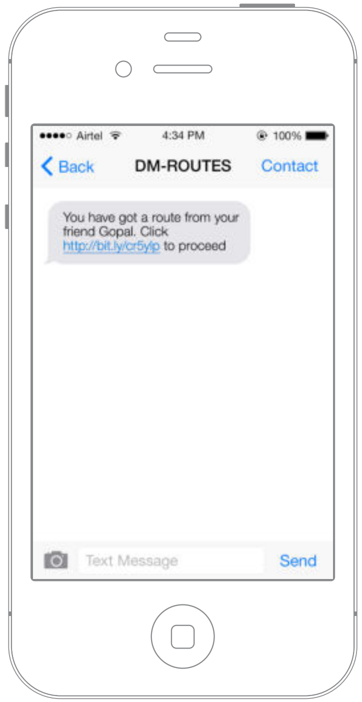
The map will be approximated from an existing path roughly using Weihua's square grid model (Weihua, et al., 2008) and then landmark photographs will be marked on it. Each nodal point on the map will have more than one photograph for easy recognition.

Users will be able create custom routes or use existing maps that would be automatically or those created by other users. Maps can be created by selecting existing photographs of landmarks or by uploading new images by the user. The images may be geotagged for easy landmark approximation. The maps are shareable with other users who can access them via the web or any mobile device. The data collected via crowdsourcing can be microstasked and once again crowdsourced for validation.

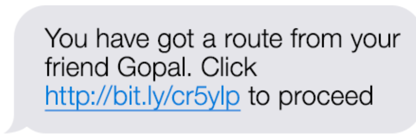
For testing the application, the prototype of the current idea will be measured against a standard application like Google Maps. The details of the testing are given in the Evaluation section of this report.

Scenario 1: Using the app

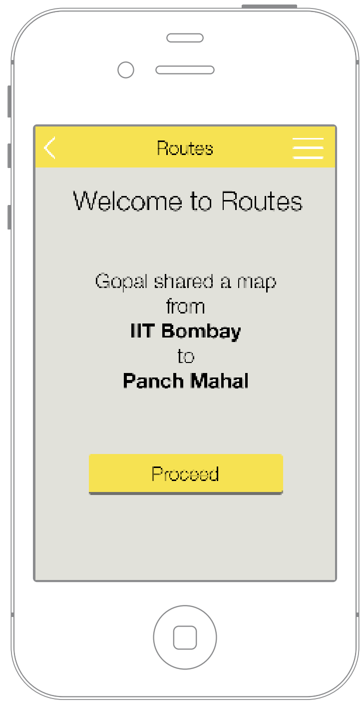
Surya gets an alert on his phone. It is a message from an application Routes.



Surya opens the phone to see that his friend Gopal has sent him route to his home via SMS

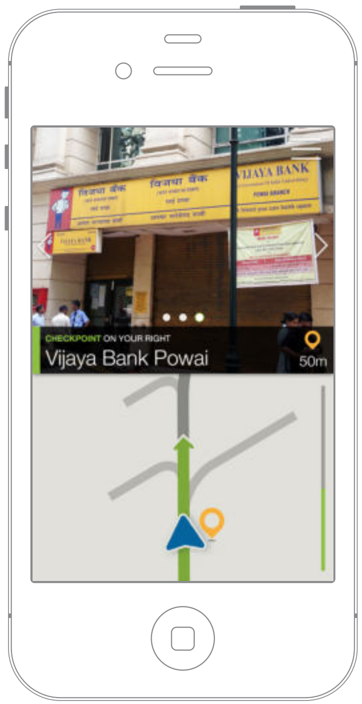


The SMS has a link in it, which Surya clicks to see what happens.

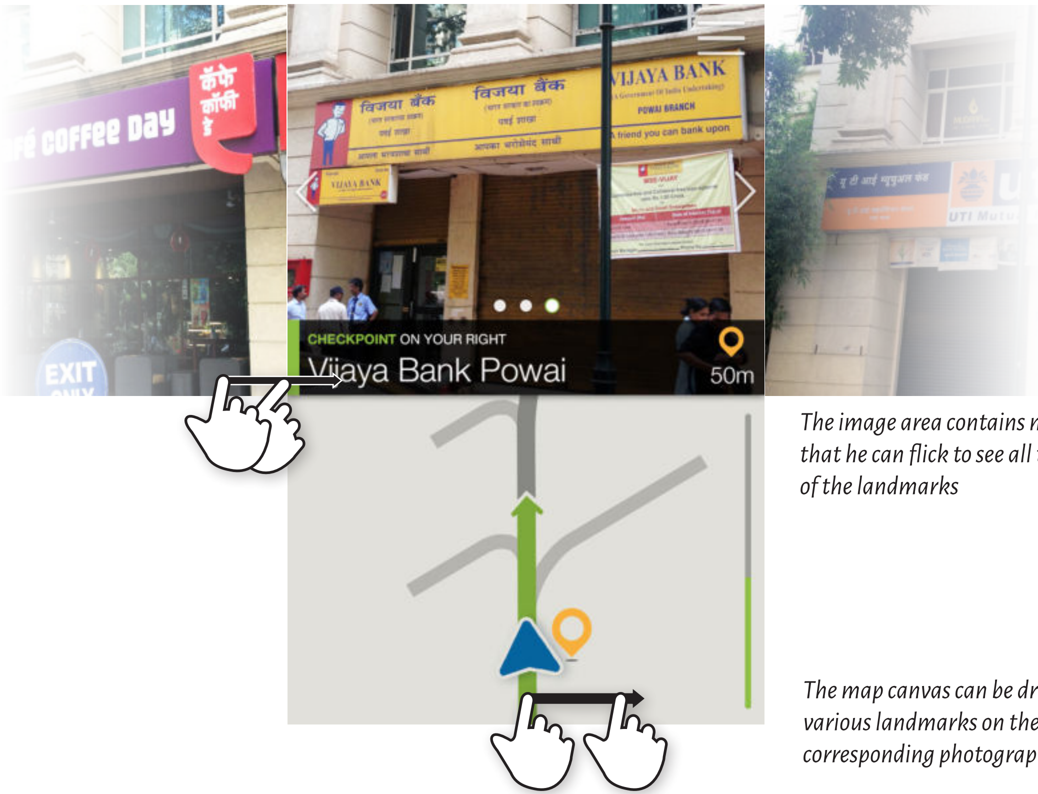


Surya is redirected to the app page and he gets a notification about the route that was sent to him.

Navigation Interface



Surya sees that the navigation interface has two components-the upper part contains the landmark photographs and the lower part contains the schematic map.

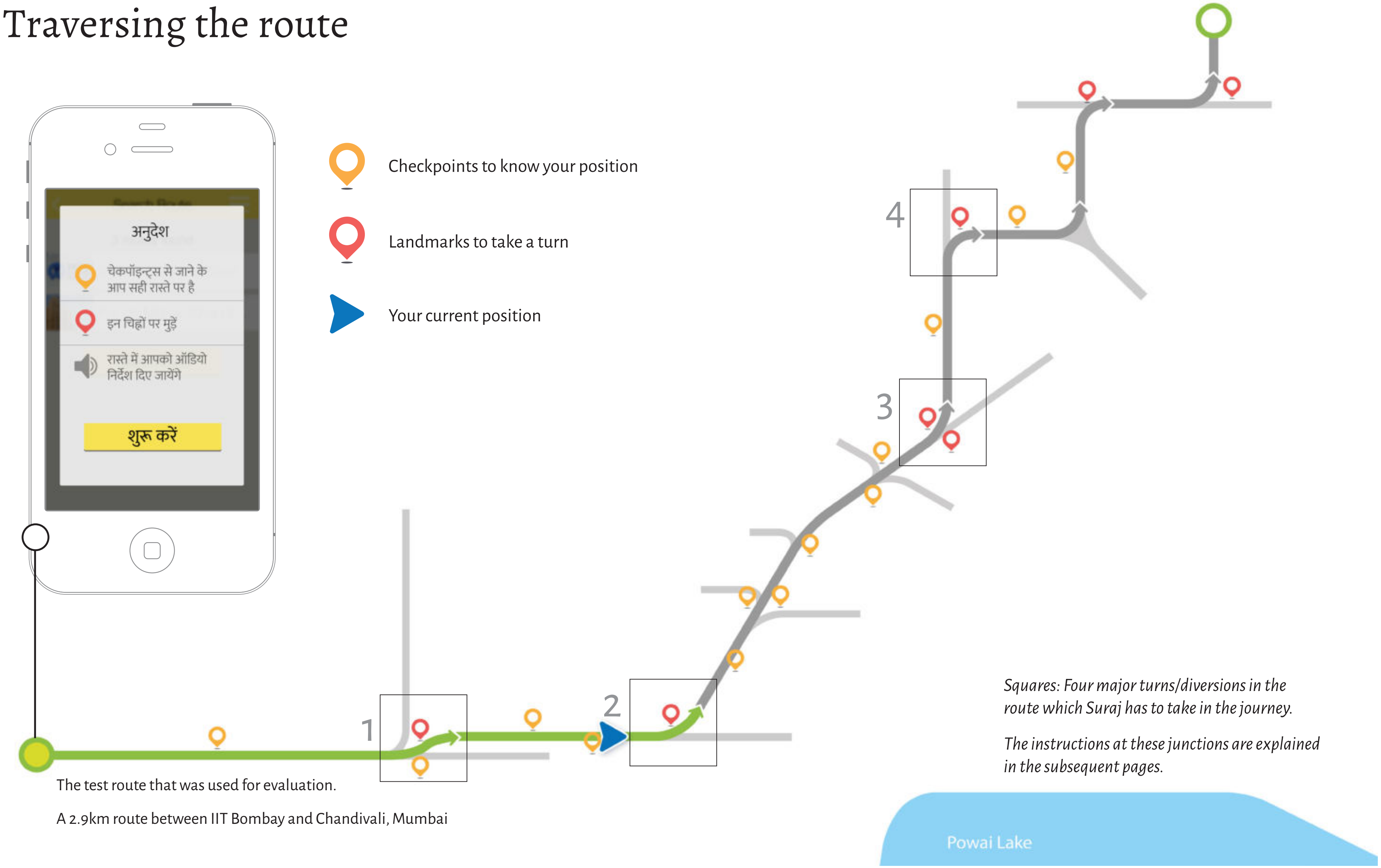


The image area contains multiple images that he can flick to see all the photographs of the landmarks

The map canvas can be dragged to see the various landmarks on the route and their corresponding photographs.

The icon shows his current position on the map. This is determined by using GPS, Wi-fi positioning or dead-reckoning.

Traversing the route



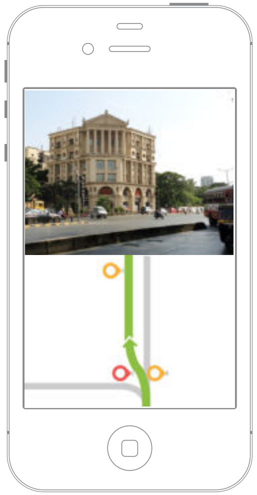
The test route that was used for evaluation.

A 2.9km route between IIT Bombay and Chandivali, Mumbai

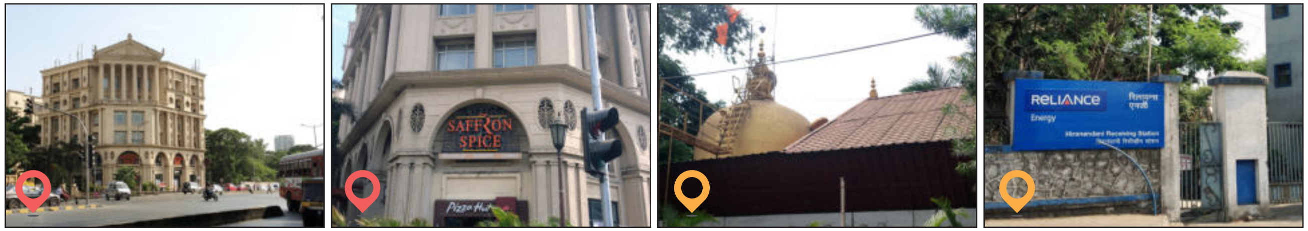
Squares: Four major turns/diversions in the route which Suraj has to take in the journey.

The instructions at these junctions are explained in the subsequent pages.

1



Example 1: *The first point in the journey where Suraj take's a slight diversion, but not a turn.*



"Drive onto the service lane next to Saffron Spice/Pizza Hut in front of you"

"सैफरन स्पाइस / पिज़्ज़ा हट से लगे हुए सर्विस लेन में आगे बढ़े"

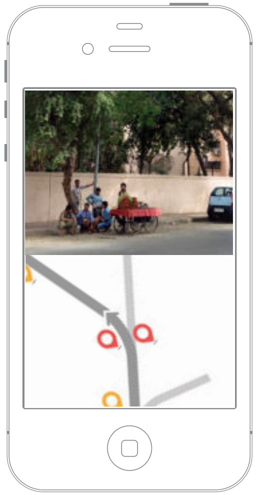
2

Example 2: *The first turn in the route where Suraj takes a turn.*

"On your right you will pass Suvarna Temple. At the next junction is the Powai Commissioner Office. Take a left here."

"अपने दाएं ओर स्तिथ सुवर्ण मंदिर से गुज़रेंगे।
अगले मोड़ पर पवई आयुक्त कार्यालय हैं। यहाँ बाएं मुड़े।"

3



“On your right is a cobbler and BEST bus stand. Take a left in the opposite road.”

“आपके दाएं ओर पर एक मोची और बेस्ट का बस स्टँड होगा। इसके आगे वाले मोड़ पर बाएं मुड़े।”

Example 3: A turn in the journey, where he takes a turn using multiple landmarks.

4

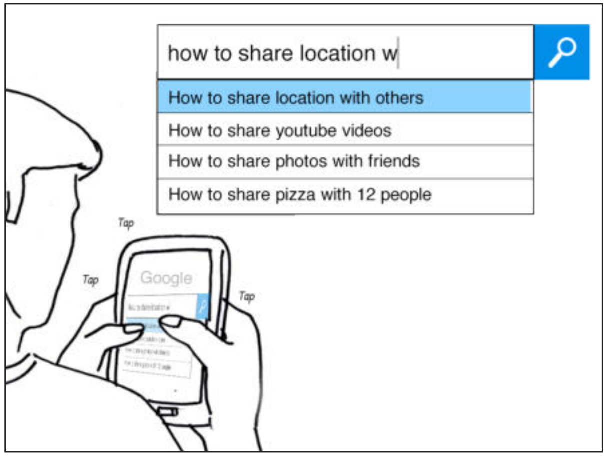
“After crossing Jal Vayu Vihar on your left, find SM Shetty School on your right, a big building on your right. Take a right into this street”

“अपने बाएं ओर जल वायु विहार से गुजरने के बाद, अपने दाएं ओर एस एम शेट्टी स्कूल ढूंढे, जो एक बहुत बड़ी इमारत है। इस गली में मुड़ जाए।”

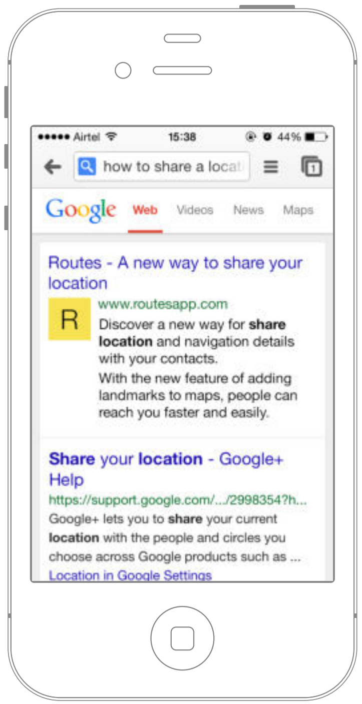
Example 4: A turn using a singly available landmark, but a prominent one.

Scenario 2: Creating a route

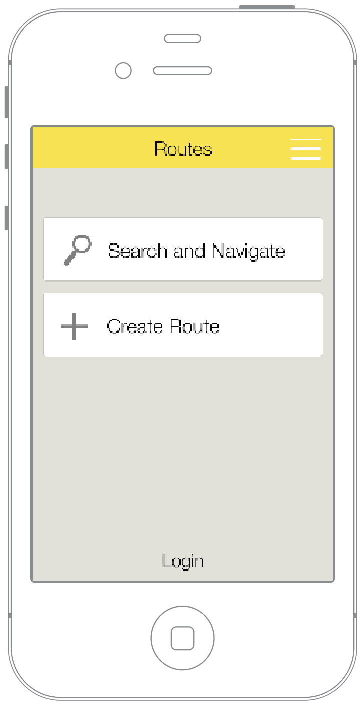
Gopal invites his friends to his home, who have never been to his place earlier.



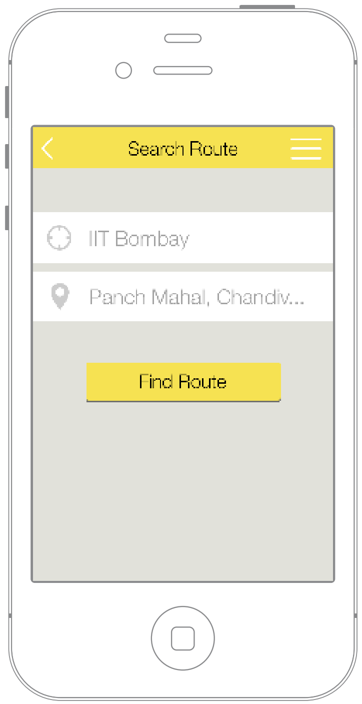
Gopal searches for an easy way to share maps with his friends so that they do not get lost.



A search on the internet shows 'Routes' as the new app using which people can share location.

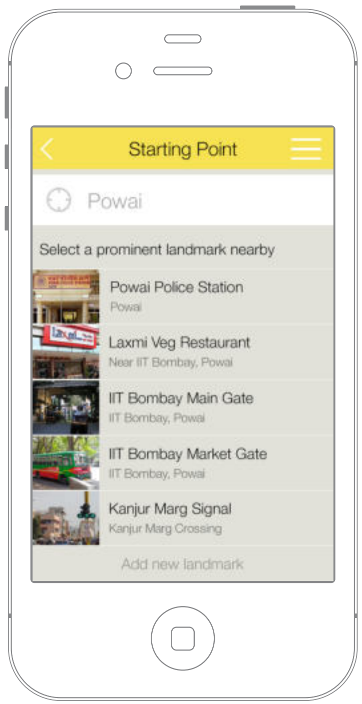


Gopal visits the website to see that he has two options to use - to create a route and to search a location.

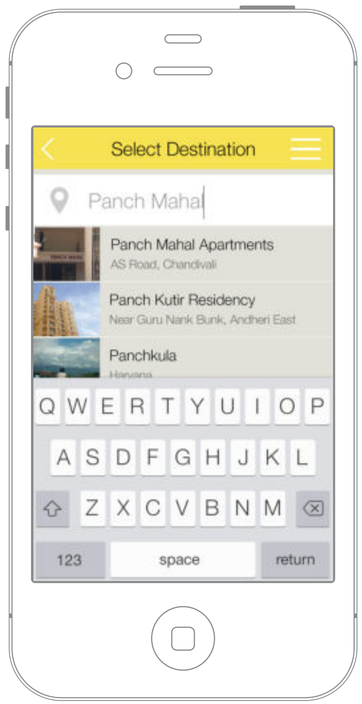


Gopal inputs his current location as 'Powai'

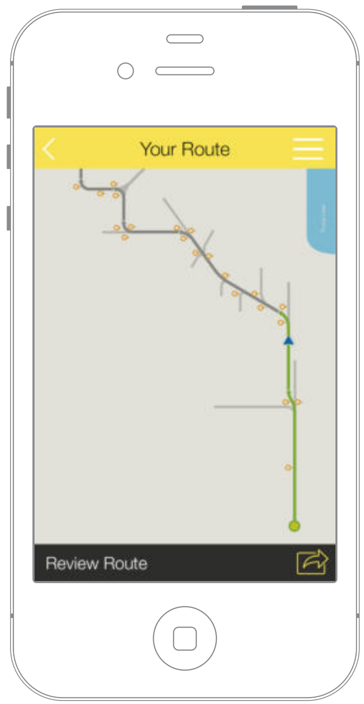
Scenario 2



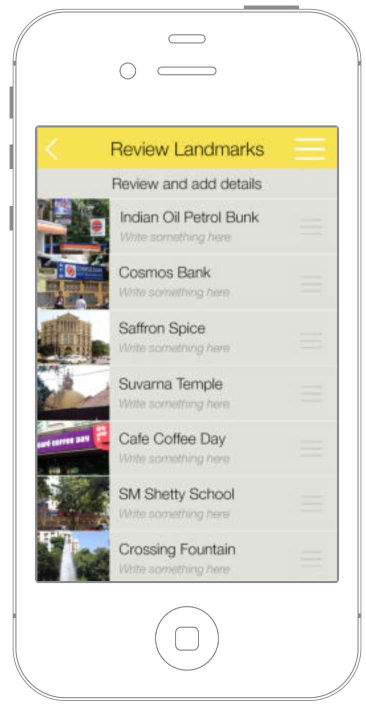
The app shows Gopal the existing locations that he can choose from which are prominent landmarks.



He then enters the final destination and the app once again suggests him some options.

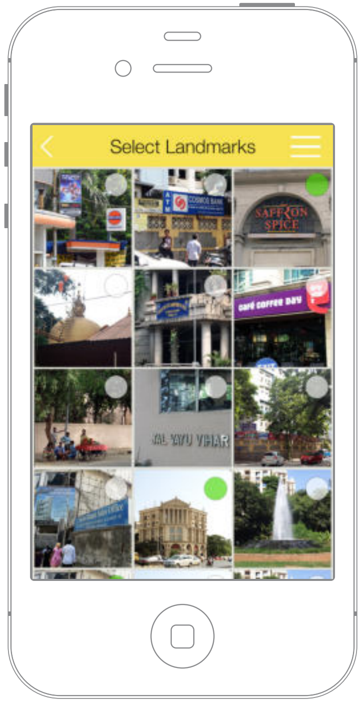


Gopal finds that the route is already mapped between the intended points.

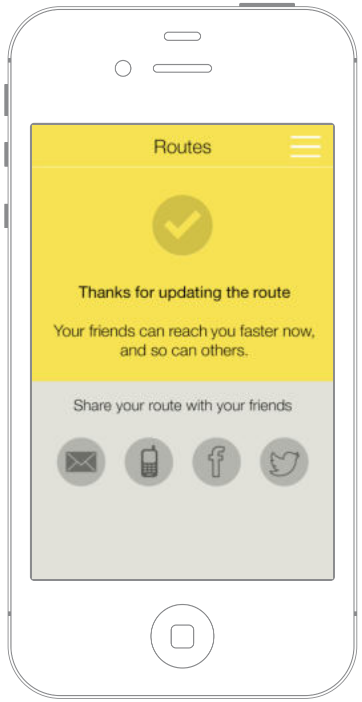


He then reviews the landmarks on the route. But finds that some of the images are old and outdated.

Scenario 2



Gopal uploads the latest images of the location from his album and updates the database.



Gopal shares the map he just created with Surya and his other friends who are coming home for the party.

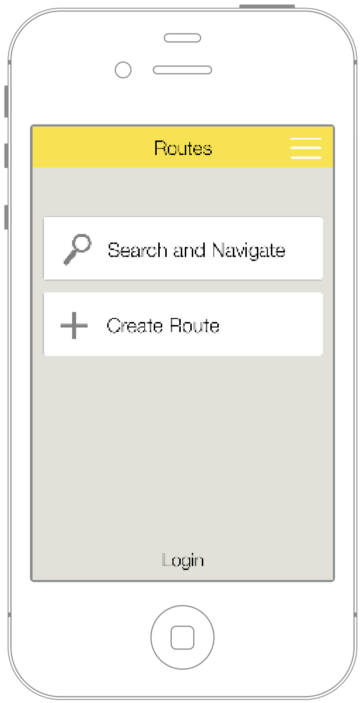
Scenario 3: Searching Route

Nitin and Vikas are new to their job at the Delivery Centre in Mumbai and have no clue about some of the routes in the suburbs

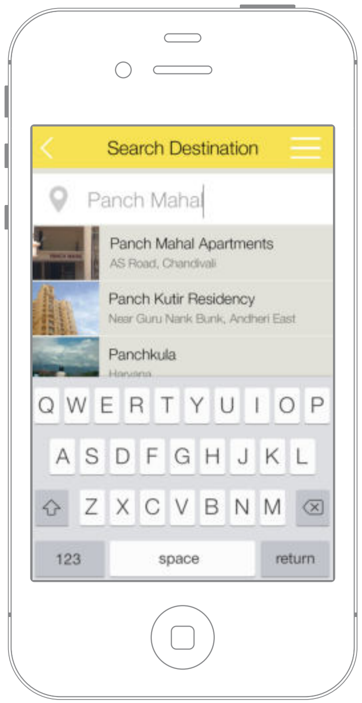
Bhandari, their supervisor hears their conversation and suggests that they use the Routes app to find their way around for deliveries.

Both of them try to use the app while they are out for their next delivery.

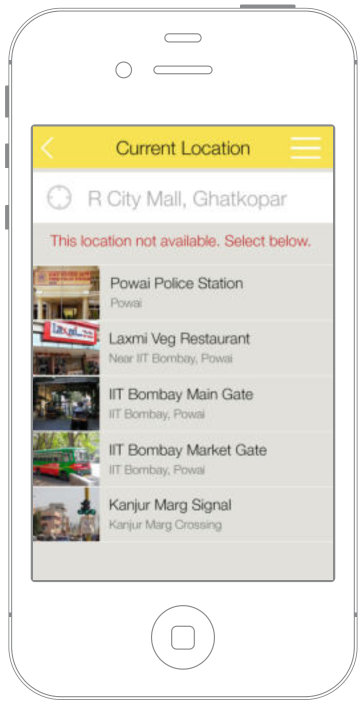
Scenario 3



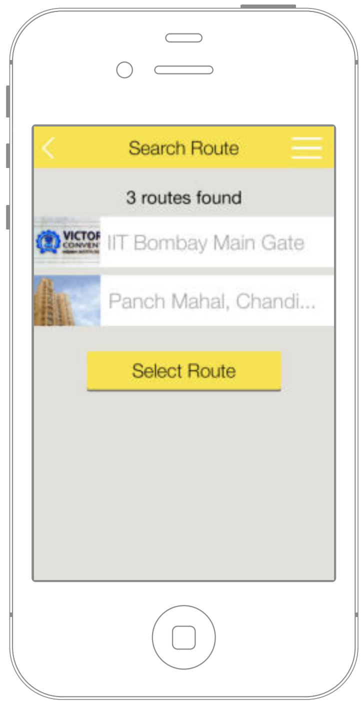
Nitin opens the app and chooses the option to Search and Navigate.



He enters his destination where he has to deliver the package.

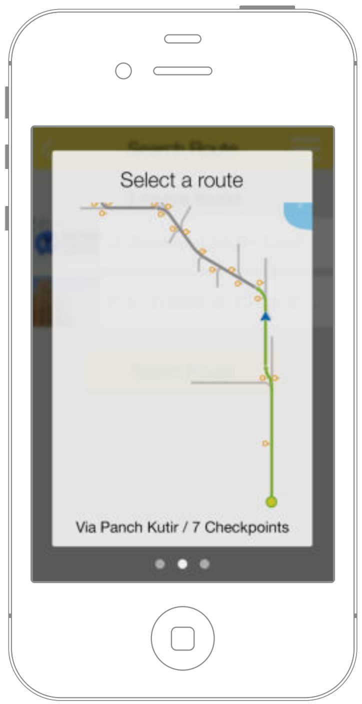


The app asks him for his current destination so that he can be guided. But as the location is not available, he is given an option to choose from the existing ones.

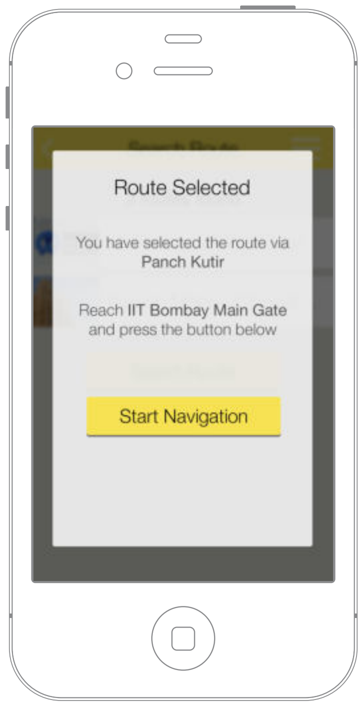


Once the data is input, the app shows that there are 3 existing options in this route.

Scenario 3



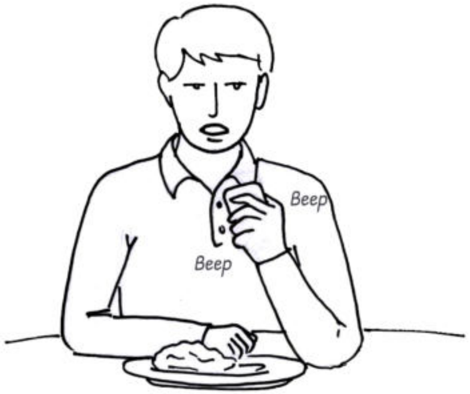
Nitin is happy to find exisitng routes and chooses the shortest one which is through Panch Kutir.



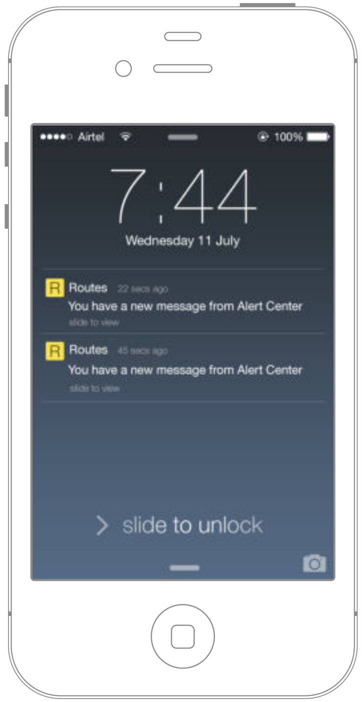
The app confirms his selection and asks him to hit 'Start' when he reaches IIT Bombay. Meanwhile, the app tracks his position via GPS.

With all the information in hand, Nitin and Vikas are waiting to reach their start position.

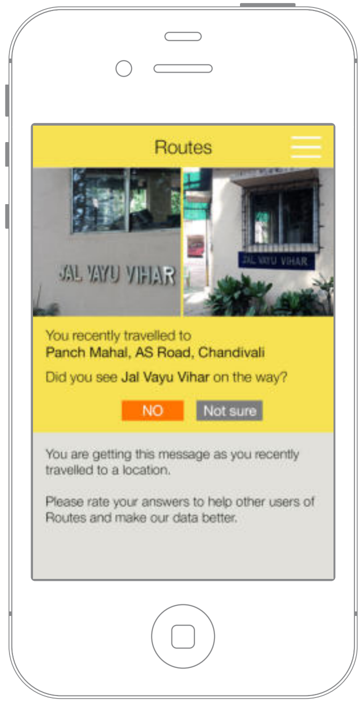
Scenario 4: User Validation of Data



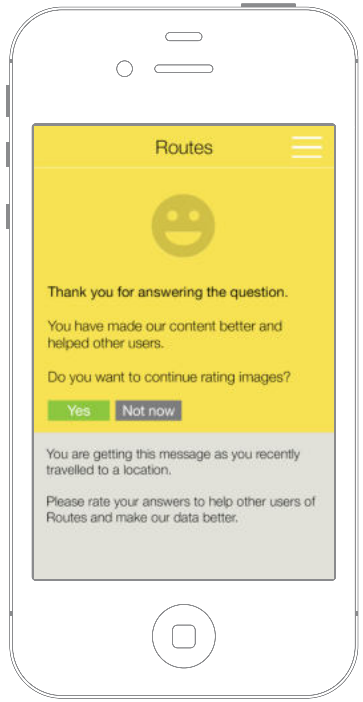
A few hours after delivery, Nitin gets an alert on his phone.



It is an alert from the Routes app, which surprises Nitin.

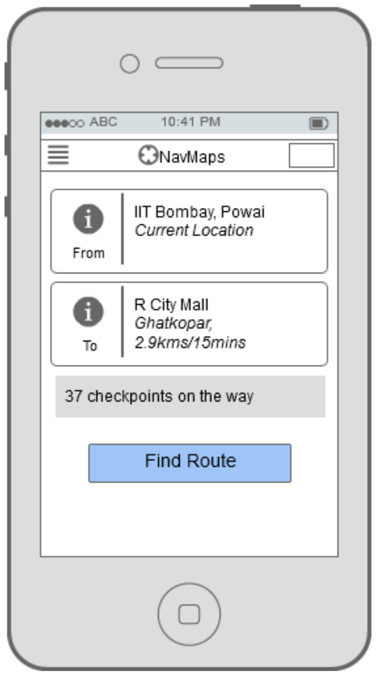


On opening it Nitin finds that the app is asking a question from the route he travelled earlier today.

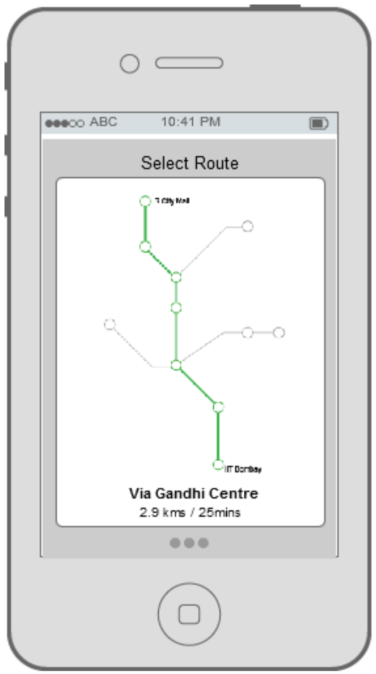


Nitin is happy that he was able to help validate the information that Routes has and that it has helped other users.

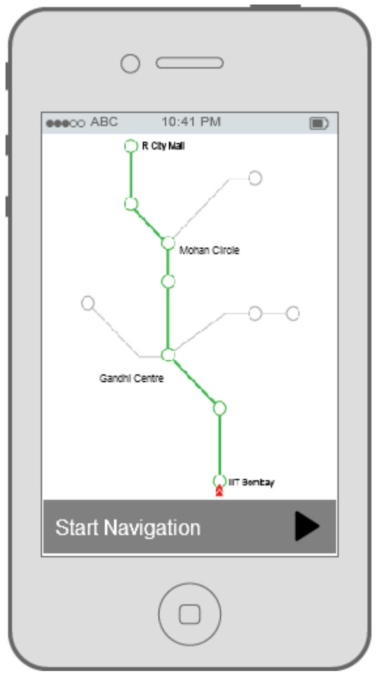
Initial Wireframes



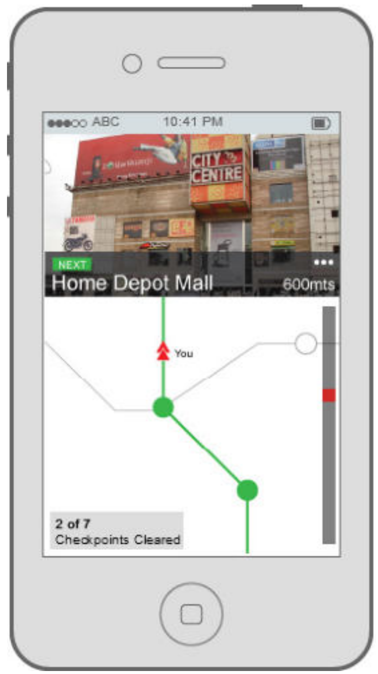
Initial screen to search or input the starting and ending points of the journey



The user can select from a choice of multiple route options that may be provided to him.

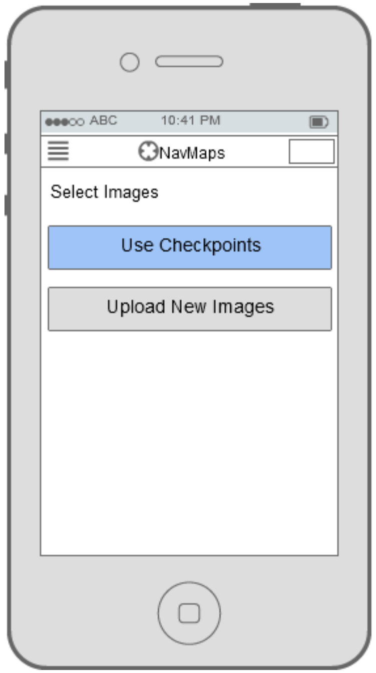


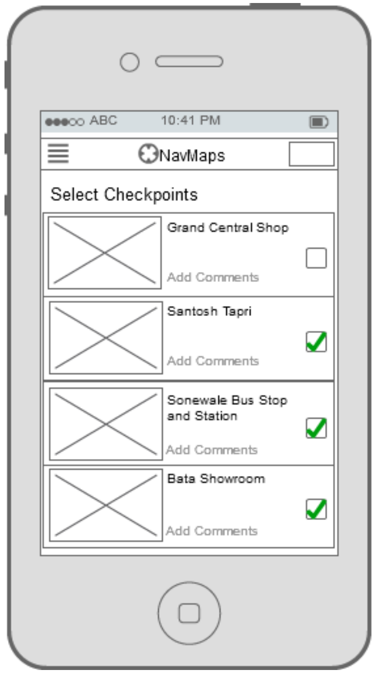
The user can review his selection and before starting on the journey.

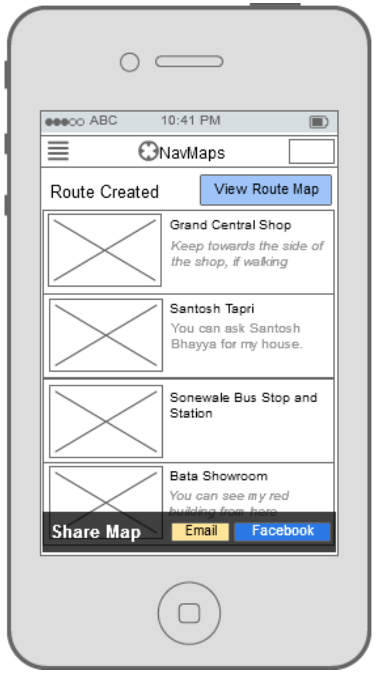


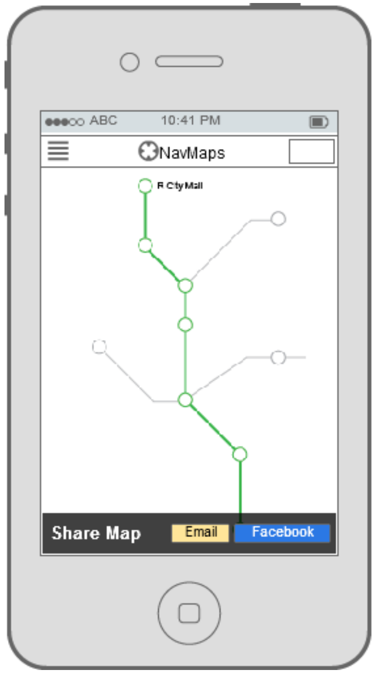
Each dot on the map corresponds to a landmark and the respective photographs are shown on top.

On the right is a bar to show the journey covered by the user.









Option for user to create route using Checkpoints

The user can select existing images of checkpoints or upload new ones to create the route

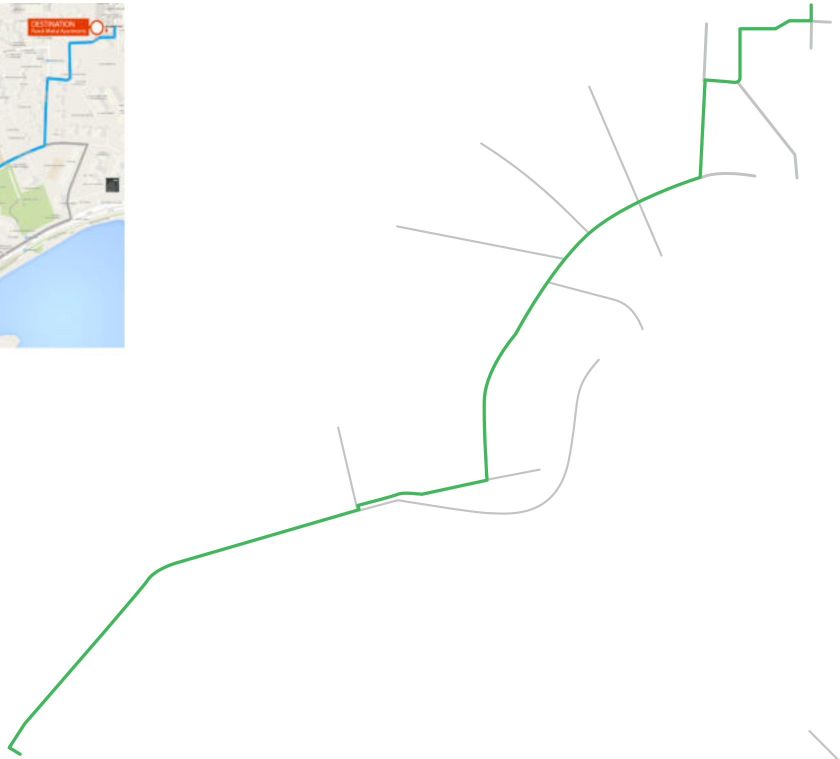
The route, once created, can be traversed just using photographs or along with the schematic map.

The schematic map of the route can be used along with photographs to complete the journey. The routes are shareable with other users.

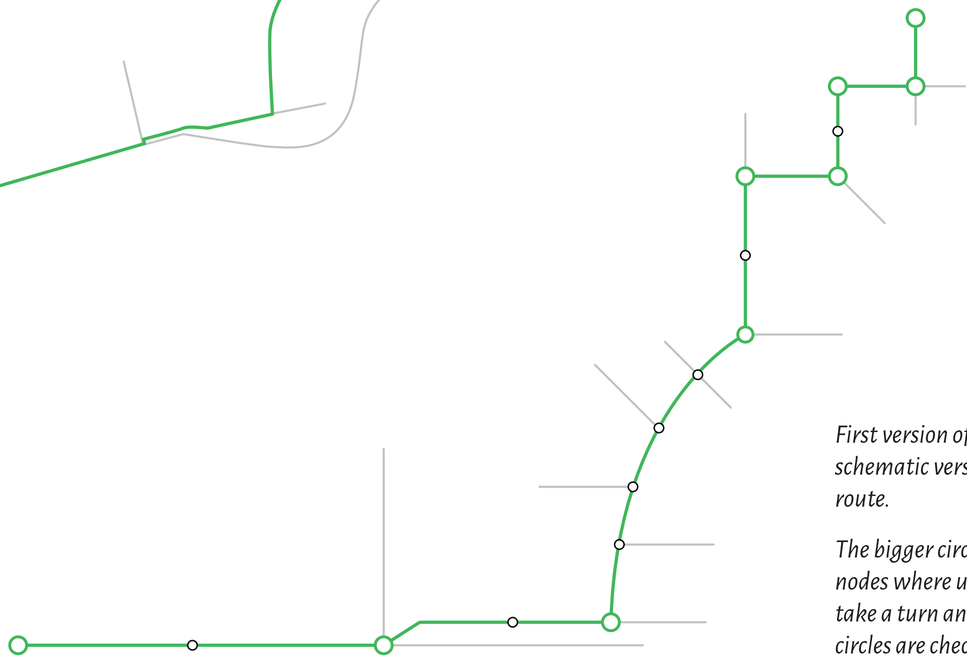
Creation of Schematic Map

A random route with enough complexity selected in Powai, Mumbai. The route is from IIT Bombay camps to Panch Mahal Apartments, Chandivali, a distance of 2.9 kms

Image Source: Google Maps

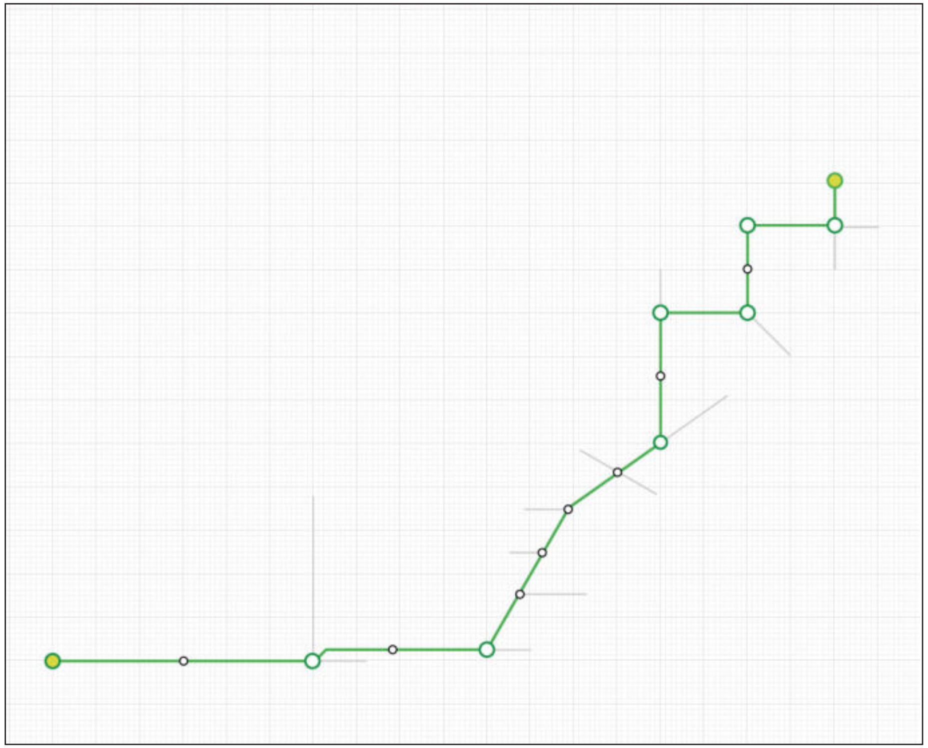


A simplified sketch of the route showing just the route to be travelled and a few adjoining roads.

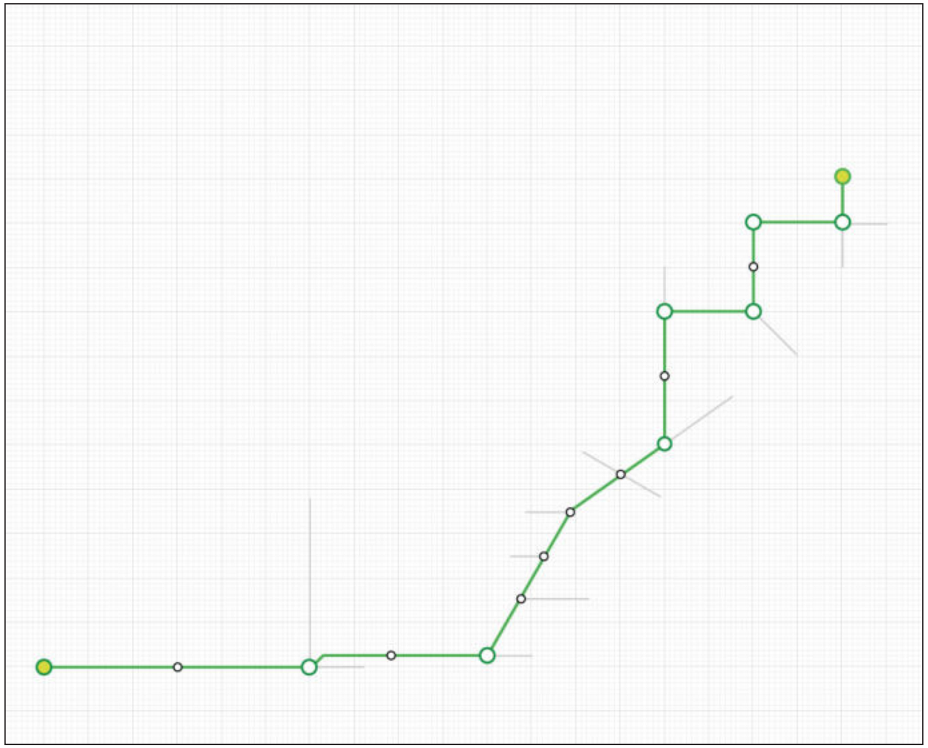


First version of the schematic version of the route.

The bigger circles indicate nodes where user needs to take a turn and the smaller circles are checkpoints.

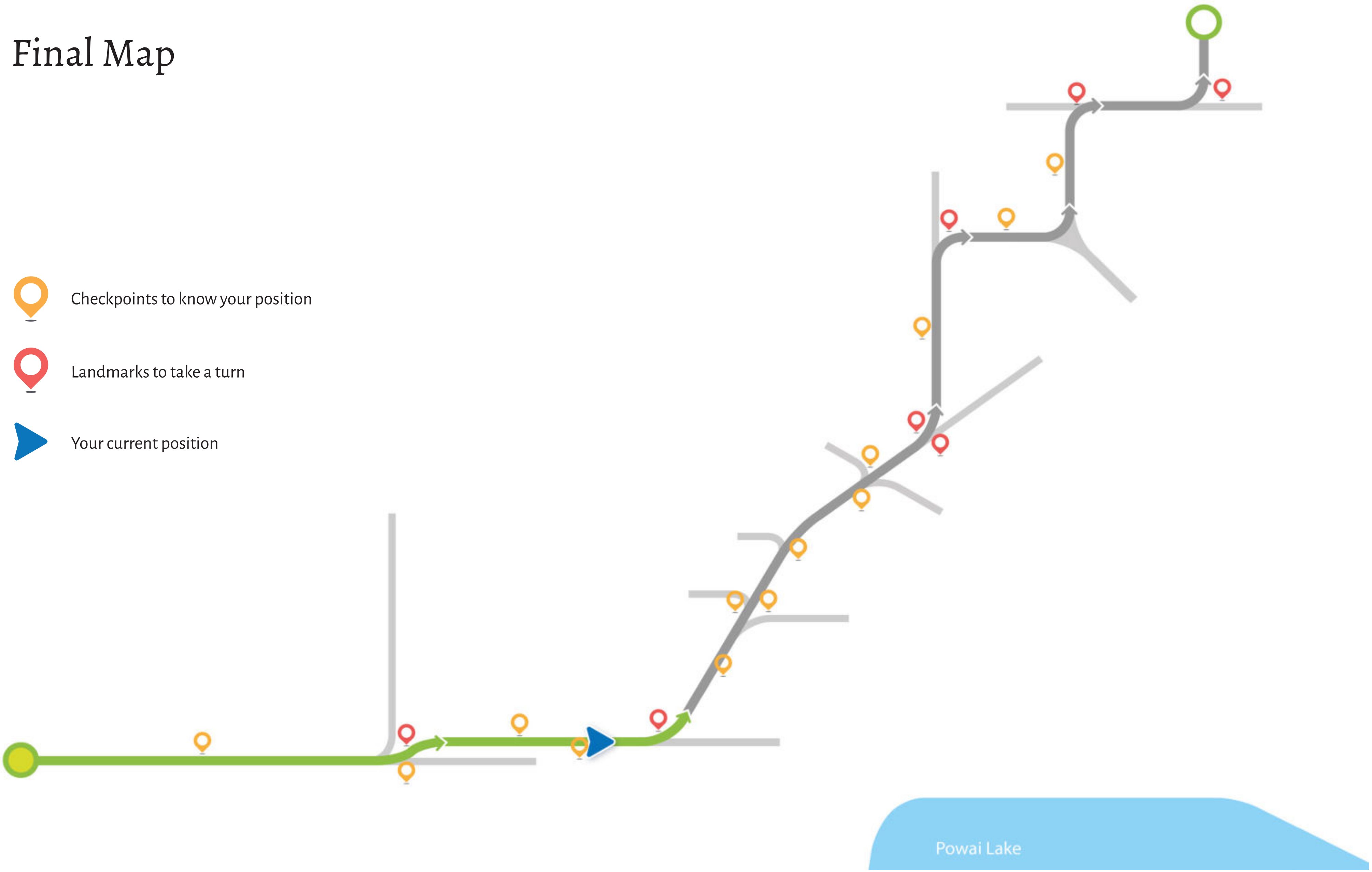


A square grid technique was followed to further refine the making of the schematic map. The earlier version of the map was overlaid with a square grid and the nodes were approximated to the nearest vertices. This would make the maps more uniform and structured.



The map was further simplified by restricting the angles of the routes to 30, 45, 60 & 90 degrees to the maximum extent possible. Further, adjoining roads were also accordingly adjusted for easier reference during the travel.

Final Map



Checkpoints to know your position
Landmarks to take a turn
Your current position
Powai Lake

Photographs by Ramprasad S. and Girish Atuvalaipil

Evaluation

The evaluation was done with the help of prototype of the final design.

User Criteria

As the project was conceptualized with less educated users in mind, the following criteria were used in recruiting users for evaluation.

Education Level: Standard 7-10

Age: 20 years and above

English Proficiency: Fair (Low)

Route for testing:
Route A - IIT Bombay Main Gate to Panch Mahal Apartments, Chandivali, Mumbai (2.9 kms)
Route B - IIT Bombay Main Gate to Supreme Business Part, Hiranandani, Mumbai (2.1 kms)

Total Users: 10

Method

A route between IIT Bombay and Chandivali was chosen due to the convenience of location and time, for testing. The choice ensured that there are enough number of turns ranging from minor diversions, 90 degree turns to curves in the road. It was also taken care that users chosen are not familiar with the place and the final destination.

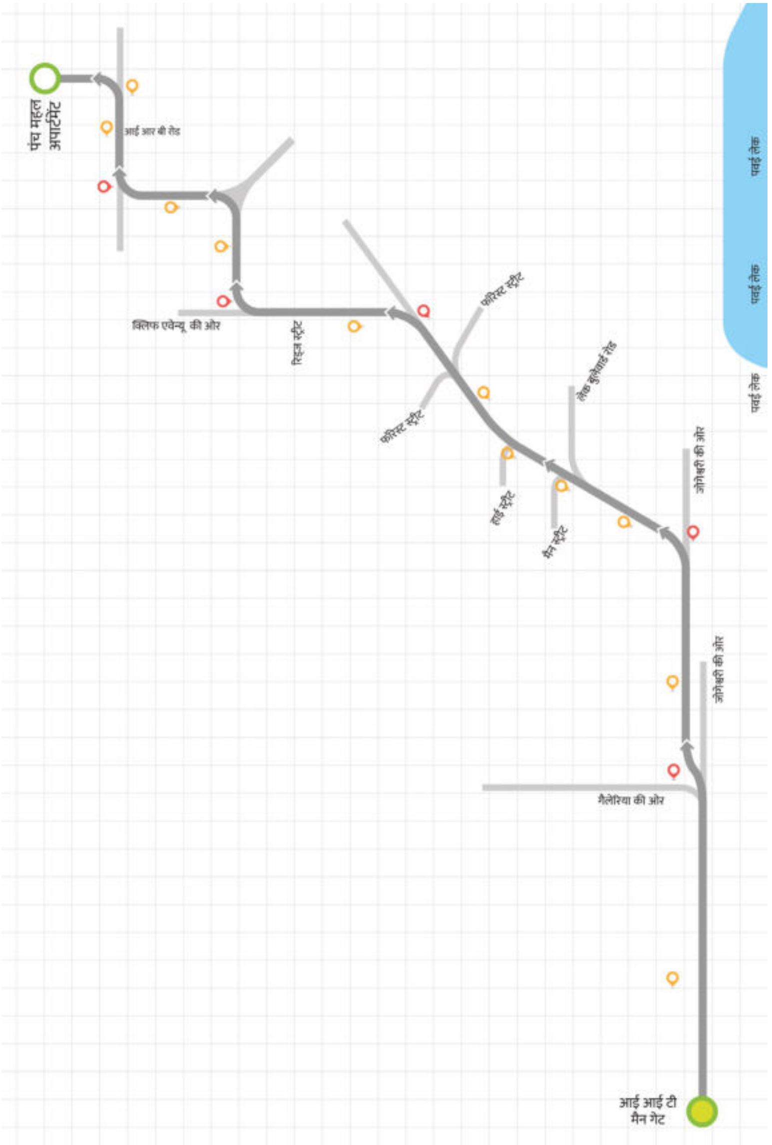
To avoid bias, users were not revealed the route they were travelling. They were briefed on how to use the app and were then asked to follow the directions given by the application. Some users who had never used maps before were explained about the concept of maps before being briefed about the online apps.

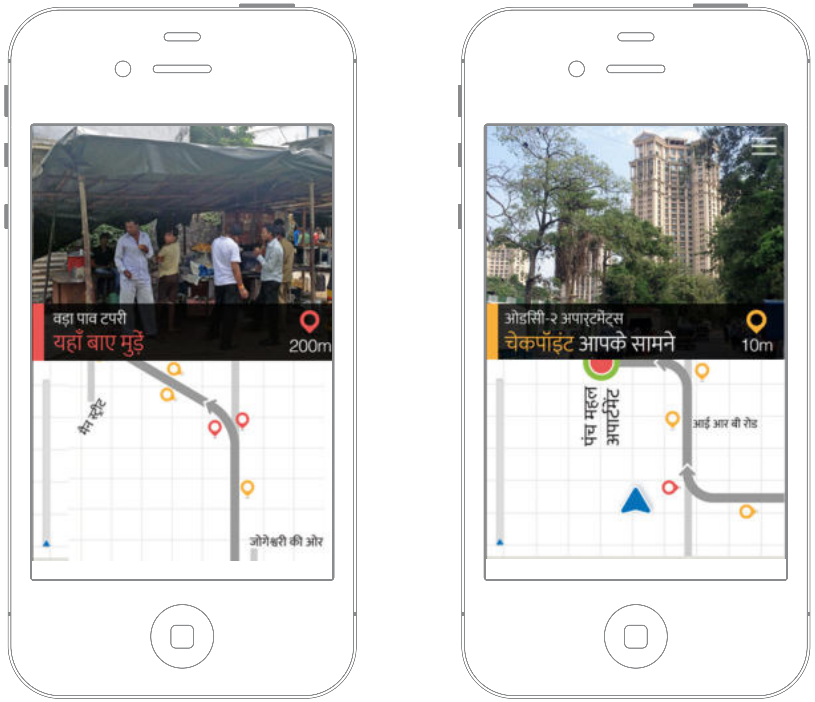
Four of the ten users were asked to follow Route A and reach their destination. Two of the users were given Google Maps and asked to follow the same route. The final set of four users went through A/B Testing where they were first asked to reach the destination on Route B using Google Maps and Route A using the project prototype.

The sequence of A or B was interchanged with subsequent users to avoid bias. 5 of the total users traversed their route via auto-rickshaw while the rest on foot.

The main aim of the evaluation was to know what kind of landmarks were more identifiable by users. Are first-time users of map able to navigate using the application and is the interface usable enough?

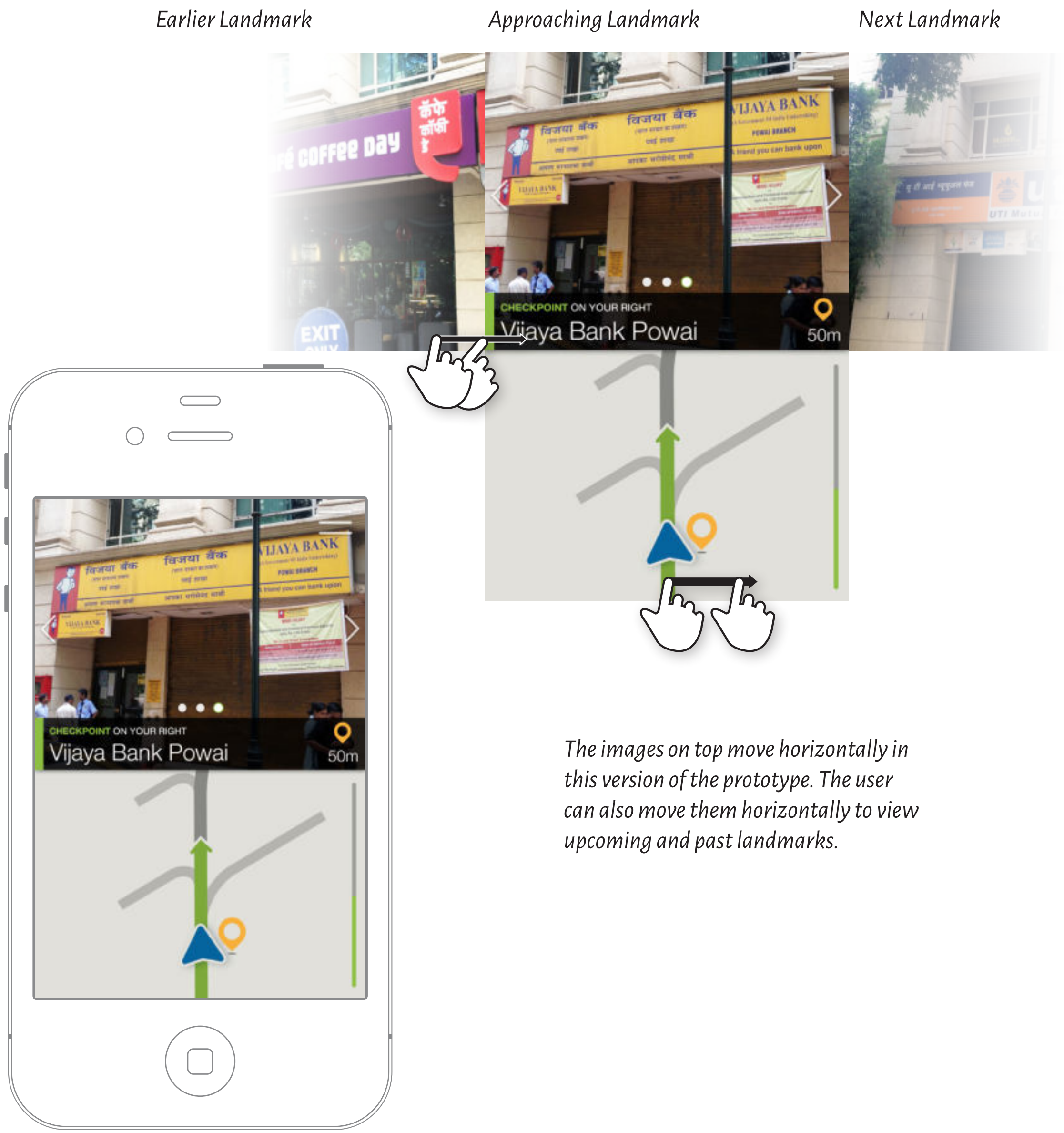
Initial Evaluation





Above is the initial interface that was used for pilot testing as well as for testing with the first set of users. The top section of the interface contains the landmark photograph and the lower half contains the schematic map.

On left is the overview of the map that was used during this cycle of evaluation.



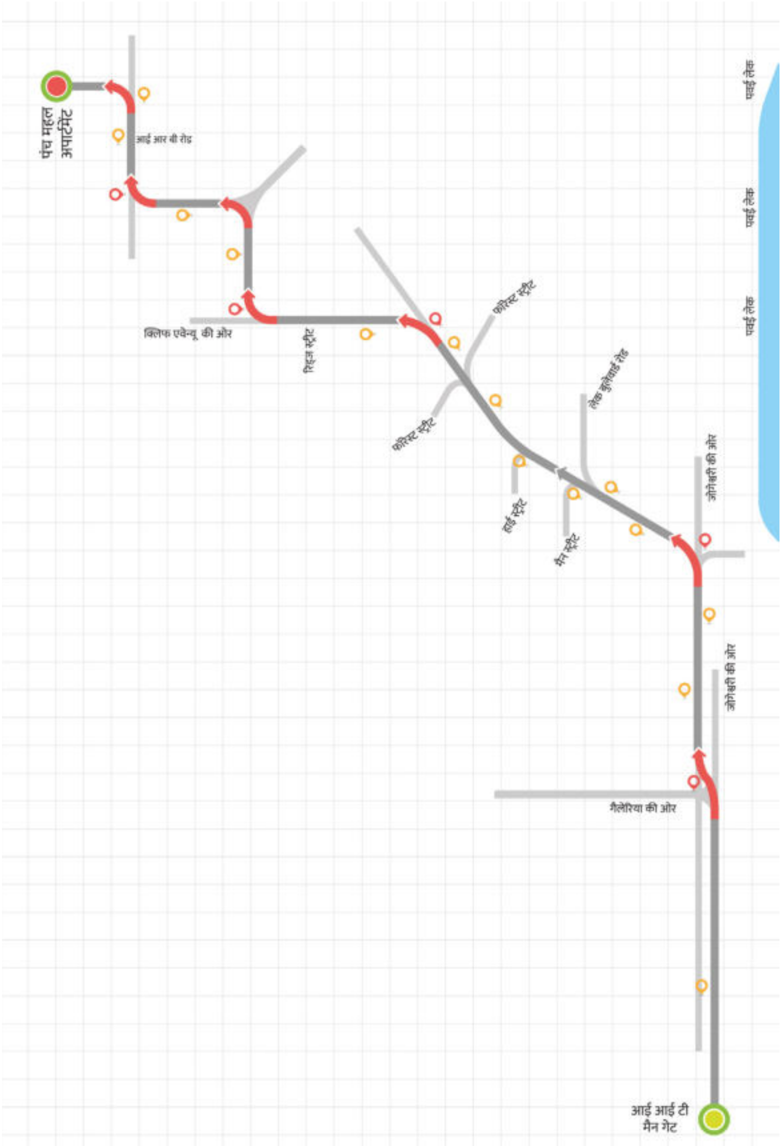
The images on top move horizontally in this version of the prototype. The user can also move them horizontally to view upcoming and past landmarks.

Findings

This version of the prototype was tested in the initial phase and the observations made are mentioned below.

- The users seemed to be concentrating more on the map than on the landmark images.
- As the users had to scroll the map due to prototype limitations, some users scrolled in the reverse direction.
- Pictures that were taken farther from a landmark and showed the complete building were easier to identify than otherwise
- When landmarks were closer, users usually missed them.
- As this set of users did most of the evaluation while travelling in an auto, their position in the vehicle affected finding of landmarks. Users sitting on the left side tend to search for landmarks on the left side of the road and similarly on the right side.

Iteration 1

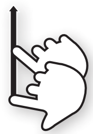


Above: On left is the initial interface and on the right is the modified interface. The central band was moved to the top so that users could concentrate more on the image and consider the whole area as a single entity.

On left is the map that was used during this cycle of evaluation. The turns have been marked red for more emphasis.

Next Landmark

Approaching Landmark



Earlier Landmark

The horizontal movement of the photographs in the earlier design was changed to vertical movement to match with the users mental model.

Changes Made

Based on the earlier findings, the following changes were made.

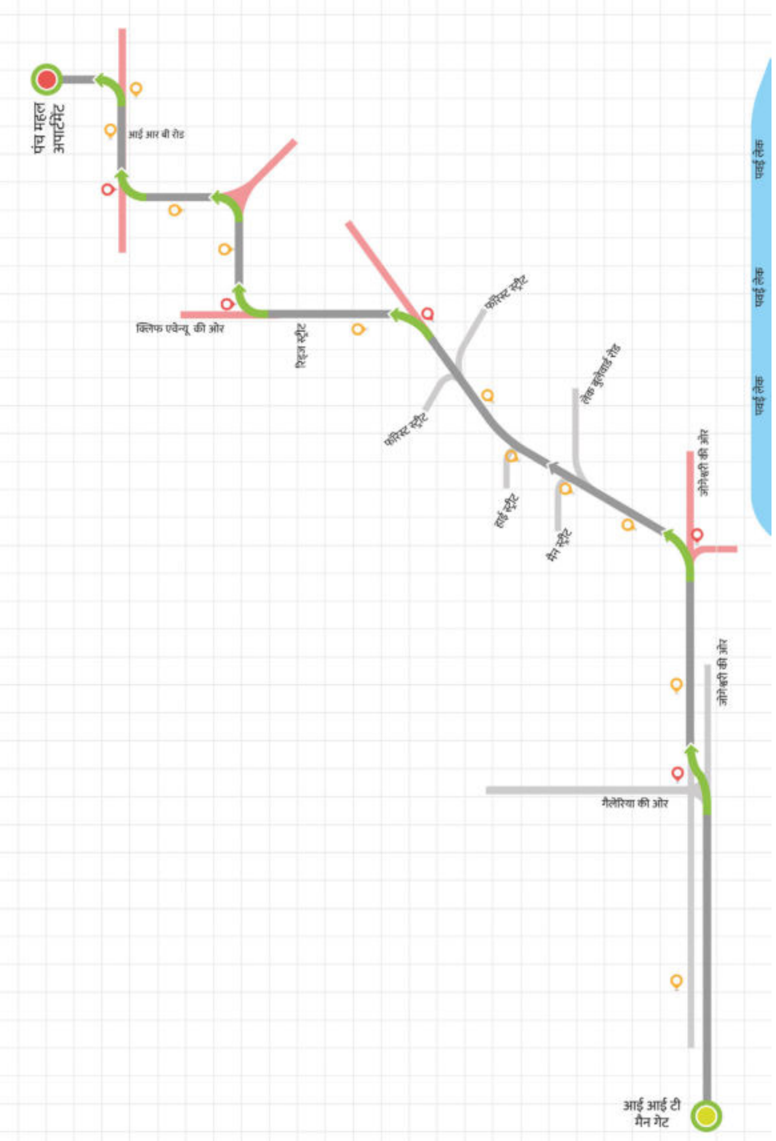
- Changed the layout and shifted the central band to the top of the screen.
- Removed the marker that showed the amount of distance covered as it seemed to distract and mislead the user.
- Added more emphasis on the turns
- Reduced the number of landmarks by increasing the distance between each of them.

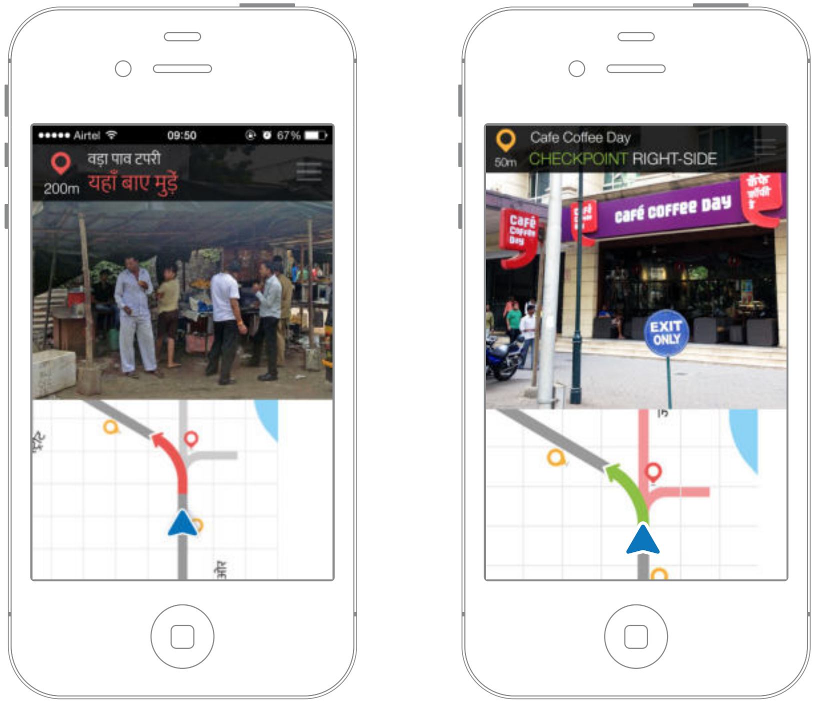
Findings

Observations made in this phase of testing

- The red colour used to emphasize a turn proved to be misleading to the users. Users thought it was an indication not to take a turn in that direction.
- Users could match the location of pins on either side of the route and their landmark location with respect to the road/user easily in most of the cases. E.g. If a pin is located on the left side of the route on the map, it would appear on the left side of the user while travelling.

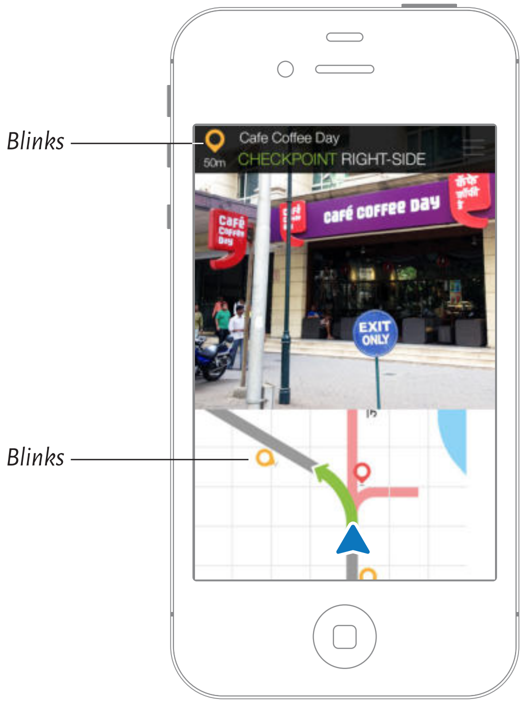
Iteration 2





Above: On left is the interface from first iteration and on the right is the new interface. It utilizes the modified map.

On the left is the map that was used during this cycle of evaluation. Compared to the earlier version, the turns have been changed from red to green for more clarity.



For easier correlation between the image being shown on top and its position in the map below, the location pins would blink as the user approaches a particular landmark.

Changes Made

Based on findings, the following changes were made.

- The red colour of the turns was changed to green to match users' mental models. The routes where the user should not take a turn were marked red.
- For easier correlation between pins and location, the pin on the map would now blink to show that the image being shown corresponds to the landmark.

Overall Conclusion

From all the user testing and the comparative analysis with other online maps, the following were concluded.

- First-time map users could use both kinds of maps - Google Maps and Routes (project prototype) without much hassle.
- Routes (seemed to) had an advantage when it came to taking the correct turn as users could identify a turn easily.
- Users during A/B testing wanted to use Routes as they were looking for visuals for navigating.
- In short, visual support was more helpful while travelling and taking turns than using a planimetrics-based map.

These findings need further substantiation with the help of more rigorous user testing.

Future Work

The success of the design will depend on the ease of identification of landmarks and their usage to reach the destination.

The solution is very data intensive which is expensive in terms of both data gathering and user experience when it comes to low internet speeds. Other issues include keeping the data up to date and creating a successful motivating-enough crowdsourcing model around it.

The seed data required for the route can be retrieved from existing repositories like Flickr and Google Street View. But in the long run, techniques like crowdsourcing need to be used. Other than maps, the system may also contain user-generated routes between certain points. These routes may be created for a specific purpose or to accentuate existing maps and landmark information. Over time, this builds the repository.

As landmark data is very volatile and may change quickly with time, user validation becomes primary and very important to keep the solution usable and trustworthy. Validation of the user-generate data can be microtasked and crowdsourced to receive quick and authentic feedback.

These have been demonstrated in the rough overview of the working of the complete system.

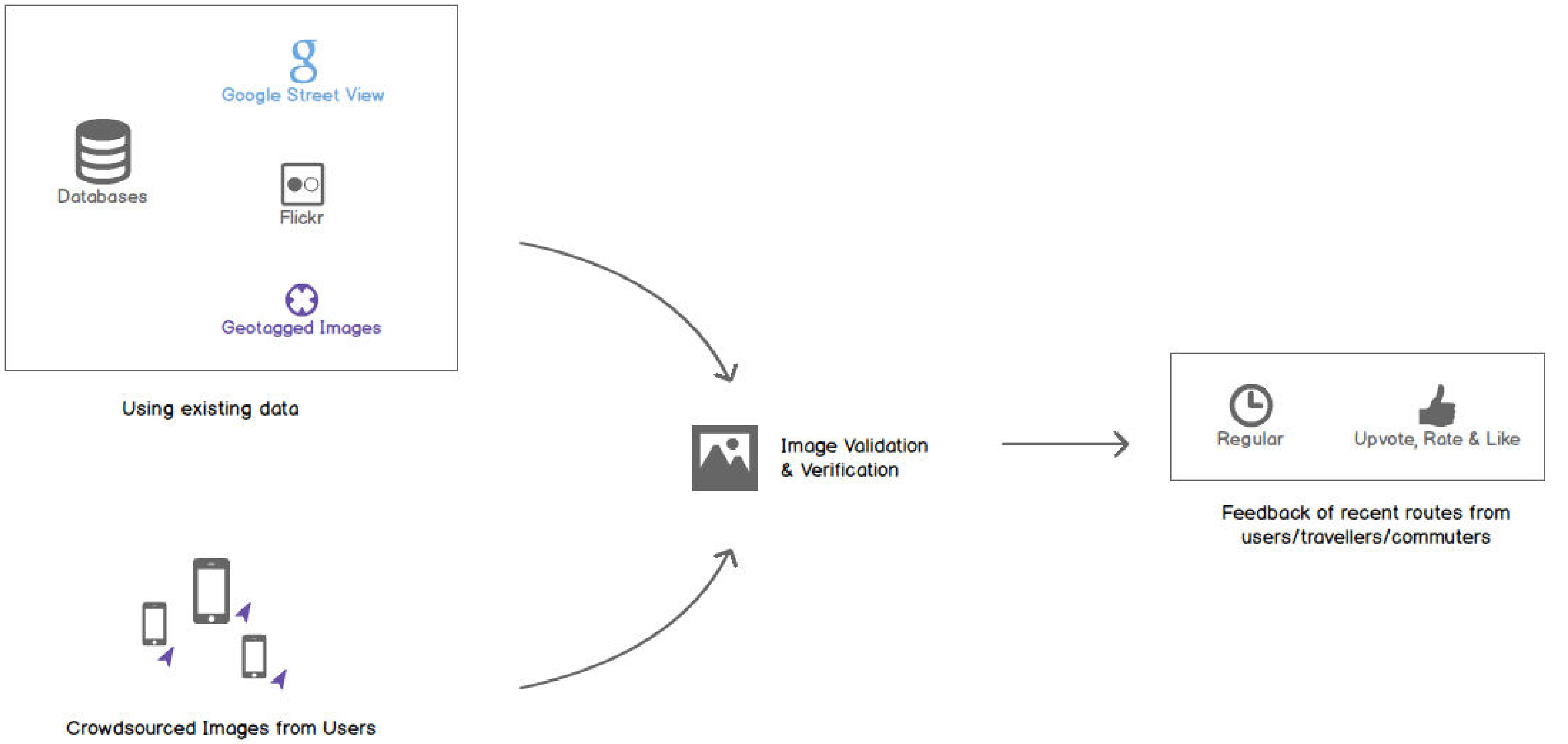
The solution can be extended to night-time usage by using night photographs of the landmarks. This will be solve the issue of landmarks looking different on different times of the day.

Data Collection Model

As the concepts proposed in the earlier part of the report are data intensive, the data has to be generated over time by the users or from the existing resources. Services like Google Street View and Flickr can be mined for geo-tagged images to generate landmark data. Users can also upload their own versions of the landmark images to help build the database.

Data collected from users or existing services needs to be validated and verified. This can be crowdsourced by inviting users to rate images by upvoting the most appropriate image.

Microtasked data can also be pushed to users in the form of minimal questions about the recently traversed path that will help in validating existing data.



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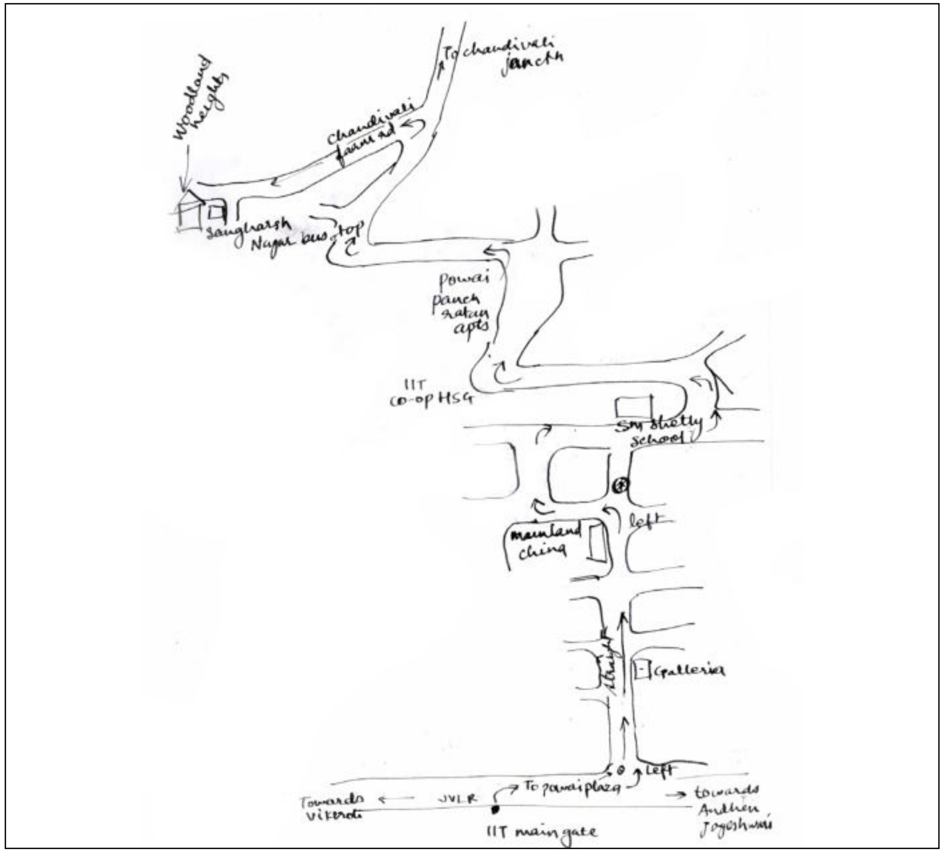
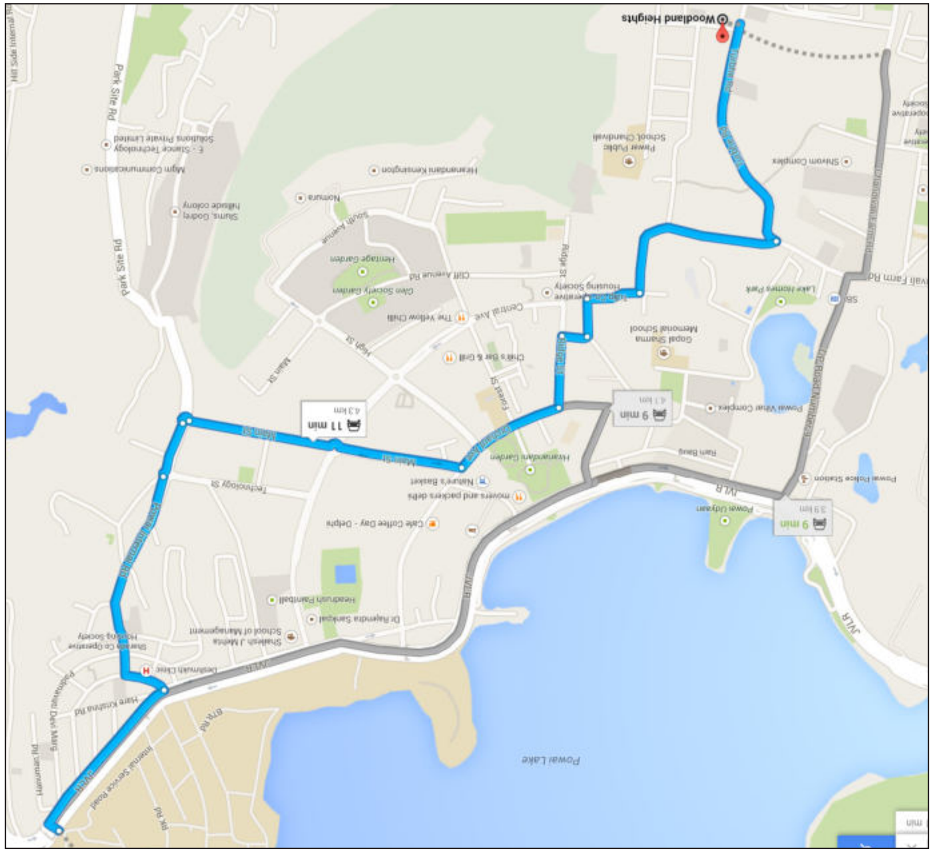
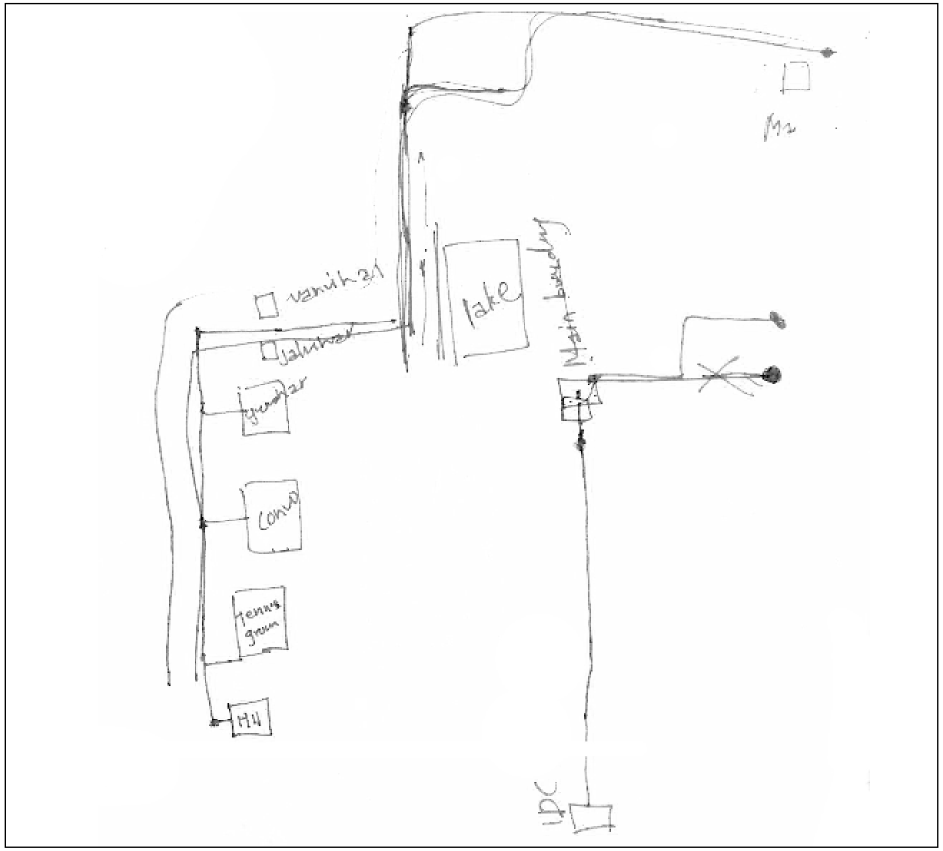
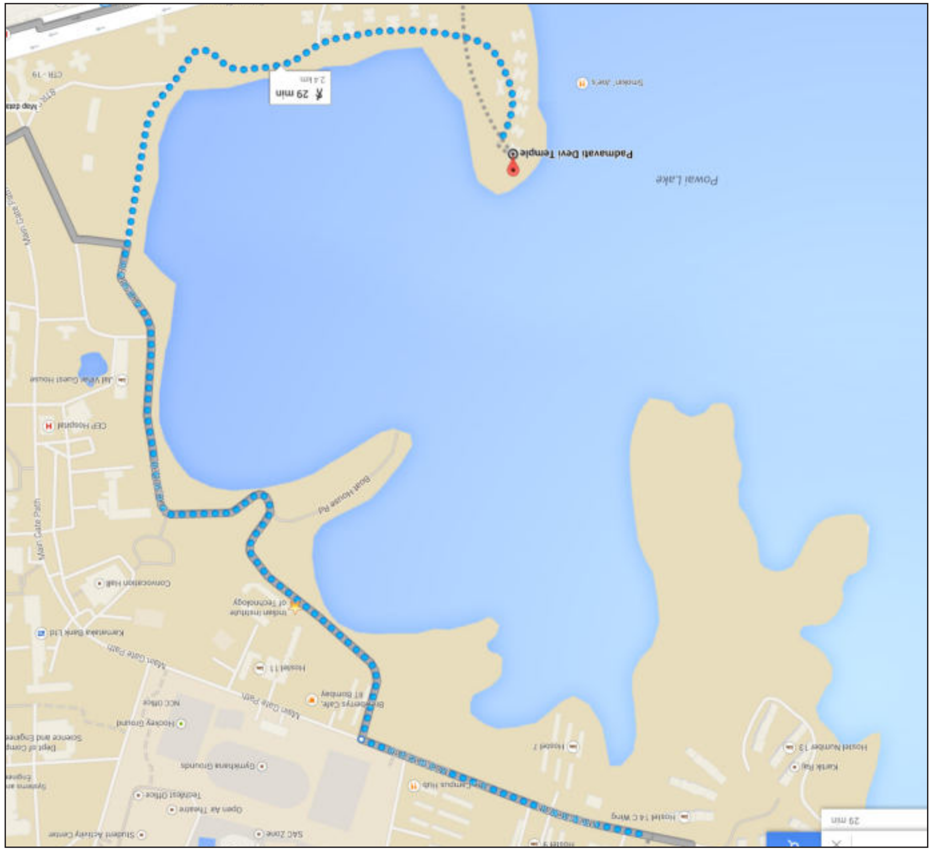
Appendix





Sketch of map between IIT Bombay and a residential complex. It must be noted that when drawing routes, the first part of the journey has been drawn in a simplest manner, but there are a lot of turns, the sketcher starts including additional features in the route like buildings and one-way indications. Towards the end of the route, the details increase. It must be noted that this is not a straight route and the sketcher has construed them to be straight as there are no turns to be taken.





Sketch of a map inside IIT Bombay campus. Though it is not geographically correct it shows the route one must follow. It should be noted that the map is not geographically accurate. Certain prominent points along the route have been marked by the user. The lake which is a larger entity on the right is just shown as a box at the point in the journey where it appears. Thereafter, as it continues to be present throughout the route, it loses its significance as a landmark.

Appendix

The prototype can be accessed on my personal website at http://www.naveedahmed.in