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Deploying an Interactive GIS System for Facility and Asset Management: Case Study-Ministry of Education, Kuwait

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Abstract

Geographical Information System (GIS) can be considered the core of the Interactive Facilities Management Environment (iFaME) framework in managing different facilities on the building bases. This study aims at building a comprehensive geodatabase for different elements of infrastructure facilities and services on the building bases for a selected number of schools and developing a GIS-based iFaME interactive application to manage different facilities at the school level in Kuwait. The iFaME is a two-dimensional/three-dimensional (2D/3D) desktop application. It is intended to take planners, decision makers, and maintenance experts inside the building to provide an interactive GIS platform to manage, visualize, query, maintain, and update the database related to school assets and facilities. The Autodesk Revit software was used to produce 3D building information models (BIM) for the selected schools. It provides accurate geometrical representation of the school building elements in an integrated data environment. The iFaME application is integrated with the Revit BIM models and the STAR-APIC Elyx 3D software solution. With the development of the iFaME applications, the facility managers in the MoE could establish greater control over the space allocation and management, asset management, emergency planning, and other areas of facility management. The school managers and maintenance engineers are considered among the most beneficiaries from this application. The school managers will monitor the maintenance activities all the time, while the maintenance engineers will use the application as a container for maintenance orders, and on the same time to document what they accomplished on daily basis. The iFaME application will reduce the maintenance cost of school assets and facilities in addition to increase their efficiency.

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Keywords

Elyx 3D, Micro-GIS, Building Information Modeling (BIM), Kuwait

1. Introduction

The Interactive Facilities Management Environment (iFaME) is the framework that was used in the National Educational Atlas for Services and Infrastructure (NEASI): Facility Information Infrastructure (FII), phase-II project developed by the Kuwait Institute for Scientific Research (KISR) for the Ministry of Education (MoE). The first phase of the NEASI covered the use of the Geographical Information System (GIS) technology to build an integrated geodatabase for different components of educational services and infrastructure on the national level. The NEASI facility information infrastructure (FII) second phase was designed to provide the end user in the MoE with the required data to manage the facilities at the micro level within the buildings from many sources and in multiple forms [1] [2]. The iFaME is considered as a Micro-GIS application. The Micro-GIS is defined as a set of tools that could map out and describe educational facilities in detail. This tool is intended to take planners, decision makers, and maintenance experts inside the building, not just to have the exterior view, but more importantly, to provide access to school features and their properties. The detailed objectives of these paper areas follows:

- Build comprehensive multi objective geodatabase for different elements of schools assets and facilities on the building basis for selected schools.
- Develop a GIS-based interactive application (iFaME) to manage different assets and facilities at the school level.

The iFaME is a cost-effective and robust solution to small and medium business enterprises (SMEs) for managing workspace, asset (furniture and equipment), work force occupancy, and emergency situations in organizations in the context of building space [3]. The developed iFaME is a 2D/3D GIS desktop application, aimed to provide a GIS platform to manage assets and facilities, and to use GIS tools to visualize, query, and update the database related to existing assets and facilities [4].

Facility Management (FM) represents one of the fastest growing sectors. However, tracking and managing facility effectively are extremely difficult. Designers always use 2D plane graphics to transfer their idea about the needed design in the past, but it is difficult for the amateur designers to understand the design completely in the 2D graphics environment [5]. Even if component-oriented CAD systems provide sophisticated functionalities for geometric modeling, they lack the comprehensive spatial analysis capabilities. For this reason, floor plans of buildings can be stored in GIS database in order to use its 2D spatial analysis functionality; while the 3D spatial analysis would be a much more powerful tool for analyzing processes in buildings [6]. To overcome these problems, the Building Information Modeling (BIM) approach was applied and 3D information models were developed to support managing and maintaining facilities in this study as a separate BIM 3D model for the selected schools. The guide to utilize the BIM technology for different categories of users, in addition to the role of BIM on construction management is discussed and presented in details [7]-[9]. Goedert and Meadati [10] studied the integration of the construction process documentation and the BIM. The BIM is a data-rich, object-oriented, intelligent, and parametric digital representation of different facilities, to support decision makers in enhancing the process of delivering the facility [11]. The different application areas and the related needed data that required for building the BIM models to support FM were discussed by Becerik-Gerber *et al.* [12]. Gheisari *et al.* [13] studied the potential future integration of the BIM technology with Augmented Reality (AR) in the FM field. The key benefit of BIM is its accurate geometrical 3D representation of the building elements in an integrated environment [14]. It is become clear that the FM is an important research topic, especially on the operation and maintenance phase of different facilities. Lin [15] discussed the man challenges in the implementation of BIM technology for FM. With the advancement in the computer hardware (H/W) and software (S/W) capabilities, most CAD vendors have launched more powerful object-based CAD S/W, such as BIM. They mentioned that 3D to nD modeling research project has been started at the University of Salford. Also, they discussed the main obstacles to the widespread use of BIM and related future nD modeling [16]. Manning and Messner [17] studied the use of the BIM technology for programming of healthcare facilities. They illustrated the benefits of BIM upstream in the project lifecycle of the healthcare projects, especially the programming stage.

According to Vasanth and Viswanathan [3], the key features of the GIS-based iFaME are property lease management, site infrastructure management, workspace management, asset management, workforce occupancy management and emergency management. Zlatanova *et al.* [18] observed the advancement in the area of 3D GIS. They concluded that the main 3D progress was concentrated on the area of data presentation and that the topological issues therein need further research focused on the main GIS functionality such as 3D buffering and 3D shortest route. The integration of the BIM with the GIS technologies was started and will be continued for the benefit of both the BIM and GIS users. The utilization of the four-dimensional (4D) and BIM modeling in managing and planning of building spaces are highly recommended. Bansal [19] was utilized the 4D GIS for space planning. He found that the GIS facilitate the topographic modeling, geospatial analyses, and powerful database management. Also, he developed and implemented GIS-based methodology for space planning, time-space conflict identification, and conflict resolution.

2. Methodogy

2.1. Data Collection and Organization

The AutoCAD drawing files were collected, prepared, and organized to extract the required data and then uploaded into the spatial Oracle geodatabase of the iFaME application. The data preparation was concentrated on georeferencing the AutoCAD data to the real coordinates, validating accuracy of the data, and verifying the topological errors like overshoots, undershoots, and spatial relationships with other features. The applied procedures to prepare and convert the AutoCAD files into GIS-ready format [4] are as follows:

- extracting the relevant data from AutoCAD files;
- converting the extracted data into GIS-ready format and classifying different facilities and assets based on their types;
- georeferencing all data layers into real world coordinate;
- applying the topology rules to clear spatial errors in different GIS layers;
- creating and classifying polygons into different space units, such as classroom, lab, administrative office, and playground; and
- preparing and loading the final GIS data sets and related feature classes into the iFaME geodatabase.

The results of the system analysis are used in preparing the conceptual, logical, and final geodatabase design. The conceptual geodatabase design supported the process of identification and extraction of the required spatial and non-spatial data from the as-built AutoCAD drawings. The conceptual geodatabase design was followed by the creation of Entity-Relationship (ER) diagram illustrating the relationships between entities in the geodatabase. Then, the final geodatabase was designed and implemented to store the iFaME data sets that prepared as mentioned before [4].

2.2. The iFaME 2D/3D Application

The 2D/3D GIS iFaME was implemented as a desktop application to integrate facility management, inventory management and GIS tool for users who want to query, update, and visualize facilities in the school level [4]. The iFaME desktop enables the user to connect to real 3D representation of school buildings. The 3D representation of schools is carried out using the Autodesk Revit S/Wand the Elyx 3D solution from STAR-APIC GIS S/W. The end user has the ability to switch to any 3D representation of any school from the iFaME desktop application.

In addition to develop the iFaME application, the Autodesk Revit software was used to develop BIM 3D models for selected schools in Kuwait. Revit Architecture has the 2D capabilities of AutoCAD, as well as the 3D modeling design functions. AutoCAD files were used and imported to produce BIM models. Revit MEP was used for the design and modeling of mechanical, electrical, and plumbing systems. Revit Structure is a modeling and drafting program that is used to model all types of materials and structural systems in the buildings [11]. The iFaME application will enabled us to call the developed BIM models and display them while the user working inside the GIS environment. Then, the end user will use the powerful capabilities of the Autodesk Revit S/W to search the detailed components of the building elements and related assets and facilities.

STAR-APIC's Elyx 3D S/W is a true 3D GIS management solution. The main capabilities of Elyx 3D software are to store, manage, and share the 3D data with direct integration with the GIS spatial Oracle. It is one of the technically strongest 3D GIS solutions in the market; therefore, it was used to present and manage the 3D models of the selected schools in Kuwait. The selected schools are exported to Elyx 3D for better 3D visualization and management. It enables the end users to manage and view the 3D data sets in their real locations and overlay them with the 2D GIS data sets from different sources either from inside Elyx 3D S/W or via the If AME desktop application. In all cases, it enables us to execute the main geoprocessing functions on the 2D and 3D data sets. Finally, the iFaME application was integrated with both the Revit BIM and Elyx 3D applications, so that the end user can switch between the different 2D and related 3D views for better management of school assets and facilities.

3. Results and Interpretation

3.1. The iFaME Database Development

The final geodatabase contains twelve main data sets, namely, air conditioning; building (building reference, space unit, furniture, and equipment); clock bell; electricity; firefighting and alarms; water supply; sanitation; security system; sound system; emergency; telecommunication; and site footprint. The number and types of the identified data sets are dependent on the content of the as-built drawings acquired from MoE. Each data set includes its own spatial and non-spatial data to conceptualize and capture the school assets and facilities. For example, the "building" data set contains all space units (e.g., classrooms, labs, and toilets) and building references (e.g., walls, windows, and doors). They are stored in spatial Oracle geodatabase. Then, the iFaME desktop application was connected directly into the original spatial Oracle geodatabase to manage the asset and facility infrastructure of the selected schools.

3.2. The iFaME Desktop Application

The framework of the desktop iFaME application contains four layers (**Figure 1**) to manage school assets and facilities as follows:

- Database layer: It uses Oracle 11-g database with spatial extension for iFaME.
- Management tools layer: It contains three management tools for iFaME, which are facilities management tool for querying and managing facilities of schools, inventory management tool for updating and managing inventory of schools, and GIS tool for measuring the length and area of the facilities of schools.
- Visualization layer: It provides two ways of visualizing the school facilities in either 2D or 3D, depending on the user's need and type of analysis being performed. If the user needs 3D representation for specific school, the desktop iFaME application calls the third party application either the Revit or Elyx 3D S/W.

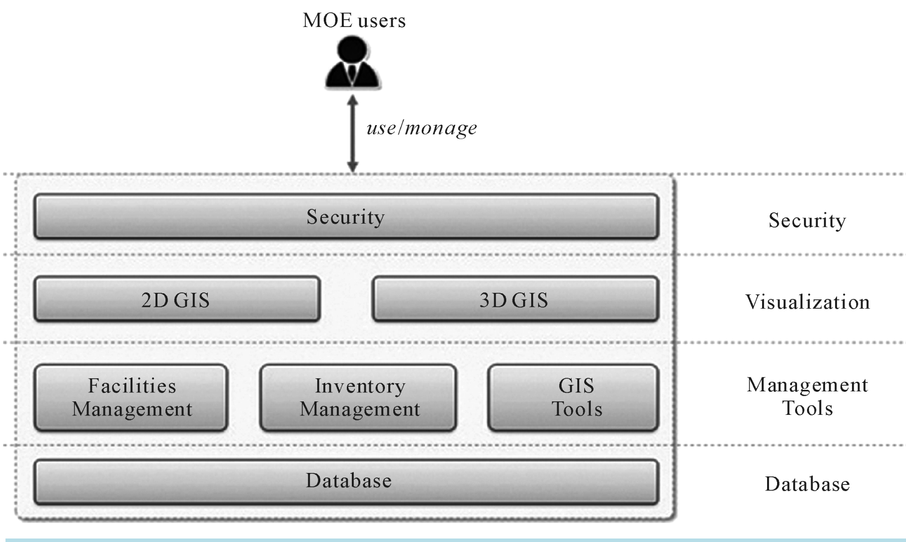

Figure 1. The framework of the iFaME desktop application.

- Security layer: It controls users and grants users specific authorities, such as updating, deleting and managing database and application tools. Three user groups are planned, administrators having all the authorities, data owners having data updating and deleting authorities, and data viewers having view and query authorities only.

3.3. The iFaME User Interface, Output and Interpretation

The main functions and user interface of the iFaME application was illustrated in **Figure 2**. The main iFaME user interface includes a "search bar" to get the name of the needed school, and the "information window" to list the main Metadata about the selected school. The "map" area is located on the center of the user interface to visualize the detailed map of specific floor of any selected school. Also, the user interface includes a "floor switcher" to enable the end user to switch between different floors on the same school building. Once the user selects the specific school from the "search ba", the full map of Kuwait that contains the distribution of different schools will shrink and will be stored on the southeast corner of the interface in the "overview map" area. The desktop iFaME application was designed to have a semple user interface. It has been integrated with third party applications of Revit 3D BIM and Elyx 3D S/W to enable the end users to display the 3D presentation of any school.

Abu Halifa high school was selected to demonstrate the result of the iFaME application. **Figure 3** illustrates the detailed map of the space units of the ground floor of the school. It shows different space units, such as auditorium, classrooms, labs, clinic, and playgrounds. Thus, the school manager can re-allocate any of these spaces into another use based on his real needs and based on the available information about each space unit in the database. So, the iFaME application could be considered as a decision support tool for the school managers in managing the available spaces for the real needs of their schools. The GIS space unit layers of other floors could be displayed upon switching the floor number from the floor switcher button on the top of iFaME user interface.

The air conditioning (AC) system in the ground floor of the school is illustrated in **Figure 4**. The AC in-out is mapped as point features; whereas, the AC ducts are presented as line features. The end user has the capability to search about any component or part of the AC network in any floor inside the school. Also, the maintenance data are stored in the database, so the manager has the capability to identify which part of the AC network need maintenance and store this in the database. Then, the dedicated maintenance engineer when he access the iFaME application will find the maintenance orders that stored in the database. After carry out the needed maintenance, the maintenance engineer will fill in the same database what he did in which time and describes what is used from materials and spare parts in fixing the problem. The system is ready to provide us with reports about the maintenance activities that happened in the school in details. Thus, the school managers and maintenance mangers in any school can manage the maintenance activities in their schools in any time once they are connected to the iFaME application.

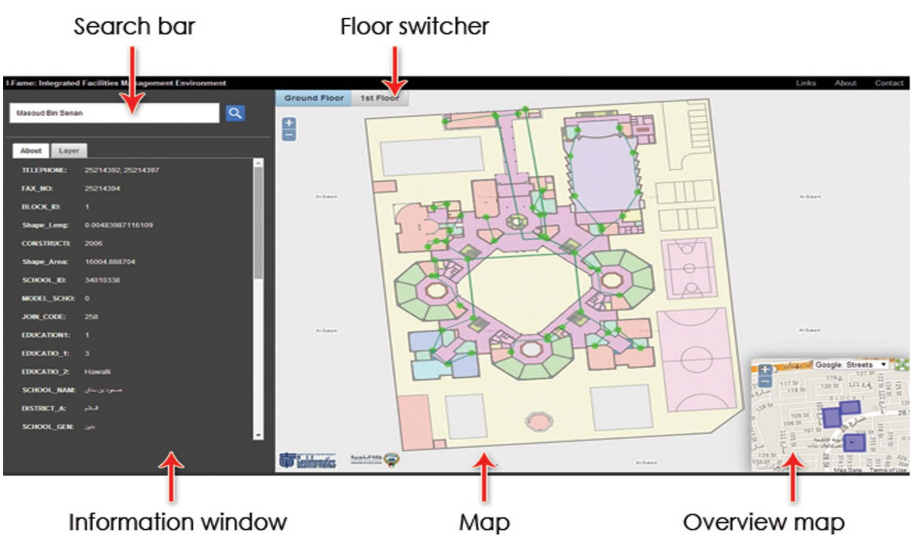

Figure 2. The iFaME user interface.

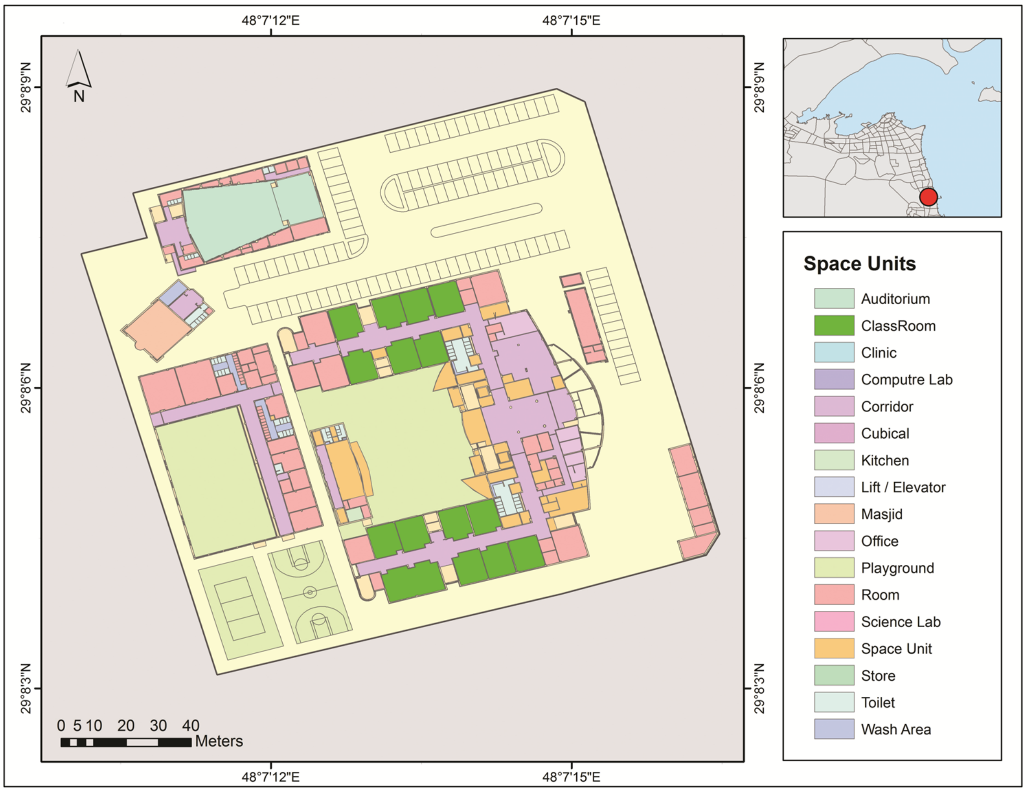

Figure 3. Space units in the ground floor of Abu Halifa high school.

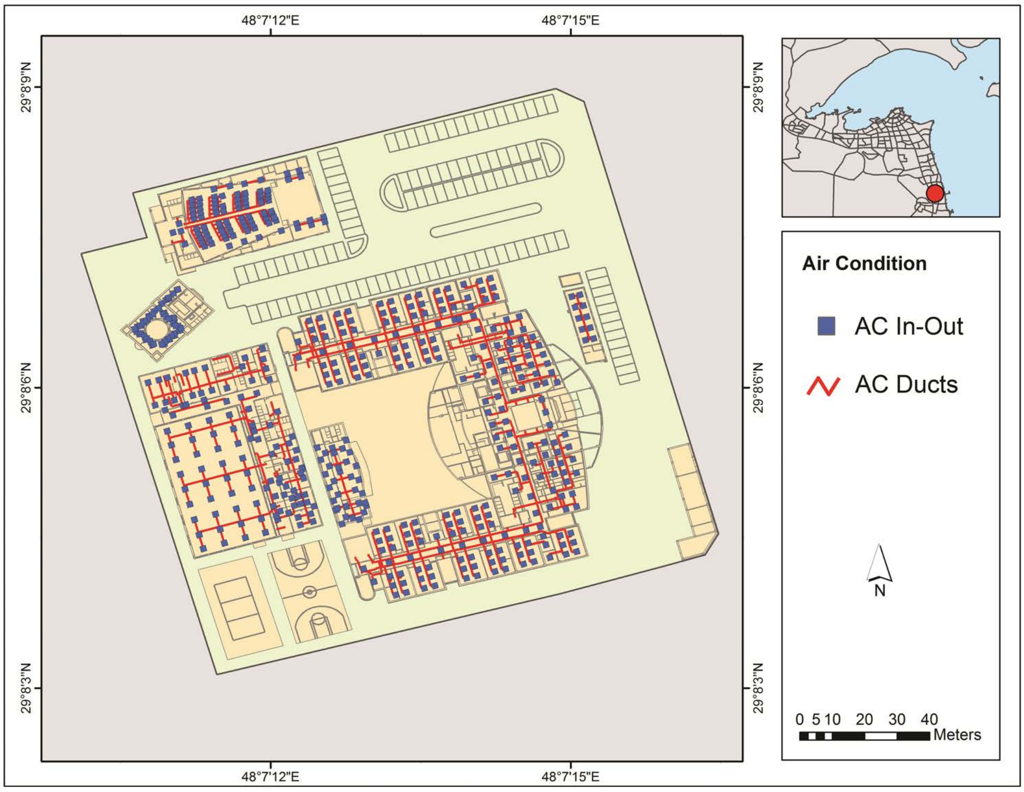

Figure 4. Air conditioning system in the ground floor of Abu Halifa high school.

Also, **Figure 5** shows spatial distribution of the electricity network inside the ground floor of the school. The main components of this network are electrical lights, power outlets, and cables. The school and maintenance managers will use the data set of electricity network in their school for better management and advanced maintenance process. Also, the electricity third party management solution could be integrated with the iFaME application, so every element of the electrical network of any school building could be managed from one-stop shop.

Thus, the iFaME desktop is a powerful application to monitor and manage different assets and facilities inside the school, such as furniture, equipment, space unit, AC, sanitation network, water supply network, and electricity network. The maintenance process in the MoE is classified into two types: 1) Partial maintenance; and 2) radical maintenance. The partial maintenance includes the periodic maintenance as well as any sudden maintenance needed for any component of the school. The radical maintenance means that the school will be removed and re-built again. So, the maintenance engineers of MoE will be able to manage the different types of maintenance activities inside each school using the iFaME desktop application. The decision makers in the MoE level, educational zones level and on the school level will be benefit from the iFaME to manage the maintenance of school buildings and related facilities and assets in a very easy and professional way.

3.4. School Buildings 3D Visualization

The 3D presentation of the selected school buildings were carried out using two different S/W, namely; Revit Structure and STAR-APIC Elyx 3D. The process of creating the 3D models of the school buildings was based mainly on the as-built AutoCAD drawings. **Figure 6** shows the Revit 3D BIM model of Msoud Bin Sinan intermediate school. It shows the 3D presentation of different buildings and components of the school. The school's 3D model could be called and be opened from the iFaME desktop application or using the Revit S/W itself. So, the Revit will be used as a third party S/W to display the 3D models and to search about different components and elements of the 3D model.

The ability of STAR-APIC Elyx 3D software was figured out also to store, manage, and share the 3D data with direct integration with the GIS spatial Oracle database and iFaME desktop application. The captured GIS

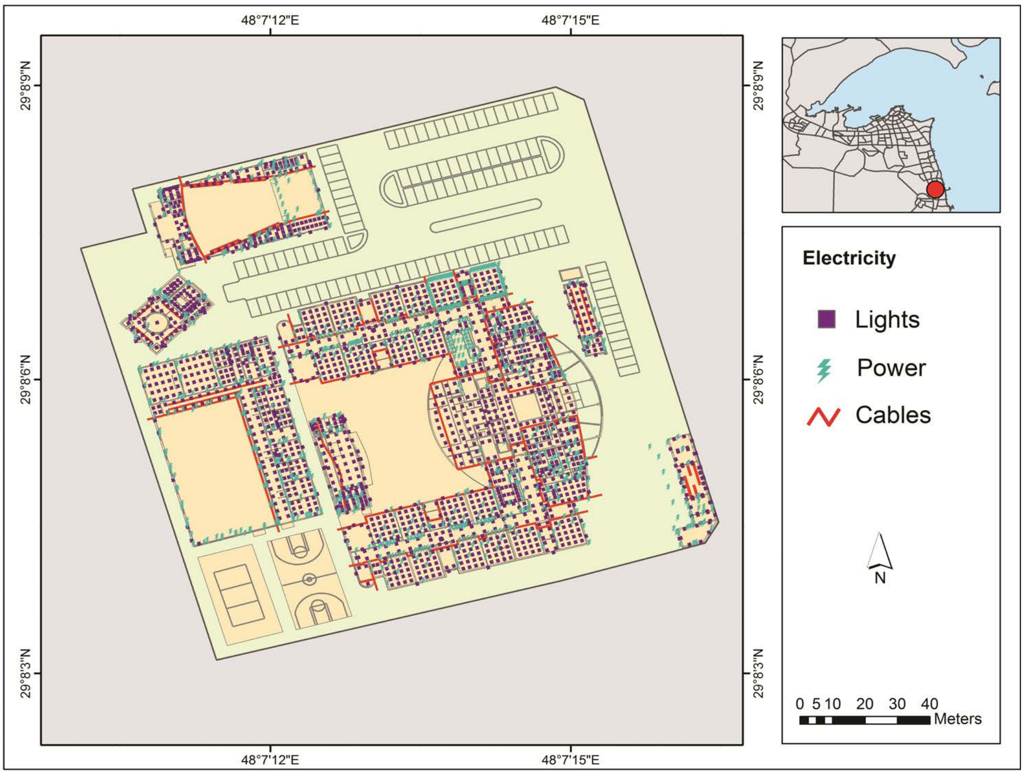

Figure 5. Electricity network in the ground floor of Abu Halifa high school.

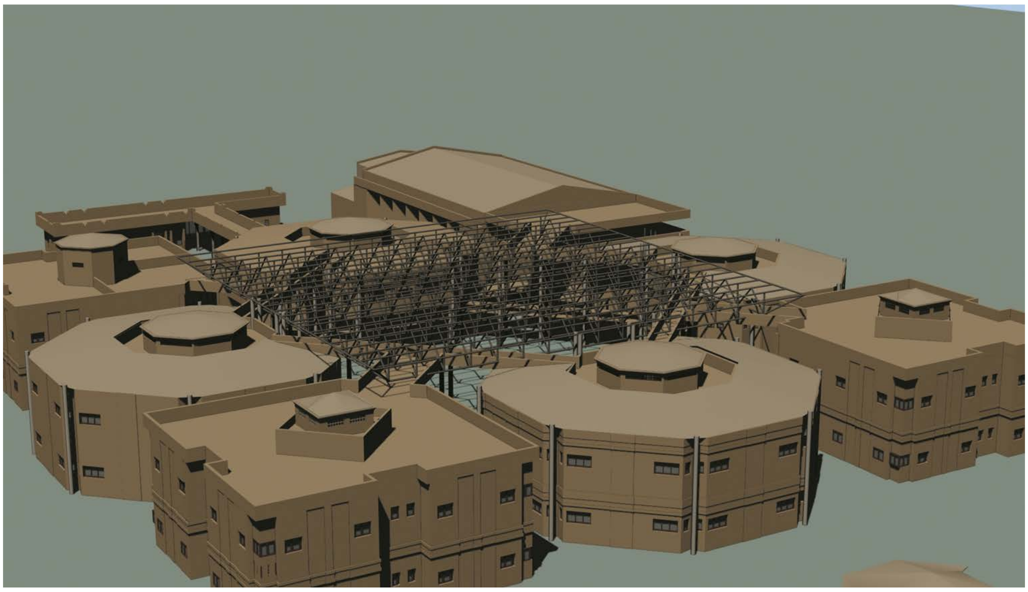

Figure 6. The BIM 3-D model of Masoud Bin Senan intermediate school showing the different sections and floors of the school.

sample data of Sabah Al-Salem district, Mubarak Al-Kabeer educational zone were imported as shape files into the Elyx 3D and its spatial Oracle database, and it contains schools, roads, parcels, storm water manholes, and storm water pipeline layers. Using Elyx 3D processor, all the AutoCAD files of Al-Imam Al-Shafee primary school located on the same district were imported into its spatial Oracle database (**Figure 7**). The AutoCAD data included floor plans, elevations, furniture, utilities, and attribute data sets. The mentioned input data were projected on the top of the digital terrain model (DTM) of Sabah Al-Salem district and imported into the Elyx 3D context in the form of georeferenced image grid. So, the Elyx 3D is used in this application as a third party to display the 2D and 3D GIS layers and manage both of them in real GIS environment. Using this option will enable the end user in the MoE to display different GIS layers for school facilities and assets and carry out different GIS functions and processes from inside the Elyx 3D because it is a GIS management S/W. The spatial oracle database is created for once and will be updated, accessed and used forever either from iFaME or Elyx 3D S/W.

The 3D symbology was used to define interactive object representation parameters of Al-Imam Al-Shafee primary school such as color, thickness, pattern, texture, and the 3D model for different school geometry. Google Sketch up S/W was used to create extrusion of the first floor of the school building based on the 3D scene of Elyx3D (**Figure 8**). Elyx 3D imports back the 3D scene from Google Sketchup and are stored into the spatial Oracle database as a new geometry (LOD1). The user has the right to select one of more flowers to display in 3D environment and their related facilities or school assets. **Figure 8** shows the 3D features displayed correctly inside GIS 2D layers of the selected school. The capabilities of the iFaME application and the third parties S/W that illustrated before will enabled the users inside MoE to manage and maintain their schools in professional way and interactive environment. The use of the iFaME application inside the MoE in Kuwait will change the existing procedures of managing schools assets and related facilities. This application will provide the decision makers and planners with the needed data and information via one-stop shop solution. It will reduce the maintenance cost and increase its efficiency.

4. Conclusions and Future Researches

The developed GIS 2D/3D iFaME application is a reasonable framework to manage the different assets and facilities in MoE. This framework could help MoE to have clear documentation, inventory, and control over all school assets and facilities. The developed geodatabase on the building bases and the related iFaME application could support the process of managing assets and facilities on the micro level within the school building. The facility managers could establish greater control over the space allocation, asset, and facility maintenance, and

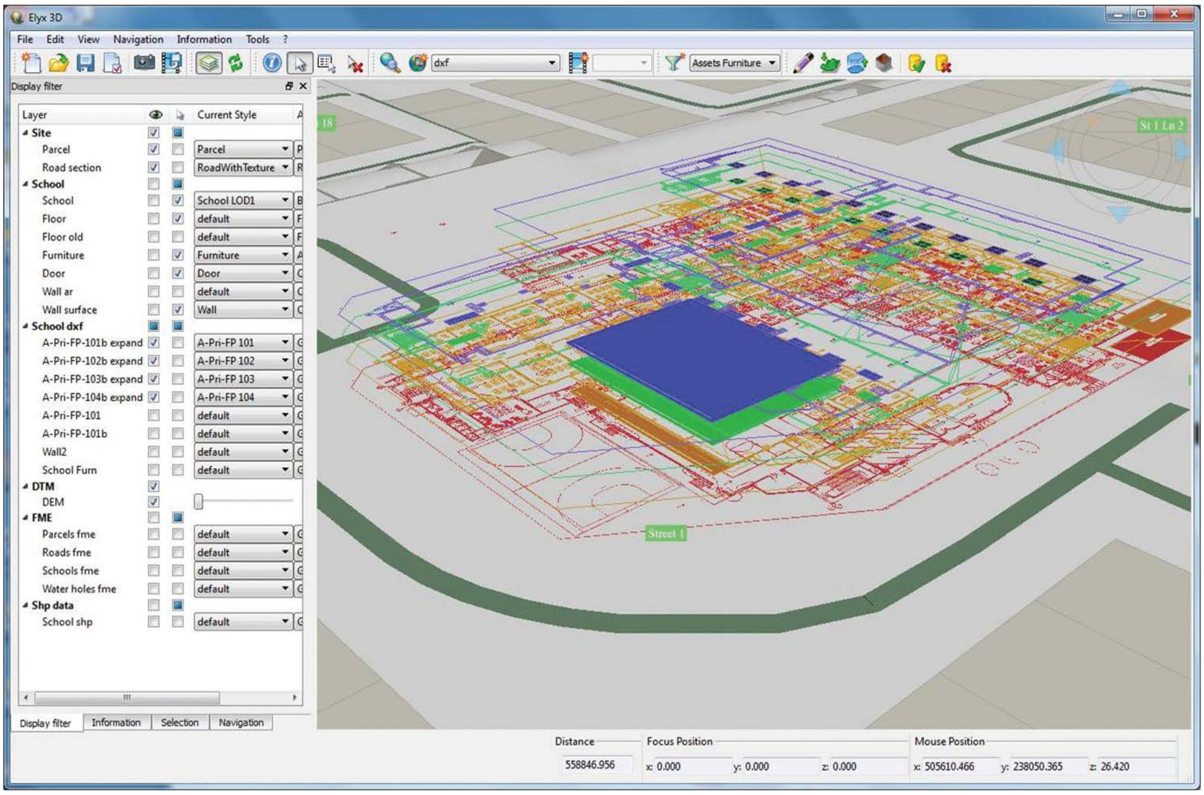

Figure 7. AutoCAD files of Al-Imam Al-Shafee primary school imported into Elyx 3D.

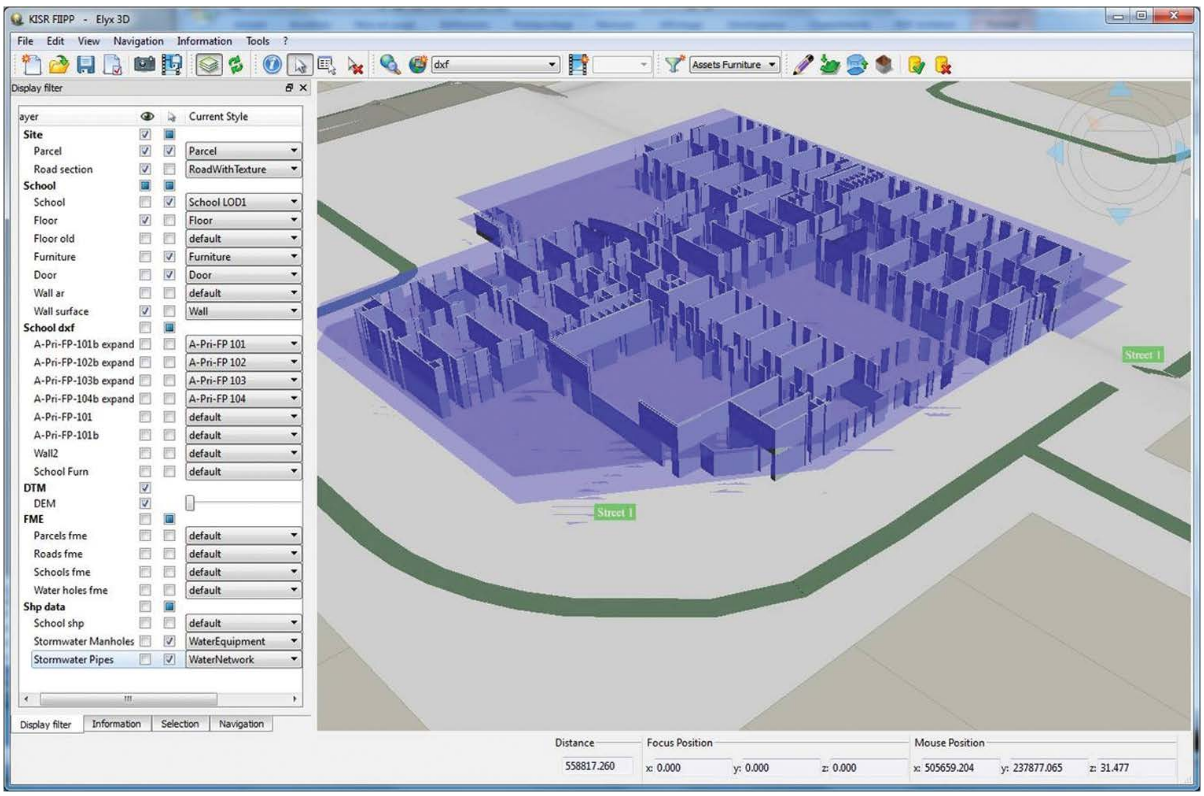

Figure 8. Illustration of extruding wall surface of the first floor of Al-Imam Al-Shafee primary school.

management, in addition to other areas of school property management.

The iFaME application is a proper tool to improve furniture and equipment utilization rates, which may reduce capital expenditures of their management. It could track and manage asset ownership and use, increase organizational accountability, and promote redeployment opportunities. The iFaME is considered a coherent process for integrating asset planning, acquisition, tracking, disposal, and investment recovery acquisition and/or disposition practices to increase the school efficiency and achieve superior financial results. Also, it is a reasonable means to improve data accuracy of asset registry, increase asset utilization, and optimize asset acquisition and disposal decisions within an overall capital plan of each school.

The research team from KISR and MoE has already started a more in-depth research to study the possibility of exporting the BIM 3D models into a real BIM-GIS 3D environment. The research is aimed at building full GIS 3D geometry and topology to enable the user to run the main GIS functionality on different school elements on the third dimension domain. The positive preliminary results from the ongoing research work would offer a great possibility toward building a real BIM-GIS framework that could lead to a paradigm shift in the facility management on the micro level.

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