Infrastructure Information Modeling and Augmented Reality

FINAL YEAR PROJECT UG 2012

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Final Year Project Titled

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ABSTRACT

Managing and sustaining urban centers has become more and more challenging due to increase in population and a high urbanization rate. The problems surfacing due to this global trend are complex. The current situation requires a scale or a yard stick against which present and future growth can be monitored and future decision making process can be aided. This can be achieved with the formulation of an interactive framework where all the individual elements of the city are interrelated and their impact on one another can be studied. "Smart cities" concept where computing technologies are used to interrelate critical infrastructure and services for better efficiency and management is the solution to the intricate problem of rapid city growth. This research project aims to create an environment where such a concept can be practically put to use. Using the well-established and now well-known Building Information Modelling (BIM) technique a 3 dimensional (3D) city model was developed. The 3D city model incorporates and animates features of the city in a virtual environment including terrain, roads, railways, water bodies, and buildings, underground and over ground features. Of the various processes that can be used to create a 3D city model this research project focused on processing archived digital as built maps of the city into a 3D model. This was done using GIS tools for digitizing maps, extracting shapefiles and converting features. The final and refined geospatial data of the city was then brought into a BIM software. Information was loaded onto the model while developing it in 3D. The model not only provides visualization but also geospatial and engineering analysis for the entire extent. The model also utilizes the ability of cloud computing. It can be accessed from different devices and by different users who can according to their access privileges assigned by the administrator can update the model. The model is also linked to wireless devices with

the advanced feature of augmented reality (AR). AR blends the real and synthetic environment by reinforcing the connection between different objects and also between objects and people. With the immense effort undertaken in developing a 3D city model, AR is what gives the virtual system a real life background. This feature can be used for maintenance, utility management, clash detection and better identification of hazards. The study talks about 3D city modelling, integrating the system with BIM and AR and how this integration can lead to “smart cities” of the future.

DEDICATION

This project is dedicated to our Parents

without whom none of this would’ve been possible

ACKNOWLEDGEMENT

We would first of all like thank our prestigious institute National University of Science and Technology for giving us the opportunity to partake in this project which has been great source of learning. We would especially like to thank Sir Muhammad Jamaluddin Thaheem our supervisor and mentor, who gave us a vision and guided us towards it. Without Sir Jamal's help this project would not had been possible.

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ACRONYMS

These are commonly used acronyms that will be repeated throughout the report.

DHA Defence Housing Authority

NUST National University of Science and Technology

2D Two dimensional

3D Three dimensional

CAD Computer-Aided Design

BIM Building Information Modelling

GIS Geographic Information Systems

GPS Global Positioning System

AR Augmented Reality

VR Virtual Reality

USGS United States Geological Survey

IOS IPhone Operating System

DEM Digital Elevation Model

DSM Digital Surface Models

QOL Qualities of Life

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CHAPTER 1

1 INTRODUCTION

1.1 Preamble

This project aims to create a 3 dimensional (3D) digital model of a neighborhood with specific focus on infrastructure, services and utilities. It aims to aid in monitoring and evaluating present and future growth of the neighborhood. Conveying preliminary design through 3D visualization, prevent clash between service lines and improve decision making ability of both planning and executing teams. Enhance facility management with a real time interactive model having the advanced feature of augmented reality. This will aid in locating precisely the position and depth of underground services and ducts thus reducing time and effort for repair and maintenance.

1.2 Problem statement

Increasing population, higher living standards and limiting resources have made urban living very complex. The sheer magnitude of urbanization has led to uncontrolled growth, coupled with the lack of infrastructure the situation threatens sustainable urban centers. High population has strained the existing infrastructure and utilities like water supply, housing, sewerage, transport, health, education etc. In today's environment each and every aspect is interlinked. Decision making and management have become extremely intricate processes. Managing and building new neighborhoods has become more challenging than ever. Collaboration between different sectoral bureaus that manage individual sectors like transport, water, land, housing and others has become imperative. Representation of all information on a 2-

dimensinal map makes the whole process more complex. Further, the storage facilities for such maps may raise concerns over their readability and usability in the long run. Thorough analysis of data and impacts is not achievable in such an environment. Similarly, for facilities management a single complete map of the entire neighborhood would be too complicated to comprehend. Every sector works in isolation for maintenance and repair works. This causes clashes between different services and change in one network affects the others causing customer dissatisfaction and more time for repair and maintenance.

1.3 Research objectives

The main objective of the research project was to try and formulate a system that would improve the efficiency of the construction industry in general by creating an environment in which planning, design and execution processes can be aided. The research project is directed towards taking the concept and approach of building information modelling (BIM) and extending it towards infrastructure and utilities. A 3D model constituting all utilities and services loaded with engineering design information. An interactive model that can overlay virtual and actual scenario in a video based augmented reality system. This allows for the worker in the field to get benefited from the concept of BIM in a way that is easy to grasp and comprehend. This can act as a game changer for the industry in terms of empowering the labor force with accurate and easy to use information. The objectives can be listed as following:

1. Model of the existing environment.
2. Ability to easily sketch and layout new design.
3. Creation of realistic visuals for better communicating new design concepts.

4. Conduct different site analysis including shadow and light analysis.

5. Measure distances and area.

6. Line of sight and area of sight evaluation capabilities from various observation points positioned at different locations and heights.

7. Capability of augmented reality where a wireless device can be used to see underground and above ground features of the model whilst standing in the actual space of the created model. This will act as a game changer for underground facilities management and repair works.

1.4 Scope of study

The research project tries to establish an environment in which collaboration between different sectoral bureaus can enhance. It aims to provide a system in which visualization and engineering design can be incorporated. The model extent selected includes a single neighborhood. The neighborhood is redeveloped in a virtual environment using archived digital as built maps. Field survey or aerial photography for data collection were not utilized. The focus remains on infrastructure modelling including roads, sewerage, water supply and electricity networks. Buildings and their implication are not studied. However, the outer façade of a building can be modelled which allows for light and shadow analysis. Analysis and simulation of 3D terrain surface and line of sight can be done within the created environment. The model has interconnectivity with other engineering software programs for detailed engineering analysis for example sewerage system capacity and flow simulations.

Augmented reality application used, works on a mobile device having positional and 3D gyroscope sensors like a smart phone or a tablet. The model published on the cloud can be accessed and utilized for augmented reality. Decent internet connection is required for this purpose. The augmented reality application used is operational only on the IOS interface however the model can be published on others applications available, to be accessed via android or windows platform. The mobile device being not a specialized engineering tool can have errors in the GPG coordinates and inability to calculate distances.

1.5 Significance of study

BIM has been on the scene now for quite some time. Many people and firms both architectural and engineering are utilizing BIM for their projects. Tried and tested BIM can improve productivity and reduce costs on projects. It decreases reworks and provide a data base for 3D maps, scheduling, estimating, sustainability and facility management. To sum up it's a 7D environment which gives a complete snapshot of the project, increasing overall coordination and enhanced customer satisfaction. The only thing that is wrong in this system is the isolation of the end user from the whole process. The labor force or the technicians in the field still utilize tape measures and paper maps while the design or control offices are much more sophisticated in the use of modern technologies. This does not allow the full potential of BIM to be exploited. The study undertaken tries to fill this void by placing BIM in the hands of the actual end users, the field workers, and aims to increase their work efficiency. This project will make BIM models accessible via mobile devices and can be used in a video based augmented reality application. The project has the potential to do away with traditional maps which can be difficult to interpret and replace it with interactive 3D visualization. The possible applications of such a system are numerous. From setting out survey points in the field to trench excavation and from locating underground services to comparing damages after a calamity, augmented reality and BIM integrated together can open new possibilities and help counter many present and future challenges. Present research on this topic is limited and the concept is entirely new to most.

1.6 Thesis overview

The thesis main objective was to recreate a complete neighborhood in a virtual environment using the process of BIM with primary focus on infrastructure and utilities. The process of BIM is said to be a 7 dimensional system that helps to give a wholesome picture of the entire project. The research tries to take this 7D environment and expand its scope to an entire neighborhood. BIM is not usually incorporated on such a large scale mainly due to the sheer volume of data they can become unmanageable. The flow of information down the line on such a scale is difficult due to limited familiarity with technological advancement by the end workers. The research identifies this missing link and provides a solution via a video based augmented reality application for BIM. This can be called the 8th dimension to BIM. The thesis then talks about the past work done on these dimensions. The first 3 dimension of BIM are identified as 3D city modelling. The work done on augmented reality in construction and its benefits and implication are then discussed. The end result of the research is seen as a well-informed, interactive environment that can help succumb to present and future problems faced by the urban centers. The thesis identifies it as a step towards smart cities. The methodology adopted to create BIM and augmented reality is then discussed in detail. The conclusion to the research, limitation and recommendations then follow.

CHAPTER 2

2 LITERATURE REVIEW

2.1 3D City Modeling

3D city modeling is a geometrical three-dimensional representation of an urban environment. 3D models mainly represent buildings, roads, trees, landscape and topography. Over the last several years there has been a vast expansion of urban areas and strong urbanization mainly due to rural resettling into urban centers, growing economies and enhanced infrastructures. In such conditions, development cannot be monitored and planned using traditional maps which consumed enormous amount of time and required technical skills and hence there is a need for efficiently utilizing the urban space and accordingly designing keeping in view the urban planning, design and architecture.

3D city modeling also helps in determining future course of action in urban environment decision making by means of visualization. Visualization is basically one of the purposes of developing three-dimensional models by 3D illustration of the real world which can be an important tool for urban planning, facilities and utilities management, geometry and texture of urban surfaces, augmented reality, property management, e-commerce, tourism and educational purposes by creating a virtual environment using VR technology and then navigating into the model by walking and flying. Walking in visualization models refers to moving on the surface as seen in games and flying describes a 3D freedom of maneuvering through the model.

Over the years several methodologies and different software's have been used to create 3D models of great quality to facilitate visualization of urban environments. These involve data collection by draping and extruding 2D features, terrestrial photographic techniques i.e. photogrammetric method, satellite imagery, airborne laser scans, ground based modeling, etc. Based on the data acquired, processing is carried out in order to generate 3D city models with various attribute modes such as in shade, textured surface mesh and simple wireframe mode. At the end photogrammetric evaluation, visualization and querying is carried out for the developed models which are then used in comparison of different 3D city models.

2.2 Merging Aerial and Ground Views

Developing and generation of 3D models involves various data sources, hardware and software's, visualization techniques and different modeling approaches. All these include various modeling approaches along with data collection methods which will be discussed in detail. An overview is provided in figure 1.

Construction of digital surface models (DSM) and three-dimensional models which incorporate both the geometry and texture of urban surfaces is carried out which will

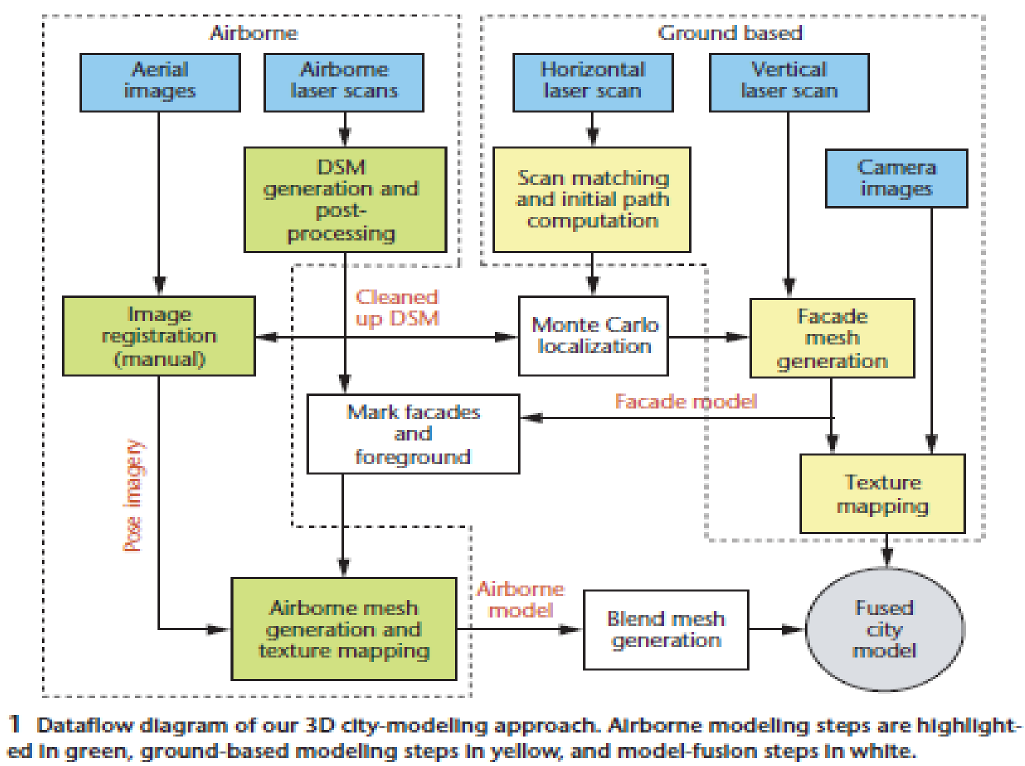

Figure 1 Overview of 3D city modeling

then help to assist in urban planning and other various services. In this method, the facade model developed from ground-based data is merged with corresponding airborne data.

2.2.1 Airborne Modelling Method

(Textured Surface Mesh by airborne laser method)

Modeling processes on terrain profile and buildings plan view is carried out after data acquisition from aerial images and airborne laser scans from which Digital Surface Model (DSM) is obtained. Utilizing the DSM acquired, localizing of acquisition vehicle for obtaining plan view and terrain for ground based data is registered by means of Monte Carlo localization (MCL).

The initial step is the adjustment or re-sampling of scan-points to get an acceptable resolution because in air borne laser scan acquisition, the roll and tilt motion causes distortion in the order of rows and columns. The scans are re-sampled to a row-column structure. In doing so there is a reduction in accuracy spatially but it keeps the resolution up to a reasonably acceptable level. These scans are then transferred to create a DSM, it is done by assigning each coordinate location(x,y) with an elevation value (z) to preserve overhanging rooftops in order to suppress the wall points.

Once re-sampling is carried out, the next step is the processing of the DSM. The main purpose is to make the digital model well defined by flattening out surfaces which include objects on rooftops such and also ground objects such as cars and trees. Moreover, the scan points at the overhanging roof causes unclear altitude values following jittery images. Therefore, first the rooftops are flattened by using segmentation algorithm to all non-ground pixels, replacing the small sectors with ground level altitude to remove those objects. The same is carried for objects on ground. Then secondly the jittery edges are straightened out by re-segmenting the DSM into parts and notifying the boundary lines, then using Ransac (Random Sample Consensus) for model fitting and straightening out edges.

The last step involves the *Textured Mesh Generation*. The developed and processed DSM is transformed into triangular mesh which is then later simplified by reducing the number of triangles and using aerial imagery by a non-calibrated camera. The matching points in these both are then connected. Then, for each mesh triangle the best image is selected for texture mapping by taking into consideration the resolution and vector orientation. (Zakhor, 2003)

2.2.2 Ground Based Modelling

This method involves the using of 2d laser scanners and a digital camera mounted onto a vehicle as shown in figure 2, for the acquisition of data while moving at a normal speed. The camera is fixed towards the scanner with its axis intersecting between the two orthogonal planes and signals are used to synchronize both the camera and scanners. The vertical scanner is for scanning of building façade geometry and the horizontal scanner to develop algorithms to approximate position changes. Later on corrections for pose error and scan matching is carried out. Monte-Carlo Localization (MCL) method in combination with aerial map is used to correct the global pose. The MCL methodology involves developing of two main type of maps: Digital Terrain Model (DTM) for the terrain altitude and an Edge Map that contains all the location of height discontinuities. Edge map solves issues of discontinuities and also defines the edges. The next step is the model registration with MCL in which accurate position within a city is determined and then using the correction principles, initial vehicle motion are adjusted in order to match the scan points from ground based map with the edges in the global edge map. (Zakhor, 2003)

The last step is the merging of models. Both aerial and ground based faced and mesh models are automatically combined from the DSM. The main purpose is to obtain the photorealistic virtual fly through navigation model which is virtually pleasing. This requires a little effort as gaps need to be filed with additional triangles while maintaining the consistency and removing foreground objects in the airborne mesh model. The meshes are blended together and buildings are draped along the axis perpendicular to facades. Finally blend triangle from aerial mesh are texture mapped i.e. they merge at one side with ground based model and at the other end with airborne model.

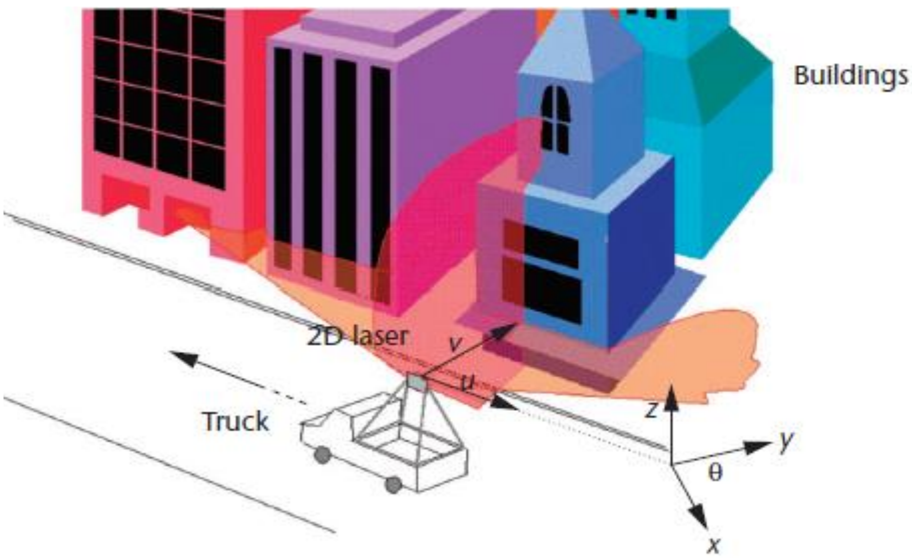

Figure 2 Ground base modelling

2.2.3 Using Photographic Techniques and existing Topographical Map Data.

The methodology for developing a 3D city model involves several techniques and requirement. Mainly Data Source, software and hardware, Modeling Approach and lastly the Visualization technique.

2.2.3.1 Data Source

The data source is in the form of Topographic map and aerial photographs. Topographic maps are used for geographical orientations which contain positional data of terrain features that include buildings, roads, land use and boundaries. Aerial photographs are more accurate than topographical maps due to no generalization process. Orthophoto maps are developed from aerial data then these in combination with topographic maps are used to get building footprints and later help in generating a Digital Elevation Model (DEM).

2.2.3.2 Software and Hardware.

Applications used for developing a model are mainly ArcGIS, Cosmo Player, Canoma, 3d Studio Max. The ArcGIS was used build up the foundation of the model which in this case study was the Shah Alam Virtual City (SAVC). Canoma was used to construct a photorealistic model of the building. 3D Studio Max was used for integrating and authoring of the buildings, foundation and other features such as tree, lamp post and signboard. Irrespective of the software the workflow remain the same.

2.2.3.3 Modeling Approach

A workflow Scheme of methods used in the project (Eran Sadek Said B. Md Sadek).The workflow is illustrated in figure 3.

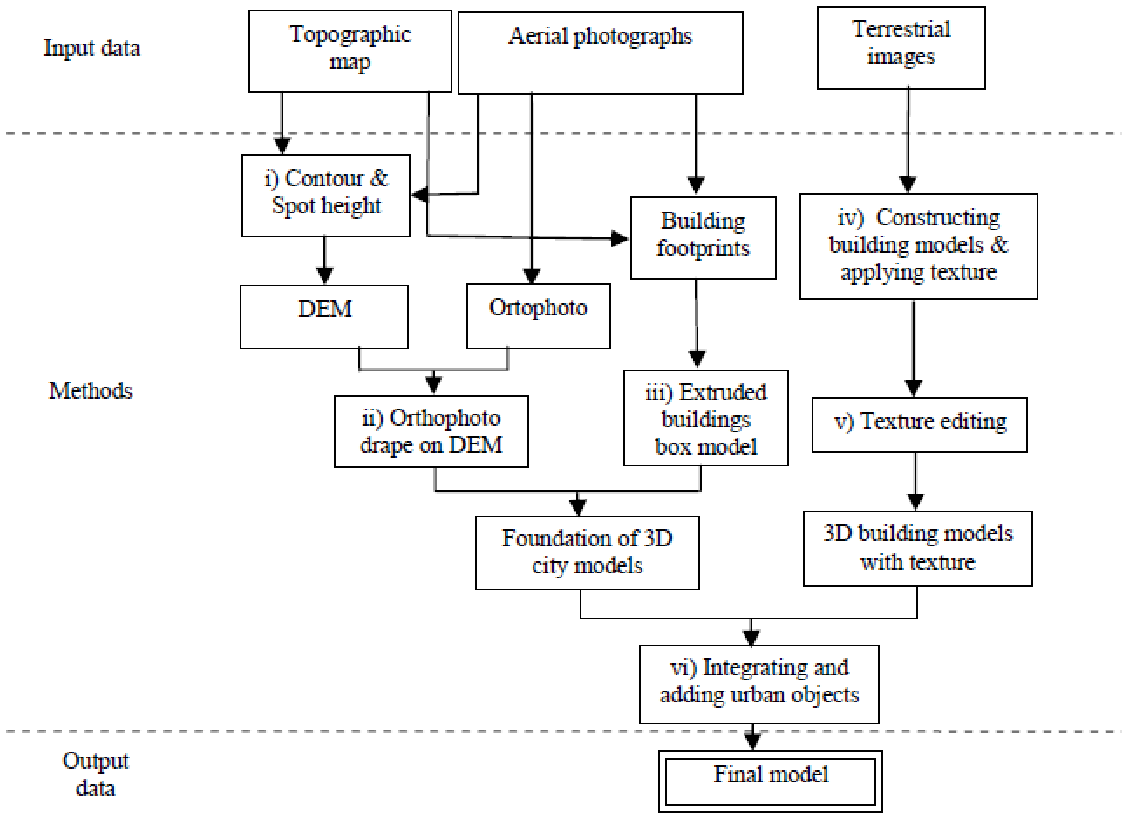

Figure 3 Data flow and methodology for modeling

2.2.3.4 Visualization

VR technology is used to achieve high visualization and the refinement process of the virtual 3D model is carried out in Virtual Reality Markup Language (VRML) and X3D format which provide high flexibility and resolve issues in VRML. By performing visualization using software plug-in like Cosmo player or Flux to provide navigation through virtual environment by walking, flying and examining. The last step is the visual analysis which helps in identifying the most suitable site for development of project.

2.2.4 Applications of 3D City Modelling

3D city models have various applications in a variety of different domains. Some of them are listed below:

2.2.4.1 Augmented Reality

Augmented reality provides a reference frame in 3D models for augmented reality applications.

2.2.4.2 Visibility Analysis

3D city models are important in terms of visibility analysis when it comes to the Line of Sight between objects and for estimating the volume of sight or visibility of a landmark. For example, evaluating façade visibility, location of surveillance cameras and price assessment in real estate based on the view from buildings.

2.2.4.3 Urban Planning

This focuses mainly on the visualization of urban environment and using 3D geoinformation for facilitating design of an urban sector for planning purposes. For example, providing space for a park, a new metro line and traffic control.

2.2.4.4 Shadow Cast Estimation

Shadow estimation as shown in figure 4, in city models is often carried out in urban planning for evaluating effect of a newly planned building on its existing surroundings. It is also important in assessment of solar potential of structures which might be affecting the photovoltaic capacity of solar panels. Further uses include: measuring thermal comfort of buildings, determining solar envelopes and also in agriculture for measuring effect of growth in shaded areas.

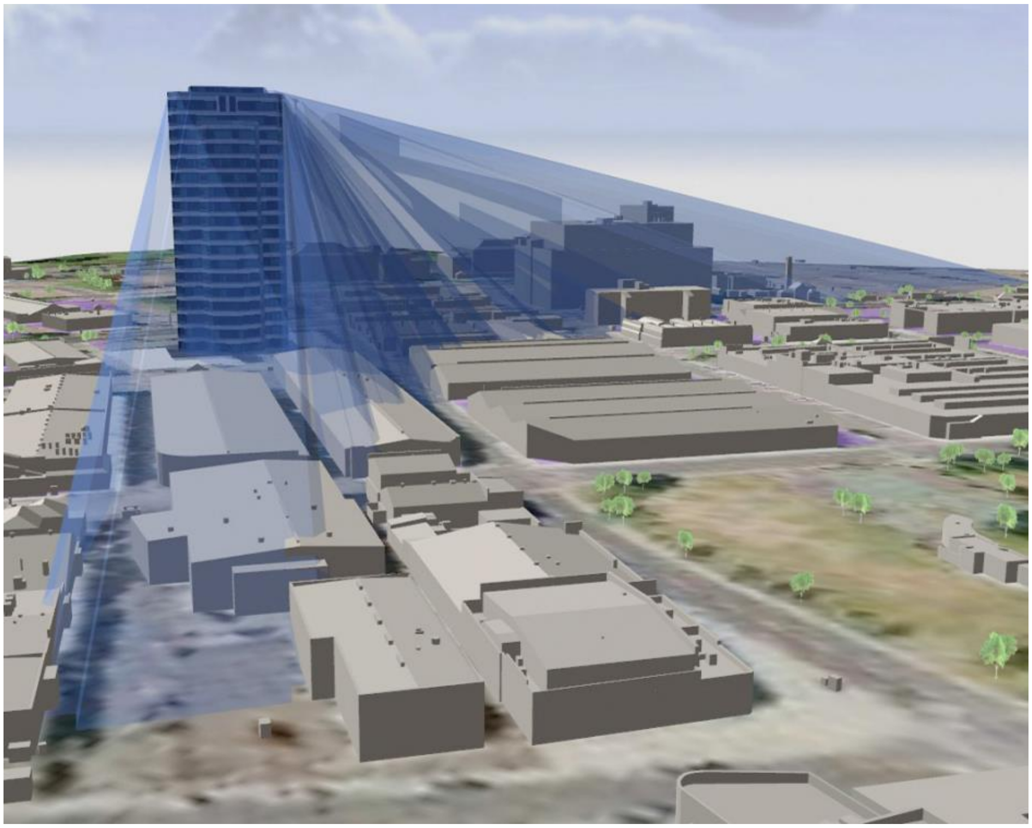

Figure 4 Shadow analysis

2.2.4.5 Noise Propagation Estimation

Estimation of noise propagation is carried out using 3D data to create models that determine how noise pollution harms the urban citizens. Models also provide solution as how to diminish noise pollution and where should the noise barriers be placed.

2.2.4.6 Navigational purpose

3D city models provide a better experience as it is more realistic and natural than 2D aerial views which provides overview information and is useful in estimating distances which is mostly sufficient but 3D views are helpful for rapid shape cognition. (Filip Biljecki, 2015)

2.2.4.7 Facility Management

Geoinformation from 3D models can be used for facility management. 3D models can be used for management of ports, airports, utility networks which mainly includes of electricity, sewage, water and gas networks.

2.2.4.8 Emergency response

Data from models can be utilized in disaster management, determining emergency exit points in a building and locating position of deploying ladder trucks for firefighters.

2.2.4.9 Change Detection

3D city models can be used for detecting changes in the existing environment for improving quality of a city and detecting if an extension to a house has been built.

2.2.4.10 Archaeology

Main use is in urban reconstruction and renovation of ancient cities, analysis of development sites with time and modeling archeological objects.

2.3 Augmented Reality

Augmented reality is technology which super imposes real-time information with virtual information. When user sees the existing environment with his AR device he not only sees the real world but he also sees the computer based information superimposed on it for example he can see a building, road, pipeline etc., which is yet to be build but its 3D model has been built in computer. AR device will take existing environment information from camera and will super impose it with 3D model, now user can visualize both real environment and the virtual environment at the same time.

2.3.1 Need for augmented reality

Other fields of engineering are enjoying fruits of 3d modeling while civil engineering infrastructure projects still follow old 2D CAD files approach. Due to this 2D approach many problems arise such as clashes in services, inaccurate drawings, missing details etc. These 2D drawings are very difficult for clients to understand because they don't know how to read such drawings. These problems lead to cost over runs, time over runs and in some cases may even go in litigation. Construction projects are getting complex day by day. To deal with this complexity we have to provide accurate real time information to engineers working in field. This can only be done through application of augmented reality in construction projects. Augmented reality takes this 3D modeling to another level by integrating existing environment with the 3D model and gives accurate information through visualization of project. In other words we can see interaction between virtual worlds created in computer with the real world. We can foresee the clashes of our project with the existing features before the project is even actually started.

2.3.2 Working of augmented reality

Augmented reality superimposes virtual world over real word enabling user to view natural environment with computer generated three dimensional model information. According to Azuma, the core functional abilities of augmented reality system are:

- Proper tracking system
- Overlay virtual information over real information in proper location and orientation
- Combine real and virtual graphics

There are four components of AR system as illustrated in figure 5

- Tracking device
- Camera
- Mobile Computing Process (registration)
- Display device

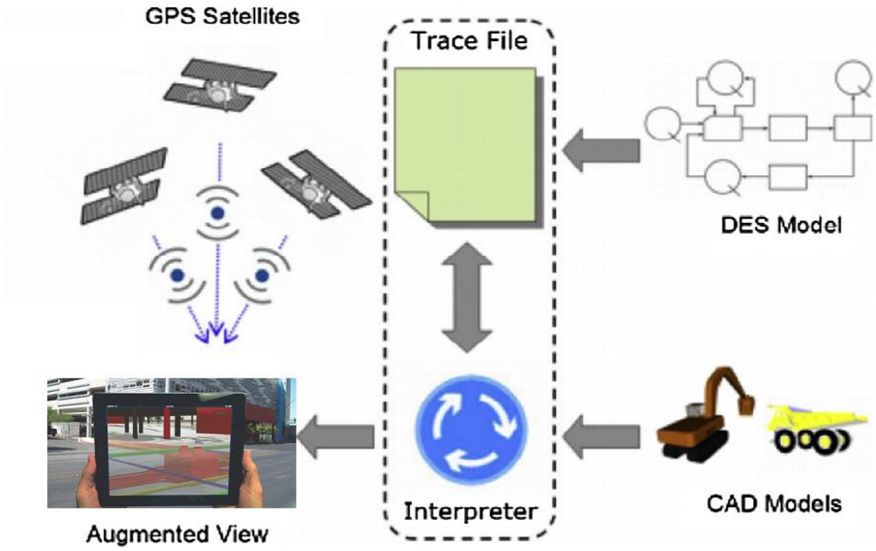

Figure 5 Components of AR

2.3.2.1 Tracking device

For superimposition of real and virtual features we must know our position where the user is located with reference to his surrounding and what virtual features are there for this we must know the accurate position of our device. GPS (Global positioning system) is used for tracking in augmented reality systems. It is a space base system to find time and location accurately. GPS sensors are used in wearable augmented reality systems however in mobile augmented reality systems GPS sensors of smart phone or tablet are used which are less accurate which have accuracy of about 10m. GPS sensors locate the position of device. These devices are also equipped with sensors that recognize the movement and orientation of device.

2.3.2.2 Camera

Camera gives the input of real world of information. This camera can be some special built camera for augmented reality or camera of mobile phone. Camera detects an object its angle with camera distance from camera through its sensors and sends this information for processing with virtual information.

2.3.2.3 Mobile Computing Process

It is the most complex component of augmented reality system. It takes information of real world from camera which has no coordinates it only knows the position of camera through GPS to overlay this real information both of them must have a single coordinate system. For that information coming from camera has to be first give coordinates .to achieve this camera is equipped with sensors that measure the pitch and the distance of objects. For this purpose, computing is required. In wearable augmented reality laptops are used for this purpose and in mobile augmented reality processor of smart phones are used. After processing the real and virtual information having the same coordinate system it becomes very easy to overlay both virtual and real information to create one visualization. Processing devices align and orient both information to create visualization. This processed information is sent to display device for users to visualize

2.3.2.4 Display device

There are two ways for visualization. User visualizes this super imposed model of real and virtual information either through glasses in wearable augmented reality or through a handheld device such as smart phone or tablet. With advancement in technologies now 3d visualization is also available.

2.3.3 Application of Augmented reality in field

Following are some uses of augmented reality by which we can benefit in field:

2.3.3.1 Visualization of perspective design

Augmented reality interlays existing environment and the feature you have designed or want to build in one picture as shown in figure 6. In other words, client can get visualization of his project before it is actually built. Communication between client and architects or designers is a big problem in construction due to this communication gap many disputes arise in the projects. These disputes can be minimized by application of augmented reality. Architects or designer can give their client a brief visualization of their clients prior to finalization if their design in this way client can visualize the design and compare with his requirements before it is actually constructed. He can spot defects in design that may lead to disputes or change orders.

Another benefit of visualization of design is that designers can propose projects to government and multinationals or convince government officials for certain project. You can easily convince them by showing their benefits from a certain project through its visualization. For example, there is traffic problem on a crossing and you propose an interchange there. It will be very hard for you to convince city government official with simple 2D drawings with augmented reality you will be easily able to show how your proposal will solve this problem and he might give you the project.

Figure 6 Visualization of perspective design through AR

2.3.3.2 On site clash detection

Often we see during the construction of roads or excavation of pipelines and utility lines get damaged because the onsite people have no idea what would they get beneath the ground. This increases the cost of product may result in cost overrun and time overrun. By the use of augmented reality, as shown in figure 7, we can easily avoid such clashes by just pointing the camera towards the ground and see all the pipelines and service lines running beneath it. We can see how deep they are located and plan our excavation or change the design according to it. During drilling of pile of a fly over in Rawalpindi they unexpectedly encountered a pipe line which was main gas supply line of city due to which worked was stopped for quite long such incidents can be avoided by using augmented reality. If augmented reality was used in that project this clash would have been identified in early stages of project and design of fly over would have been changed according to it.

Figure 7 Underground services detection

2.3.3.3 Utility management

Augmented reality will be very helpful for maintenance crews they can easily locate the pipelines or lines through pointing their IPAD camera without using tape or measuring distances as presented in figure 8. They can easily locate the desired pipeline which will save a lot of time and resources. In case of any emergency it will be very easy to identify valves and other control points through application of augmented reality. It can also be used to locate damaged cables or pipelines. In short augmented reality can save a lot of time resource in utilities management operations by providing the accurate information through visualization.

Figure 8 Locating service

2.3.3.4 Identification of hazards

Safety is one of the key concerns now a days in projects. There are many unknown hazards present on site that can cause severe injuries to workers. Augmented reality can be used to identify such hazards. For example, there is an underground electric cable running underground and there is excavation going on near it. That electric cable is hazard to workers that we are unaware of it can cause electrocution. By application of augmented reality, we could have easily identified that cable as hazard and take some measure to eliminate this hazard.

2.3.3.5 Better collaboration

Completion of project in time and in budget depends on the collaboration and communication between project stake holders. Augmented reality helps in improving communication and collaboration between contractor, client and designer. A contractor can take instantly take a picture or make a video of any ambiguity in design and send it to designer for further information or clarification. Sometimes people working in field do not get change orders in time and they are working on old drawings this communication gap can be eliminated by using cloud based augmented reality.

2.3.4 Impact of augmented reality in construction

Augmented reality will improve construction process in following ways:

2.3.4.1 Eliminating guess work

In traditional 2D approach information is limited due to which people working in field have to assume any missing information or apply guess work such guess work and assumption can be avoided by use of augmented reality because 3D model contains a lot more information as compared to 2D drawings.

2.3.4.2 Improving accuracy

With the application of augmented reality we can get precise and accurate information about location and measurements by using augmented reality user will visualize the exact location where work have to be performed. This information would be very helpful in excavation projects.

2.3.4.3 Early identification of problems

With help of augmented reality we can identify problems such as clashes, design problems, hazards etc.in the very early stage of project hence it will minimize the effect of these problems

2.3.5 Past research on Augmented Reality

Augmented reality has been around for some time now. Its use in gaming and media has helped these two industries thrive. AR in civil engineering is still finding its foundation. Research on this topic has been done in the past but the industry is slow to adopt the new concept. The terminology augmented reality was first introduced by Tom Caudell in 1990. Augmented reality can be defined as system having following properties:

- It should mix real environment with virtual environment.
- It should be real time and it should be in 3D.

In simple words augmented reality means addition of information to real or natural world this addition can be a virtual model sound, graphic, image, video etc. Studies have shown that is easier for humans to understand information if it is physically visualized. In recent years mobile AR has experienced a transformation from larger heavier setups towards more user-friendly handheld devices. Early forms of augmented were wearable augmented reality equipment but with advancement in computing powers now we are able to use augmented reality on our smart phones tablets and hand held devices. In the beginning augmented reality was used for military purposes only now it is being used in almost every field. The use of augmented reality in construction industry is in early stages as compared to military, medical, gaming and other industries but it is gaining popularity. Rosus gave overview of recent advancement of hand held augmented reality in civil engineering and presented a augmented reality system "Vidente" which helps in increasing the efficiency of common field task related to utilities. Use of augmented reality in Architecture, Engineering and Construction have increased rapidly in past few years. Construction industry can benefit from augmented reality technology in at least three levels: visualization, information retrieval, and interaction. Shin and Dunstan (2008) discussed general application of augmented reality in construction industry they identified eight tasks in AEC industry which can directly benefit from augmented reality, these tasks are layout, excavation, positioning, and inspection, coordination, supervision, commenting and strategizing. A detailed review of application of visualization in construction industry was presented by Kamat (2008) they identified application of visualization techniques in activity level construction and operation level construction. AEC industry can benefit from the augmented reality in error reduction, better marketing, review of project, saving man hours and cost reduction. The intricate nature of the architecture, engineering, construction, and facility management (AEC/FM) industry and its high need for access to information for estimation, communication and cooperation, increases the industry's demand for information technologies. Augmented reality fulfills this demand of industry by providing high detailed information and better communication medium. A detailed review of augmented reality AEC related research was conducted by Rankohi and Waugh (2013) they studied 133 articles and presented their statistical review of augmented reality research in AEC industry. An AR system was developed by Webster to improve the inspection by visualization of columns behind walls and reinforcement inside columns to improve renovation and showed structural analysis of columns. A ‘‘discrepancy check’’ tool has been developed by Georgel (2013) to compare planned with actual as built structure to find any deviation or difference between them. In another project they overlaid as built drawings of a pile on site photos for investigation of bored pile construction. Another mobile augmented reality system was developed by Thomas to visualize extension of a building. VTT Technical Research Centre of Finland developed mobile augmented reality application to give user access to BIM information in field to compare scheduled building with real time construction of building. They used this application for planning approval of a hotel design by local authorities. Other than just visualization augmented reality is being used for facility management such as electricity, water supply, sewerage and other utility services. Augmented reality can replace current method of locating facilities based on 2D maps to aid in trench inspection and excavation. In many places electricity lines, gas pipelines, sewerage lines and many other utility lines share same space while repairing one-line excavator damages other lines too because it is very difficult to identify accurate position of line through traditional practices causing a lot of damage. J.T. Spurgin, J. Lopez, K. Kerr in their study told that in the U.S. alone, an underground utility is hit by an excavator every 60 seconds causing billions of dollars in damage each year. Augmented reality is also serving as a tool for collaborative design and information delivery. The Laboratory for Interactive Visualization in Engineering(LIVE) at the University of Michigan have developed many augmented reality applications related to construction operations, safety inspection and education, they developed visual excavator-collision avoidance system which enables excavator operator to see underground cables and pipes in the digging area to intercept any accident in advance. Behzadan and Kamat discussed applicability of advanced technology to improve safety during construction of projects in urban environment by enhancing visualization of construction equipment operators. According to Wang remote collaboration is a fundamental aspect of designers' working routine and it is becoming more important for planners and decision-makers to correctly identify and understand other remote team members' intentions and work with a high level of alertness and conscious as if they were present in the same room. Bechtel UK used mobile augmented reality in a cross rail project to improve performance and safety of people working in field by providing maximum information for identification of hazards and decision making Roberts presented an augmented reality system for visualization of underground structures such as pipe lines, electric lines gutters etc. this system improves safety and prevents accidents that may damage these lines or pipes during excavation. Kamat and Tawil discussed feasibility of post-earthquake damage identification Augmented reality system by super imposing pre earthquake information of building over post-earthquake information to access and quantify damage. Pap works a mobile augmented reality application developed by university of Illinois which geo tags elements of building on field and displays information about their specifications. This app acts as site dairy which is accessible not only on field but from anywhere else also you can retrieve this information. The VTT AR Research team developed a mobile augmented reality application to identify hidden lines and pipelines in a building to help in facilities management and maintenance. Application of augmented reality technology will increase in coming years, in future augmented reality will not only be main part of design phase of project but will also be extensively use during construction and operation phase. This will increase overall performance and efficiency of AEC industry.

2.4 Smart Cities

With the increasing rise of global population and rural-to-urban migration, almost half of all human population now lives in some form of urban districts. Urban centers are becoming increasing complex and face new difficulties like public health, waste management, air pollution, traffic congestions, resources scarcity, aging infrastructures etc. as illustrated on figure 9. Rapid Urbanization has pushed the need for rapid solutions to these various problems; hence the integration of numerous city amenities and infrastructure are vital to ensure better livable conditions for its citizens and stakeholders.

Figure 9 Different challenges of Smart Cities

2.4.1 Definition

Smart Cities can be defined as

A city that monitors and integrates conditions of all of fits critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens.(Hall, R. E. 2000).

There is still a lot of debate as to how to define 'smart cities' and what are the parameters.

Various studies have been done and ultimately eight core components could be related to smart cities as illustrated on figure 10. The eight components include (1) management and organization, (2) technology, (3) governance, (4) policy, (5) people and communities, (6) the economy, (7) built infrastructure, and (8) the natural environment.

(Hafedh Chourabi, 2012)

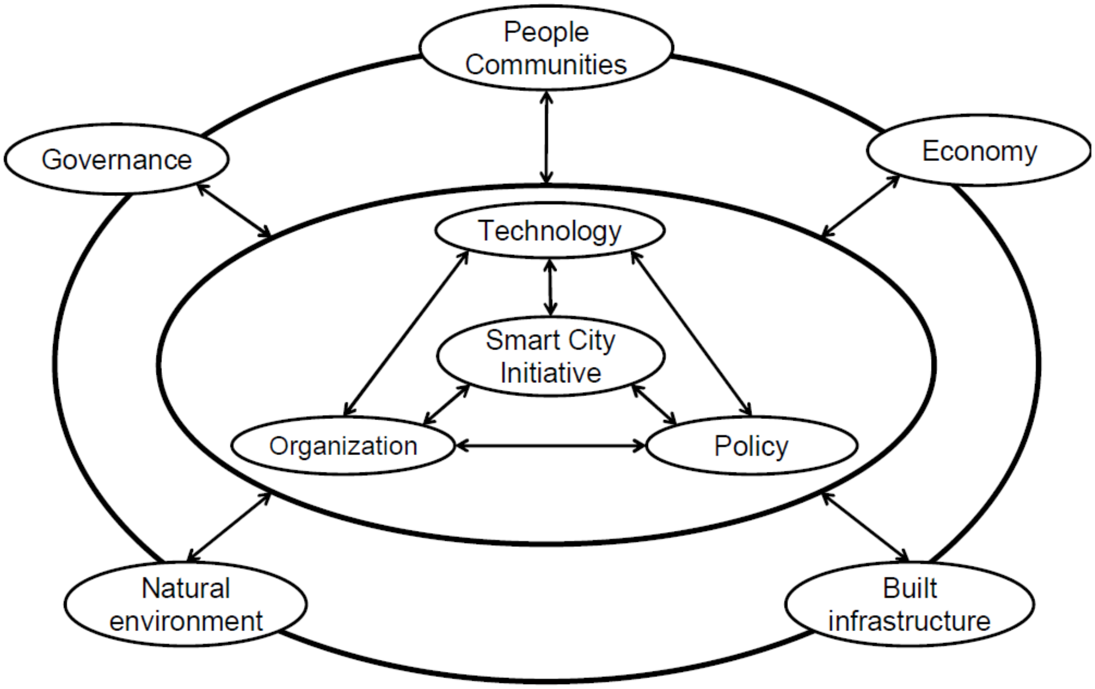

Figure 10 8 Components of Smart cities

2.4.2 Challenge facing modern cities

Cities face new problems. The pace of urbanization is increasing exponentially. Every day, attributable to migration or births, urban areas grow by almost 150 000 citizens. Between 2011 and 2050, the world's urban population percentage is projected to rise by seventy two, almost doubling world population to 6.3 billion and also the population share in urban areas has risen from fifty two throughout 2011 to sixty seven throughout 2050. Additionally, global warming and different environmental pressures are pushing cities to become more "smart" and take substantial steps to fulfill demanding obligations and commitments imposed by law.

The incremented mobility of our societies has engendered excruciating competition between cities to attract adept workers, companies and organizations. To promote a thriving culture, cities must experience budgetary, societal, and ecological sustainability. This will only be made possible by amending a city's efficiency, and this requires the integration of infrastructure like residences and commercial areas. While the availability of astute solutions for cities has discovered quickly, the changes will require radical transmutations in the way to other cities run today.

2.4.3 Stakeholders

Stakeholders are key drivers to smart city solutions. A sensible town can't be obligatory by decree, because the town is formed by a sizably voluminous number of individual decisions plus social and technological progress cannot be predicted. Current advances in telecommunications, information and communication technologies (ICT) have brought cheaper energy potency and production tools, measuring the connection between voters and town services.

Citizens are becoming not solely users only but also additional suppliers of town services. A good strategy involves the contribution of a good vary of stakeholders inside town. This implies that urban planning has to leave bottom-up processes of modernization. The stakeholders are:

- City government admins
- Political leaders and local representatives
- Municipals of water, electricity, gas, waste, etc. (public or private)
- Inhabitants
- Financiers, Investors and big businesses

- Solution providers

Giving every one of them a real stake is imperative to achieve the compulsory consensus for the changes. Their considerations got to be rigorously thought of and acknowledged, and ultimately the direction and next steps ought to be conjointly approved. With the absence of correct consultation, the authorities can sooner or later face sizable extra obstacles to push towards their vision. Smart cities are possible without the integration of network of systems.

2.4.4 Solution

Hence, developing good cities is not a method where technology suppliers provide technical solutions and town authorities get hold of them. Smart cities additionally need the correct atmosphere for good solutions to be effectively adopted and used. The sensible participation of town is needed to input ideas and experience from a large vary of stakeholders. Public governance is of course important, however participation from the non-public sector and people of the community are equally vital. It additionally needs a correct balance of interests to realize the objectives of each the town and therefore the community at massive. This may ultimately result in a lot of integrated, efficient, cheaper, and environmentally friendly solutions. The wants of cities vary place to place however the most 3 pillars of development remain identical.

There is no single trend, resolution or specific approach for smarter cities. Local trends show the divergent urban growth patterns among major regions and the different caliber of economic development. Still, important disparities within the level of urbanization may also be discovered across completely different countries inside constant region. However, all cities attending to be converted into good cities have to be compelled to be engineered on 3 sustainability pillars as shown in figure 11:

2.4.4.1 Economic sustainability

Citizen need to be provided the opportunity to attract business and capital and full their economic potential. The economic sustainability of cities has become even more significant after the recent global financial crisis. The global downturn exposed many faults in the financial models and the planning strategies undertaken by the public authorities to provide services and investments. The sustainability of the businesses now depends on new financial model which are more productive and better-integrated with facilities and infrastructures.

Figure 11 The 3 Sustainability pillars

2.4.4.2 Social sustainability

People, businesses and capital are drawn to a city based on the city's quality of life (QOL), which deals with social inclusiveness guarantee business opportunities and security and stability.

2.4.4.3 Environmental sustainability

Modern cities face many environmental problems that are both man-made and natural caused like weather or events. We need to encourage the efficient and intelligent operation of technology, reduce their consequence on the surrounding resources and integrate it to our infrastructure system. This will also help in increasing the city's adaption to environmental changes.

These three pillars have a common goal of efficiency; in a way that makes the city more adaptable and accessible to all citizens with opportunities of success.

In contrast to common opinion, smart cities are more likely to add to a city's value rather than decrease it. More technology can bring improvement in efficiency, enhancement in economic potential, cost reduction, encouraging new commerce and services, and improving the living standard of its inhabitants. For this a common and consensus-based standards that focus on interoperability can help achieve integration through value creation by compatibility of various technologies.

Presently, smart city projects focus only on the vertical integration of already existing independent infrastructure and facilities, for example transport, water or sanitary. Horizontal integration is also vital to achieve an aim of true "smart city". This will create a network of systems that is able to achieve considerable increases in productivity and generate new prospects for the city and its citizens. Smart solutions can only be approached if the necessary finances are allocated and the necessary designs are implemented.

The classical approach of planning, procuring and financing are not enough for the needs of modern cities. They face more complex challenges. Smart cities are possible only if fundamental reforms are carried out.

CHAPTER 3

3 METHODOLOGY

3.1 Definition

The US National Building Information Model Standard Project Committee has the following definition for building information modelling (BIM):

Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition

BIM has taken over as the new versatile and effective tool for planning, design, construction and operation of complex infrastructures such as pipelines, bridges, roads, ports, buildings and communication utilities.

The use of BIM is not just restricted to the design and planning phase of a work but extends throughout the life of a project in terms of cost management, construction management, facility management and operation.

The study has focus on infrastructure modeling excluding buildings and the following approach towards creating BIM is particular to under and over ground utilities. Buildings are not covered in this study.

3.2 Spatial data

Spatial data is also known as geospatial data or geographic information that represents the size, shape and location of a feature on the earth's surface. This may include man made features like roads or pipelines and natural features like lakes and mountains. Spatial data is the first building block toward the formation of an infrastructure information model. Spatial data is represented in 2 formats namely raster and vector as represented in figure 12.

Raster data is made up of pixels that are equally spaced and usually in a square grid pattern. They are used to record continuous features. Aerial and satellite imagery including elevation surfaces are all types of raster data. The accuracy of a raster dataset is depended on the pixel size. Smaller the pixel size better the resolution. However high accuracy data comes at a substantial cost. Raster datasets can be obtained from the USGS website. Raster data is good at:

- Representing continuous data
- Multiple feature types like line, points and polygons as a single feature type
- Rapid computations which use raster layers as elements of mathematical expressions

Vector data unlike the raster data is not made up of pixels but is formed by a series of vertices and lines. It is graphical in nature. The three representative symbols of vector data are points, lines and polygons. They can be used to represent different features as deemed appropriate by the user. For example, pipelines can be represented as line features and man holes as point features. Obtaining vector data is more challenging. Vector data is more commonly named as shapefiles. Vector data is good at:

- Accurately representing true shape and size
- Presenting non continuous data like rivers, road lines, mountain peaks etc.
- Creating realistic and aesthetical maps

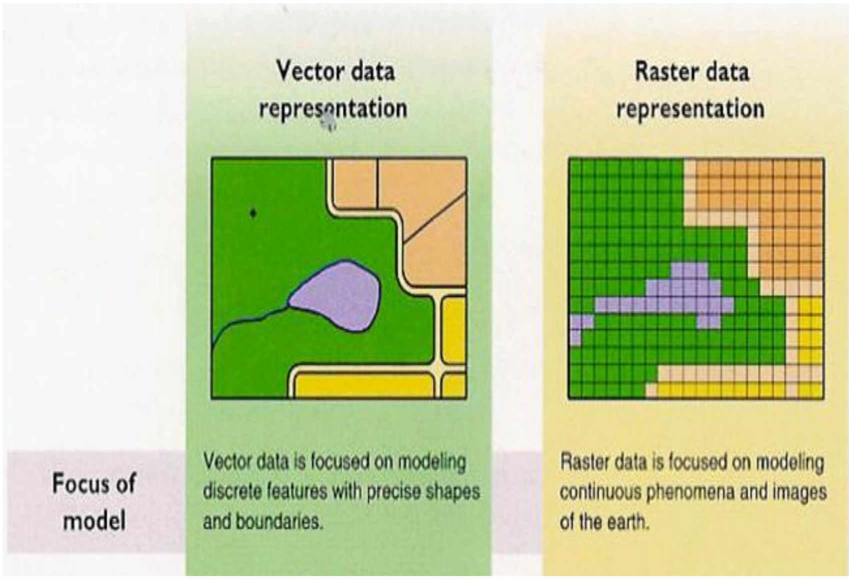

Figure 12 Raster Data vs Vector Data

3.3 Digital Elevation Model (DEM)

A DEM is 3 dimensional representation of the earth's terrain.

A DEM can be represented in both raster and vector format, figure 13. The raster format is also known as a height map. Individual pixels represent the height of the surface in shades of grey color. The vector format is called the triangular irregular network (TIN).

DEM data is also available from different online sources. The accuracy of the DEM is depended on the resolution of the data. Most commonly 30 meters and 90 meters DEM are available online.

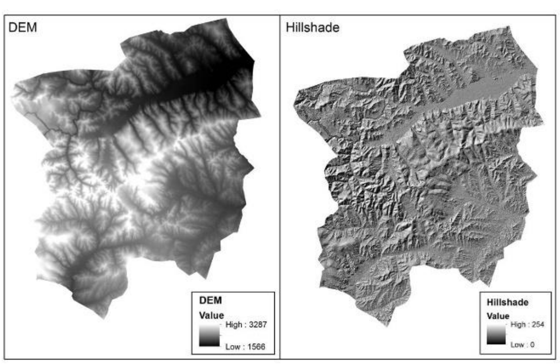

Figure 13 DEM, raster and vector format

3.4 Coordinate system

Knowing your data is important. The geographic reference to the data comes from the coordinate system it is assigned. A coordinate system is a three dimensional reference scale which places points and other features on the surface of the earth. Knowing the correct coordinate system is important. Data that is not geographically referenced to the correct coordinate system will yield inaccurate results.

Most data will be in a local coordinate system. These systems are much more accurate in their limited geospatial extend as compared to global coordinate systems. GIS software have a power base in converting and assigning coordinate systems to unreferenced data.

However, in some cases it may not be simple to assign a projection to the data. In this case the user can formulate his/her own coordinate projection system. The parameters for a user defined projection are best obtained from the GPS or total station used in that same area.

3.5 Structure of BIM for Infrastructure model

The different approaches mentioned before in the study were all analyzed and the most cost effective method was selected to develop a BIM focusing on infrastructure and utilities. This approach takes an indirect route by using spatial data of different services and integrating the positional information with 3D modelling.

Layers:

1. A geospatial raster image forms the base map of the entire model. Satellite imagery, Bing or google maps can be used for this purpose. Satellite orthophotos are the best in this regard but they may not be available for free.
2. DEM is then draped over the satellite image to give a realistic effect of the actual topography of the area.
3. Positional data of different services and utilities can now be added to the model. This information will be contained in the form of shapefiles.
4. The data is then 3D modelled. Using appropriate templates and style pallets different networks are then extruded.
5. Information regarding individual models can then be added to the model.
6. The model is now ready to be put to work. It can be used to carry out different analyses, draw results, conduct presentations etc.

3.6 Building the BIM

Software tools used:

1. ArcMap 10.1 (GIS)
2. AutoCAD 2015
3. Infraworks 360 (BIM)

PC requirements:

Operating System	Windows® 7 64-bit Professional, Ultimate, or Enterprise edition (SP1), or Windows® 8/8.1 64-bit Professional or Enterprise operating system

CPU Type	Dual-core Intel® Core™2 or equivalent AMD processor (Quad-core Intel® Core™ i7, 6-core Intel® Xeon®, or better processor highly recommended); to use the ray traced rendering functionality, CPU must support SSE 4.1
Memory	8 GB RAM minimum (16+ GB recommended)
Display Resolution	1,280 x 720 or greater (1,440 x 900+ recommended)
Display Card	Any DirectX® 10.1 capable graphics card with 2 GB (or more) graphics memory, supporting 8x Antialiasing (8x AA), such as NVIDIA Quadro® 5000 or 6000 for desktops and NVIDIA Quadro 2000M or GeForce® GT 650M for laptops; (Any DirectX 10.1 capable graphics card with 1 GB graphics memory supporting 2x antialiasing (2x AA) minimum)
Disk Space	10 GB free disk space for installation (additional space required depends on data size)
Pointing Device	Microsoft-compliant mouse
Media	DVD or download file
Browser	Microsoft® Internet Explorer® 11, Google Chrome™ (latest), or Firefox® (latest)
Internet	Internet connection for full online help and learning materials accessibility and Autodesk® Cloud service

Step1:

Collect relevant data of all the infrastructure components. This should be the as built maps and shapefiles. Shapefiles can be directly imported into Infraworks 360. If the as built drawings are in AutoCAD format then they must be first converted into shapefiles. If the same data is in raster format it would have to be digitized.

AutoCAD to shapefile:

1. Organize the CAD drawing into layers. Every feature must be in its prescribed layer.
2. The CAD data needs to be in its actual coordinates and orientation.
3. If the data is already projected ArcMap will automatically recognize the coordinate system and units. However, if the data is not projected the "define projection" tool can be used to assign the correct coordinate system.

   https://www.youtube.com/watch?v=xbFV2N4GxH4

   Define and project data layers in ArcMap 10
4. User defined coordinate system can also be created in case the projected coordinate system of the data is not available in the ArcMap library.

   http://support.esri.com/en/knowledgebase/techarticles/detail/30583

   How to create a user defined coordinate system
5. Import CAD data into ArcMap.

6. Select individual features in separate layers and then convert them into shapefiles.

   https://www.youtube.com/watch?v=-6r1B0snYzo

   CAD to shapefiles conversion

Raster to shapefiles

1. Import raster data into ArcMap.
2. The image will first have to be georeferenced. At least two points of known coordinates on the image must be selected and their coordinates added manually. This orients and sizes the image in its proper form.
3. Start editing the image and trace all features.
4. Once saved the traced features form digital vector footprint of the respective features.
5. These features can then be converted into shapefiles.

Step 2

Download Digital Elevation Model (DEM) from online sources. DEM can also be created if sufficient survey points with elevation data is available.

https://www.youtube.com/watch?v=tyy0_kPSR8Y

Download DEM

DEM can be in TIN or raster format. It is better to convert the DEM to the raster format as Infraworks 360 readily accepts this format. Use “TIN to raster” tool in the 3D analyst tool box for conversion.

DEM may also require coordinate system adjustment. It may or may not be in the same coordinate system as the rest of the data. This may require coordinate conversion.

Step 3

Good resolution satellite image is required to form the base map of the entire model. Imagery can be downloaded from the USGS online resource bank.

https://www.youtube.com/watch?v=aNns-yGpO1A

Download satellite images

Infraworks 360 can also automatically place a base map for the model extent. This image is take from Bing maps. With the base map in place the foundation of the model is ready.

Step 4

Infrastructure data can now be imported. Infraworks can import data in many different formats. Choose the correct data type and import it to the already created base map. The data will have to be configured first. The configuration setting include information about the imported data. This is the where we put the “I” of BIM in the BIM. It will include the type of infrastructure, its design template, its style, material type, date of commission, geolocation etc. Once all the correct information has been input and the correct geolocation set, the data will take its respective place on the base map and according to the design and style setting will appear in 3D.

https://knowledge.autodesk.com/support/infraworks-360/learn-explore/caas/CloudHelp/cloudhelp/2015/ENU/InfraWorks-UserHelp/files/GUID-DE99D7DA-EF3C-4B13-A9B1-4283A955AD85-htm.html

Importing data to Infraworks.

Step5

Analysis on the model can now be done. The software provides various functions that can be used to simulate variable conditions and extract results. The analyses that can be carried out include shadow and light, watershed area, traffic simulation, drainage designs, bridge designs and geospatial site analysis.

Resources:

1. Tutorial: “Autodesk Infraworks and Infraworks 360 Essentials: Autodesk Official Press” by Eric Chapel
2. https://knowledge.autodesk.com
3. http://www.lynda.com/InfraWorks-training-tutorials
4. https://www.youtube.com/user/TheMrDarani/videos
5. https://www.youtube.com/channel/UCkleYnTbDyRZFJxmNg1e0nQ
6. Autodesk Infraworks training guide.

CHAPTER 4

4 RESULTS

4.1 The Model

The final outcome of the project was a 3D model of an entire neighborhood. DHA phase 2 and NUST H-12 campus Islamabad were recreated in the virtual environment. Underground and over ground facilities and services were mapped. These models were then uploaded on the cloud and were linked to an augmented reality application to be used on an IPAD. The services mapped were:

4.1.1 DHA phase2 Islamabad

- *sewerage system*
    1. 24 inch pipelines
    2. 12 inch pipelines
    3. 6 inch pipelines
    4. Manholes main
    5. Manholes secondary
- *Natural gas system*
    1. 6 inch pipelines
    2. 4 inch pipelines
    3. 2 inch pipelines
    4. 1 inch pipelines
- *Water supply system*
    1. 8 inch pipelines
    2. 6 inch pipelines
    3. 4 inch pipelines
    4. 3 inch pipelines
    5. 2 inch pipelines
    6. 2/3 inch pipelines

7. Overhead water tanks
8. Tube wells
9. Valves

- *Road network complete*

4.1.2 NUST H-12 campus Islamabad

- *Sewerage system*
  1. 24 inch pipelines
  2. 18 inch pipelines
  3. 15 inch pipelines
  4. 12 inch pipelines
  5. 9 inch pipelines
  6. Manholes

- *Natural gas system*
  1. 24 inch pipelines
  2. 6 inch pipelines
  3. 4 inch pipelines
  4. 2 inch pipelines
  5. 1 inch pipelines
  6. Natural gas meters and pump units
- *Water supply*
  1. 12 inch pipelines
  2. 10 inch pipelines
  3. 8 inch pipelines
  4. 6 inch pipelines
  5. CDA line
  6. Overhead water tanks
- *Electric network*
  1. Generators

2. Transformers
3. Light poles

- *Road network complete*
- *Buildings*
- *Fences*

4.2 Analysis

Analysis conducted within the 3D model are quick and accurate to the degree of accuracy of the imported data. An accurate model can give very precise and usefully analysis that can be used for planning and decision making processes.

4.2.1 Terrain theme

Terrain Themes, figure 14-15, allows to compare terrain based on Elevation, Aspect, or Slope. This allows for easy visualization of the change in terrain where the contour interval and theme format are easily controlled to match the accuracy required.

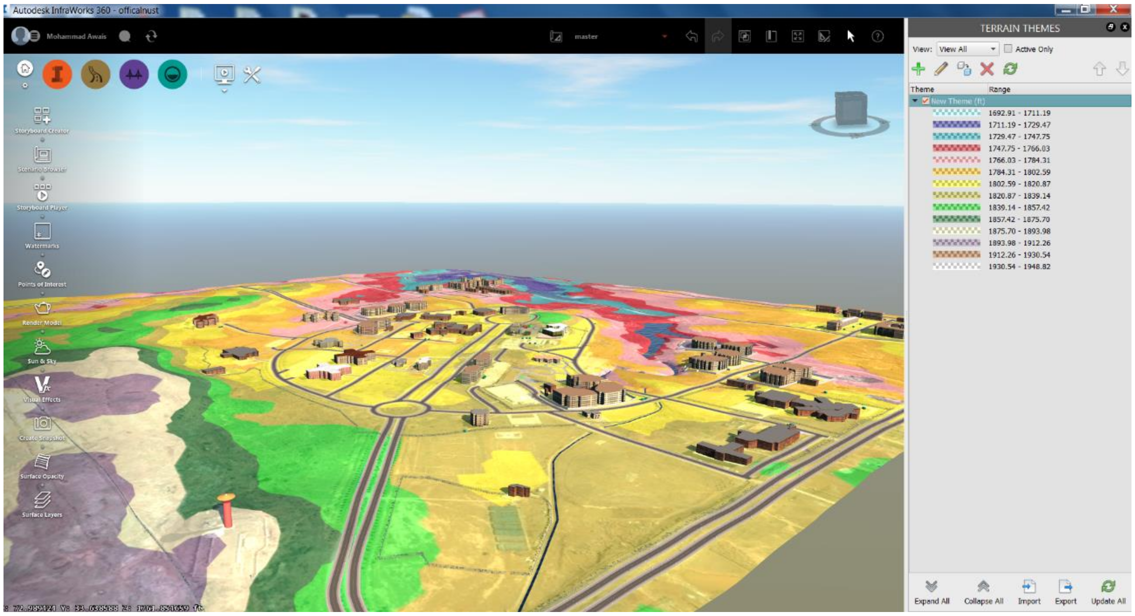

Figure 14 Terrain themes

4.2.2 Feature themes

This analysis is similar to the terrain themes but is applicable on any individual feature within the model. The difference in elevation, slope and aspect can be visualized with a few clicks in the accuracy required. Figure 15 shows terrain themes applied to water areas.

Figure 15 Feature themes

The image show feature theme applied to water areas.

4.2.3 Light and shadow analysis

Conduct real-time lighting analysis by specifying a location and time of day and year to predict how shadows could affect your project proposal. Analyze sun shadows throughout a period of time. See how shadows change over the course of a year, and capture that information in your videos. Assist city planning activities by predicting how proposed buildings will throw shadows throughout the day and how it could affect other building owners’ view.

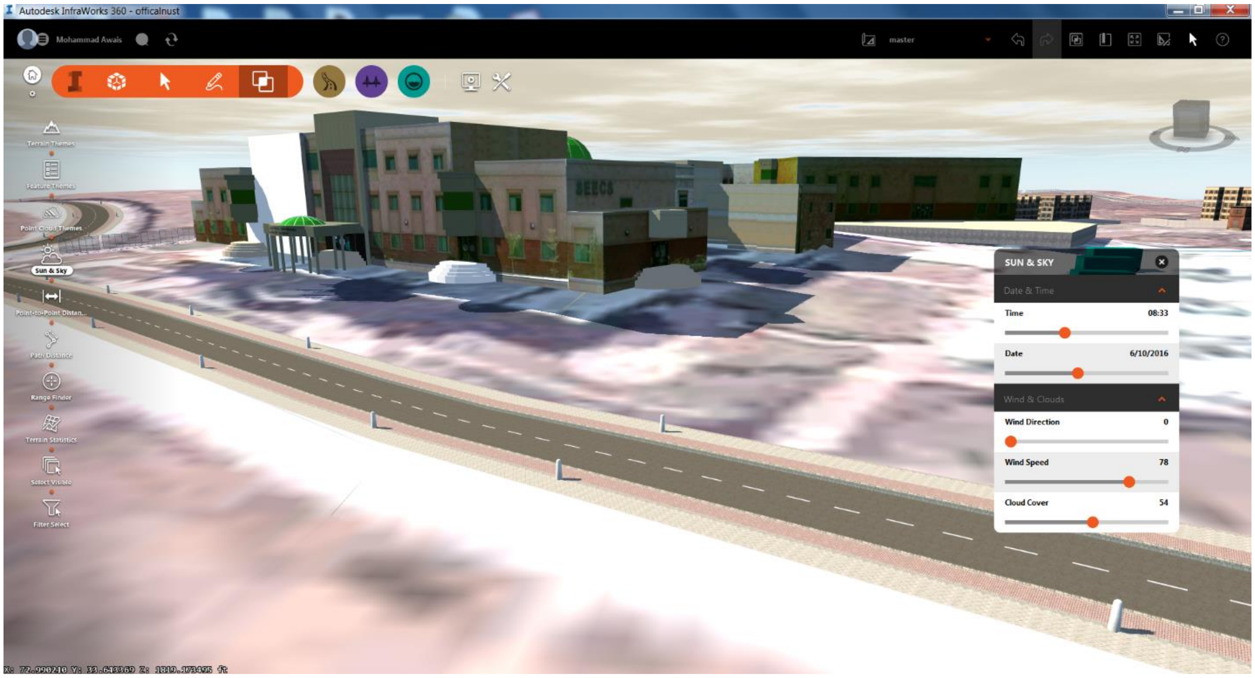

Figure 16 Light and shadow analysis

Light and shadow analysis SEECS 8am (figure 16)

Figure 17 Light and shadow analysis

Light and shadow analysis SEECS 2pm (figure 17)

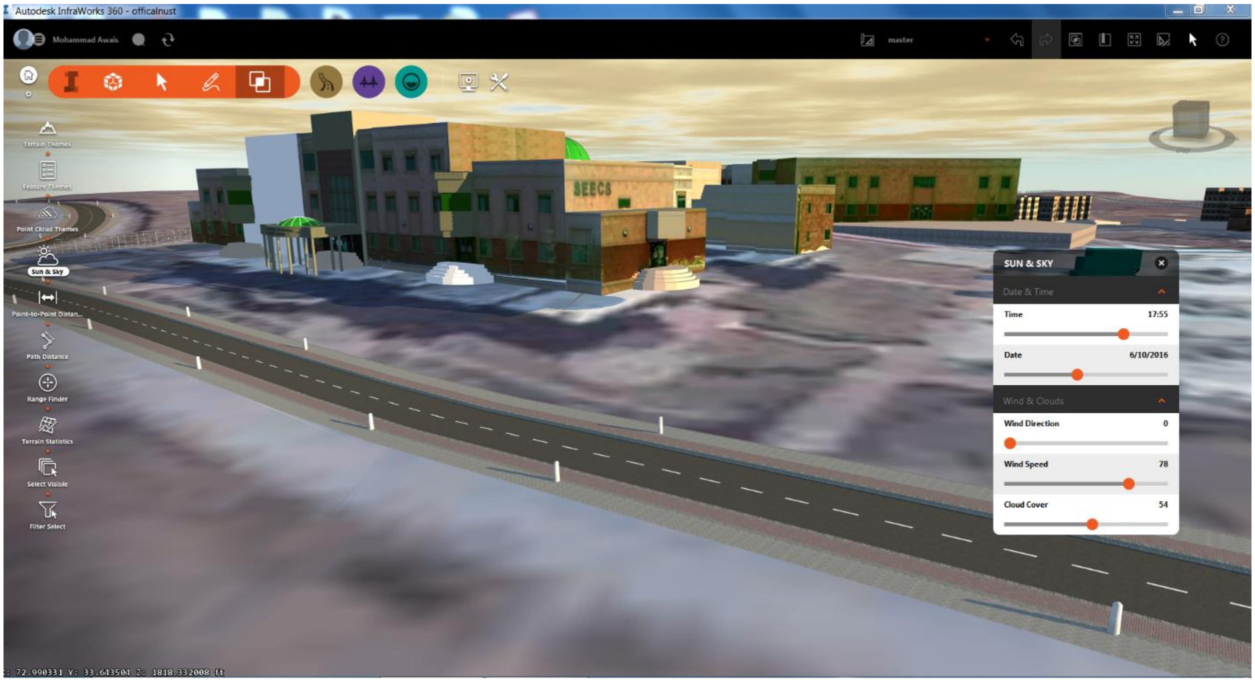

Figure 18 Light and shadow analysis

Light and shadow analysis SEECS 6pm (figure 18)

4.2.4 Point to point distance

Point to point distance is fairly easily to calculate. Selecting the corresponding point does the job, figure 19. The resulting distances are displayed as dimensions. A label shows distance values for each measurement, using the current unit of measurement.

Figure 19 Point to point distance

4.2.5 Distance along a line

Point-to-point measurement does not take into account the variation of terrain. That is, the lines between points are not "draped" on the surface. For more accurate measurements across terrain, polyline measurement can be done. The vertical distance between points for individual features within feature classes such as 3D models or buildings can be measured as shown in figure 20. The resulting distances are displayed as dimensions. A label shows distance values for each measurement, and for the total distance, using the current unit of measurement.

Figure 20 Distance along a line

4.2.6 Range finder

This tool is used to measure from the current position to a target point. A label indicates the altitude, direction heading, and angle of inclination to the target as shown in figure 21. Distances between the viewpoint and other targets can be measured by clicking more end points. Each one is labeled separately.

Figure 21 Range finder

4.2.7 Terrain statistics

The Terrain Statistics tool measures total length, 2D & 3D area, as well as volume of a selected terrain area, illustrated in figure 22.

Figure 22 Terrain statistics

4.2.8 Visibility analysis

Analyze the visibility of design elements from different locations to help determine optimal locations for placement. Highlight items that are visible within the viewport from a position that you select to easily determine what can be seen from a particular location in the landscape as shown in figure 23.

Figure 23 Visibility analysis

4.2.9 Engineering analysis

Engineering analysis would include the behavior and simulation of engineered works within the model. This would include pipelines, services, drainage, road and traffic etc. These analysis are possible by exporting the built model from INFRAWORKS 360 to CIVIL 3D. Trials were run for this matter.

- **Geometric design**

The data from Infraworks is imported to civil 3D and geometric design can then be done. This is shown in figure 24-25.

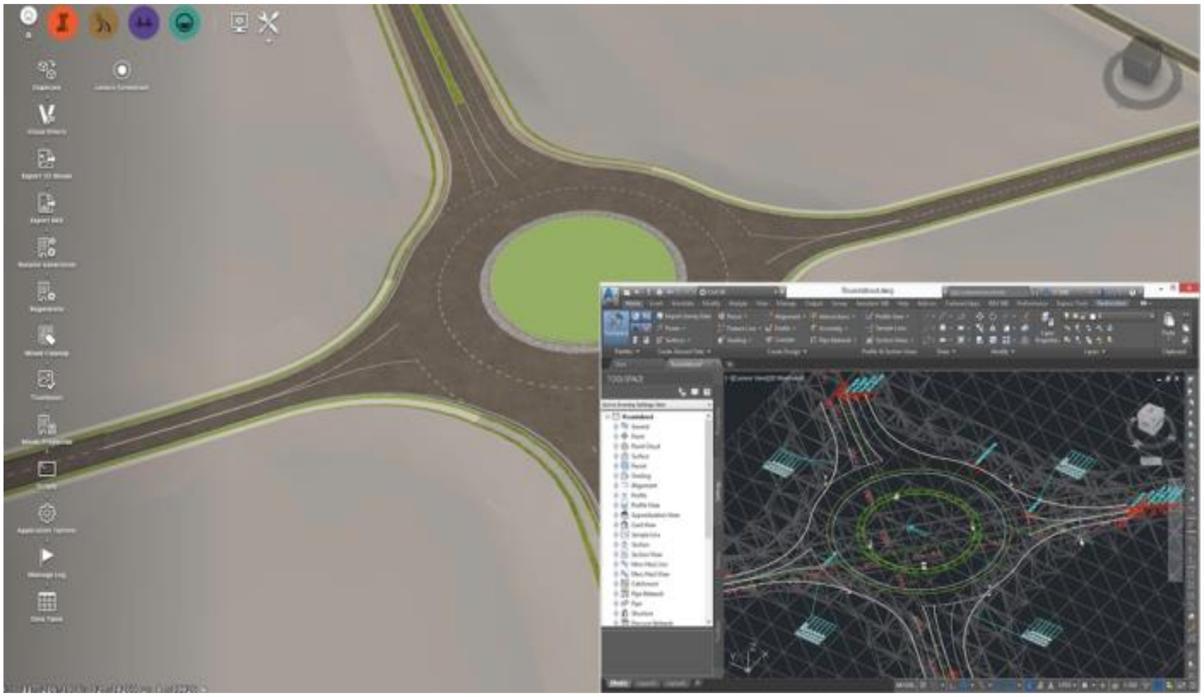

Figure 24 Geometric design in civil 3D

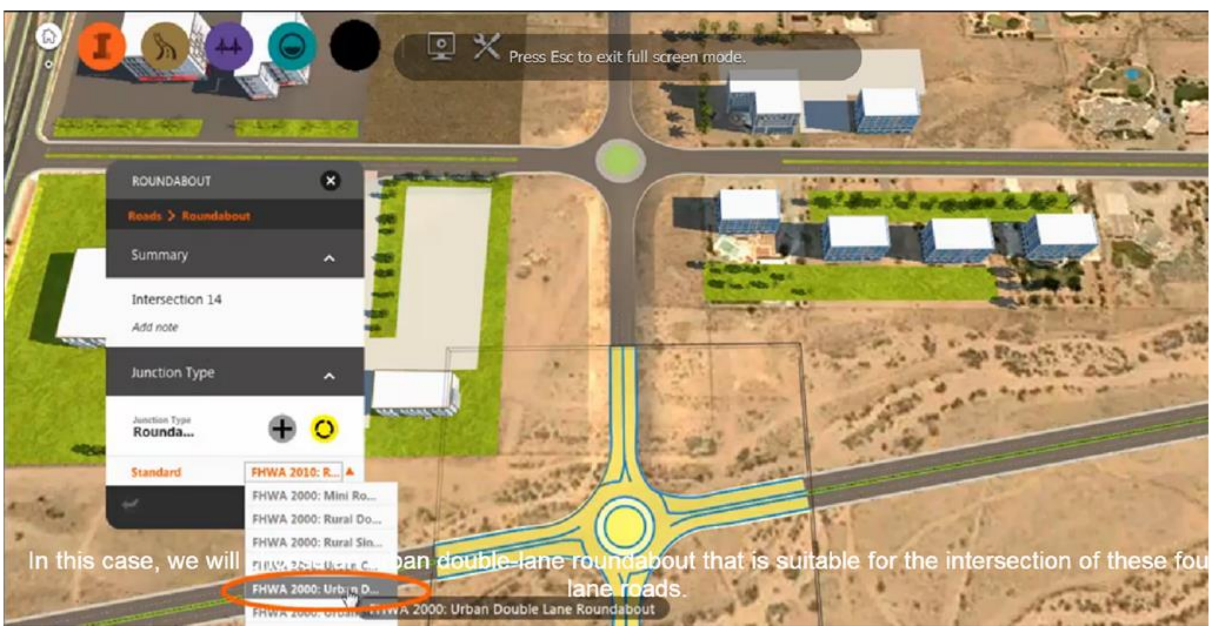

Figure 25 Geometric design Infraworks

- **Sewerage system design and analysis**

Just as road geometric design, sewerage system design can also be conducted in civil 3D by importing sewerage data from Infraworks into civil 3D. Figure 24 shows a part of drainage network in DHA phase 2 Islamabad. Drainage design analysis of the same part is shown in figure 25.

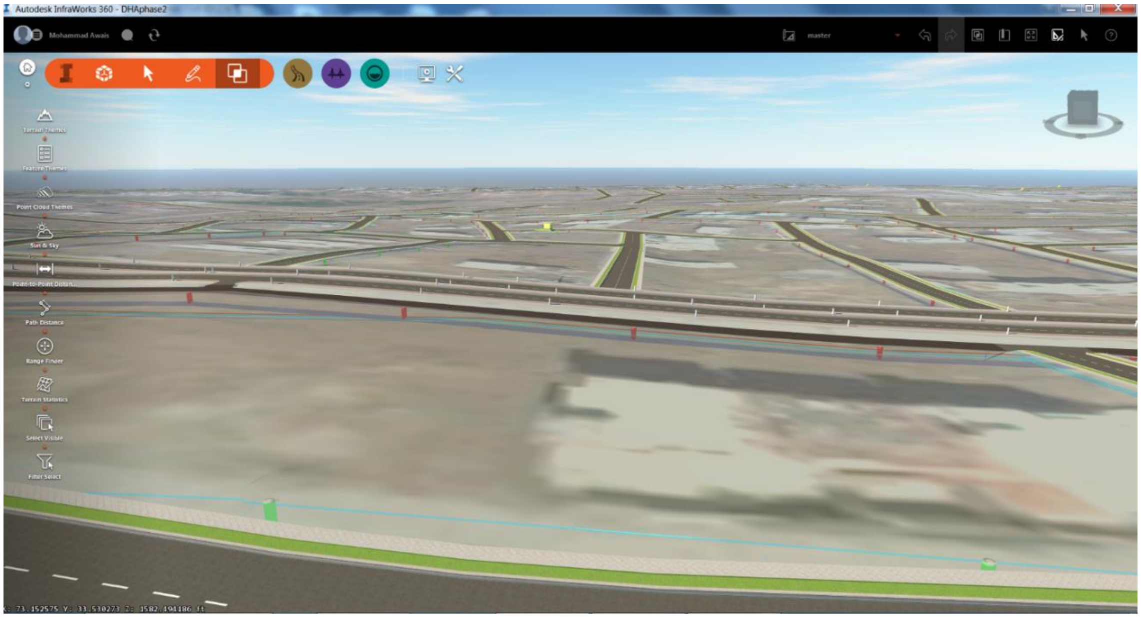

Figure 26 Part of a drainage network (Infraworks model DHA phase 2)

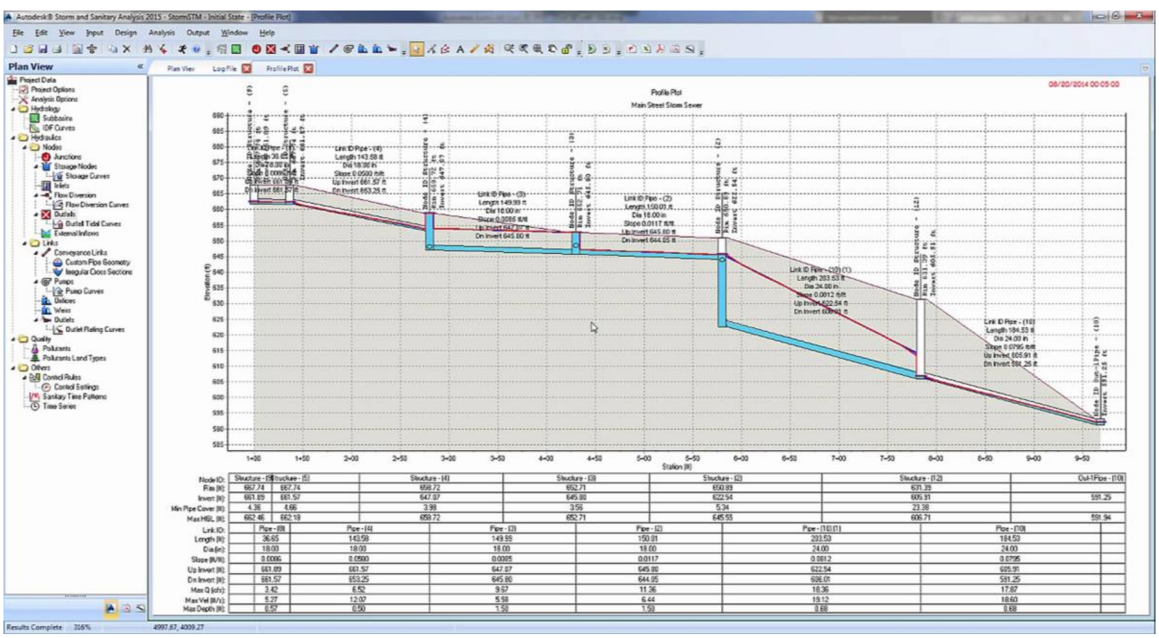

Figure 27 Sewerage analysis (Civil 3D)

CHAPTER 5

5 CONCLUSION

5.1 Introduction

The process of BIM is extremely helpful throughout the life cycle of a construction work. It aids and helps in conception, design, construction and facility management. Workflows become more streamlined and coordination between different stake holders increase. BIM captures reality by working within a 3D environment. It increases control and simulate conditions in a virtual system. These simulations can help encounter problems before construction. BIM can resolve conflicts by clash detection and provide a sequential strategy to complete the project enhancing efficiency. Modern cloud and 360 features are allowing all of this data to be accessible from anywhere on any device. With all of the design completed on a capture and alteration of existing reality, the model is the ultimate communication tool to convey the project scope, steps, and outcome but there's also a need to share a traditional plan, section, and elevation, as well as other reports with your project team. This need arises due to a lack of understanding by the end workers, the labor force, about BIM.

5.2 Conclusion

The research conducted here establishes and reaffirms BIM as an extremely valuable and helpful resource in construction. It takes the concept of BIM and widens its scope to incorporate a complete neighborhood through 3D city modeling. It also tries to bridge the gap between the end users and the management utilizing BIM. This was done using augmented reality. A user within the actual space of the model can overlay virtual data on a real physical background. BIM is usually referred to as a 7D process; which compromises of 3D model of the facility, scheduling, cost estimation, sustainability and facility management. Augmented reality can be the 8th dimension to this process. It can help to overlay design on the real environment, act as a way of information transfer that is easy to comprehend and help in facility management and repair work. Use of this technology can help shape the future where systems are more closely monitored, have less downtime and continuously generate data that can be made visual. This can truly be a step towards “smart cities”.

Development of “smart city” models by 3D modeling, BIM and innovating technologies to make them simple and easy to use by a layman is the way forward to counteract the present and future challenges of cities’ exponential growth. However, these tools may appear to be the solution of a complex problem but their limitation and boundaries should be tested. These system and tools should be scientifically put to test in order to determine the extent of their advantages in a tangible form.

5.3 Limitations

1. For 3D modeling archived digital as built maps were used. These maps can have error and there is always a question of their accuracy. To map existing features, the best solution is LIDAR and aerial survey which was not conducted due time and cost constraints.

2. The digital device used for video based augmented reality application was an IPad AIR 2. This is not an engineering tool and can have error especially in its built-in GPS. Furthermore, the IPAD is unable calculate or display distances

3. The digital elevation models used were free of cost SRTM 30-meter resolution terrain models. Better and accurate results can be obtained by using 1 meter or half a meter resolution terrain models.

4. The bases of the models were aerial imagery of the model extent. This was simple imagery obtained for free from different web sources. Again better results could be achieved using satellite orthophotos.

5.4 Recommendation

1. The system developed should be tested in the field. The workmen should be trained and equipped so that the benefits of the system can be examined the real world.
2. An augmented reality device custom made for construction should be used. It should have a dedicated engineering accuracy GPS, high processing power and distance measuring system.
3. Using an actual construction case study, the perceived benefits and limitations of the proposed system should be tested.

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