BIM Extension into Later Stages of Project Life Cycle

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This paper discusses the process for extending the implementation of the Building Information Modeling (BIM) into the later stages of the project life cycle. The project life cycle includes planning, design, construction, operation and maintenance, and decommissioning. BIM is a process and it provides the framework to develop data rich product models. This model serves as gateway to provide any time access to insert, extract, update, or modify data by all the project participants involved in the life cycle. Though the BIM implementation offers several benefits to the project participants of the life cycle, but the current practices facilitate the implementation of BIM upto early stage of construction phase. BIM implementation stops beyond early stage of the construction phase due to unavailability of three dimensional (3D) as-built model and lack of integration of the construction process documents to the 3D as-built model. This paper discusses the means for collecting 3D as-built coordinates, developing 3D as-built model, developing four dimensional (4D) as-built model and integration of construction process documents for facilitating BIM implementation during the maintenance and decommissioning phase of the life cycle.

Key Words: Building Information Modeling, BIM, 3D as-built, 4D as-built, Lifecycle

Introduction

The life cycle of the project includes planning, design, construction, operation & maintenance, and decommissioning. The construction phase can be divided into pre-construction, actual construction, and post construction stages. In each phase lot of information is exchanged among various project participants. This information can be categorized into graphical and non-graphical data. The graphical data includes 2D and 3D drawings and non-graphical data includes other project documents. Traditionally, these two information categories exist as independent entities and are not linked to each other. This non-linkage decreases the project participants' productivity due to implementation of time consuming information retrieval methods, and regeneration of data. Implementation of Building Information Modeling (BIM) increases the project participants' productivity by facilitating easy information access, and reusage of data. BIM is a process of representing a facility through a 3D digital model and linking the information associated to it. Some of the benefits offered by BIM implementation include four dimensional (4D) modeling, five dimensional (5D) modeling, hazard analysis, and risk analysis. However, the existing industry practices facilitate the implementation of BIM only up to the early stage of the construction phase. This is partially due to unavailability of 3D as-built model and lack of integration of the construction process documents to the model. The objective of this paper is to study the feasibility of BIM extension beyond pre-construction phase by creating a single repository of facility data for operation and maintenance phase of the project lifecycle. This paper discusses a process for extending the BIM beyond the pre-construction stage and facilitating its implementation during the maintenance and decommissioning phase of the life cycle. The paper also presents a case study conducted to demonstrate the feasibility of the process by using commercially available BIM software products**.**

Building Information Modeling (BIM)

BIM is a process. It provides a framework to develop data rich product model and facilitates to realize the integrated benefits. In this process the real world elements of a facility such as walls, doors, windows and beams are represented as objects in a three dimensional digital model. In addition to modeling, facility information from conception to demolition is integrated to the model. Thus the model serves as a gateway to provide any time access to insert, extract, update, or modify digital data by all the project participants involved in the facility life cycle.

Implementation of BIM offers benefits in all the phases of the project life. The solutions offered by BIM include integration for fragmentation, reuse of model based digital data instead of data regeneration, and using spread sheet type product modeling tools instead of traditional CAD systems to reduce errors and mistakes.

Current Scenario of BIM in Construction Phase

The traditional media of communication among various phases of life cycle is two dimensional (2D) drawings. During the construction phase, 2D drawings are interpreted to prepare the pre-construction schedule and cost estimates. Information exchanged between the designers and constructors in 2D format are often subject to misinterpretation resulting in request for information (RFI) and change order requests. The advent of object oriented computer aided design (CAD) software facilitated usage of 3D graphical models as media of communication between planning and design phases. Three dimensional (3D) models facilitate easy visualization, reduce misinterpretation, and reduce rework. To some extent these 3D models are used during pre-construction to resolve constructability problems, space conflict problems, hazard analysis, and resource allocation. Additionally, 3D models are also useful for developing 4D models and 5D models during the pre-construction phase. The pre-construction 4D models are developed by linking design 3D model with pre-construction schedule. These 4D were used for visualization of project progress, interference check and space conflict problems identification and effective site utilization (Koo & Fischer 2000; Chau et al. 2004). The integration of 3D model with time and cost estimates results in five dimensional (5D) modeling. This facilitates easy demonstration of the impact of changes on the project and helps in decision making for owners, project engineers, or managers (Tanyer & Aoudad 2005). Kim et al. 2005 developed and demonstrated the feasibility of 5D data model integration with resources and specifications to a high rise steel structure apartment building.

The integration of 3D model with schedule and cost is extended only up to pre-construction disregarding construction and post construction phases. The 3D models were successfully used for pre-construction stage applications such as visualization, resolving constructability problems, space conflict problems, resource allocation, and hazard analysis. However, little has been done to extend the usage of 3D model into construction, post construction and maintenance stages in the project life cycle. Construction and post construction phases continue to be accomplished using 2D drawings. During the process of construction, project participants exchange construction process documents such as request for information (RFI), submittals, change orders, shop drawings, specifications, and site photos. These are not linked to either the 2D or 3D models. By using current practices, when the information of a building component is to be retrieved during its operation and maintenance phase, the facility manger needs to search 2D as-built drawings for spatial aspects and multiple construction documents for other information. Much of the engineer's time is spent on non-value added works such as searching and validating information due of the lack of linkage of information to either 2D or 3D models. Though the information exists during the construction process, lack of quick access to the information during operation and maintenance phase is resulting in unnecessary expenses.

The current status of graphical data and non graphical data in the construction phase is shown in Figure-1. It shows the 2D as-built drawings developed in the post construction stage and the related documents exist as independent entities. The 3D model developed in early stages of the life cycle is generally not in use after the pre-construction stage. The implementation of BIM needs a 3D product model and association of relevant information to each component to serve as information resource. Thus by using the existing practices BIM implementation process tends to stop at the pre-construction phase leaving large amounts of relevant data out of the final model needed by facilities management for operations, maintenance, and possible recommissioning or decommissioning efforts.

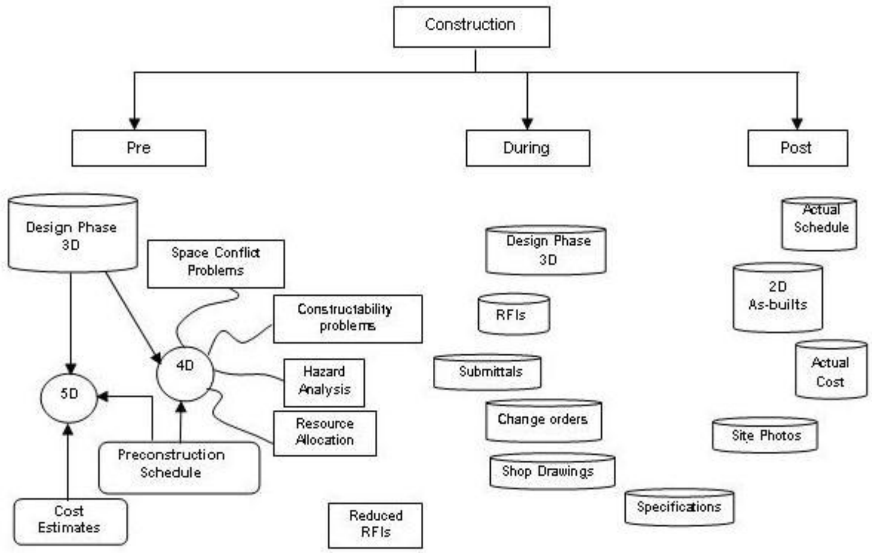

Figure 1: Current status of BIM in construction phase

Desired State of BIM in Construction Phase

Two reasons for not achieving BIM during post construction of the facility are (1) unavailability of 3D as-built model and (2) lack of integration of construction process information to the 3D as-built model. The desired status of information flow from the construction phase to operation and maintenance phase that facilitate BIM implementation is shown in Figure-2. The existing 2D as-built drawings have to be replaced with 3D as-built model. Project data such as RFI, submittals, change orders, shop drawings, specifications, site photos, actual cost, and actual schedule must be attached to the 3D as-built model. This integration of construction process documents to the 3D as-built model facilitates BIM implementation beyond the pre-construction stage.

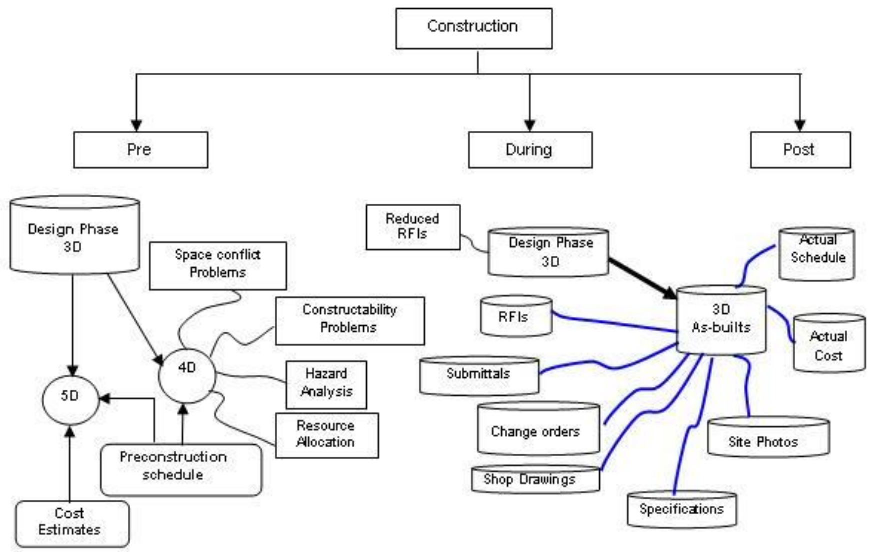

Figure 2: Desired status of BIM in construction phase

Methodology for Extension of BIM into Later Stages of Life Cycle

This section discusses about the methodology adopted for a case study conducted to demonstrate the feasibility of achieving the desired status of BIM. A two-story residential house of 2400 square feet was considered for this study. The owner was interested to develop 3D as-built model and link the information to the model to create a single repository for BIM implementation during operation and maintenance phase of the building. The steps involved to extend implementation of BIM into maintenance and decommissioning phase of the lifecycle include development of 3D as-built model, 4D as-built model, and integration of the construction process information to the model. This was accomplished by using Autodesk's commercially available BIM software. Objective driven data acquisition technique was used for developing 3D as-built model. In this method an individual target object is selected and x, y, and z coordinates of a minimum number of points are acquired to represent the object in a 3D as-built model. The 3D as-built model is developed by selecting the target object from parametrically defined graphical objects stored in the database and placing it spatially using the scanned x, y and z coordinates (Cho et al. 2002). For small size projects this process is a cost effective alternative for developing 3D as-built model than compared to the 3D laser scanning process. The accuracy attained by this process is less than the 3D laser scanning accuracy. But the accuracy achieved through this process is well within the tolerances needed for subsequent repairs, maintenance, and renovation (Goedert & Meadati, 2008). A 4D as-built model was developed by integrating the 3D as-built model with the actual construction using Navisworks. Additionally, construction process documents and other useful information were associated to the 3D as-built model. The information which was available in paper format was scanned and converted into digital formats.

Development of 3D as-built model

The development of 3D as-built model included collection of x, y, and z coordinates of the as-built components and development of 3D as-built model. The x, y, and z coordinates of the as-built conditions were acquired using a robotic total station. The x, y, and z coordinates of the target points were collected depending upon the shape, orientation and cross section of an element. The target points of each component were selected to place and match the parametrically defined graphical object that represents the actual component. Using AutoCAD these x, y, and z coordinates were joined and a 3D as-built guide line layout was developed. This AutoCAD file was then imported into Revit and used as an underlay to place the various components by using guide layout lines as reference lines. For example, in Revit, the placement options for the wall object include Wall Centerline, Core Centerline, Finish

Face Exterior, and Finish Face Interior. Depending upon whether the collected 3D coordinates represent an exterior or interior face appropriate placement option was used for developing the 3D as-built model. The plumbing 3D as-built model developed by placing the respective building components over the guiding layout is shown in Figure-3.

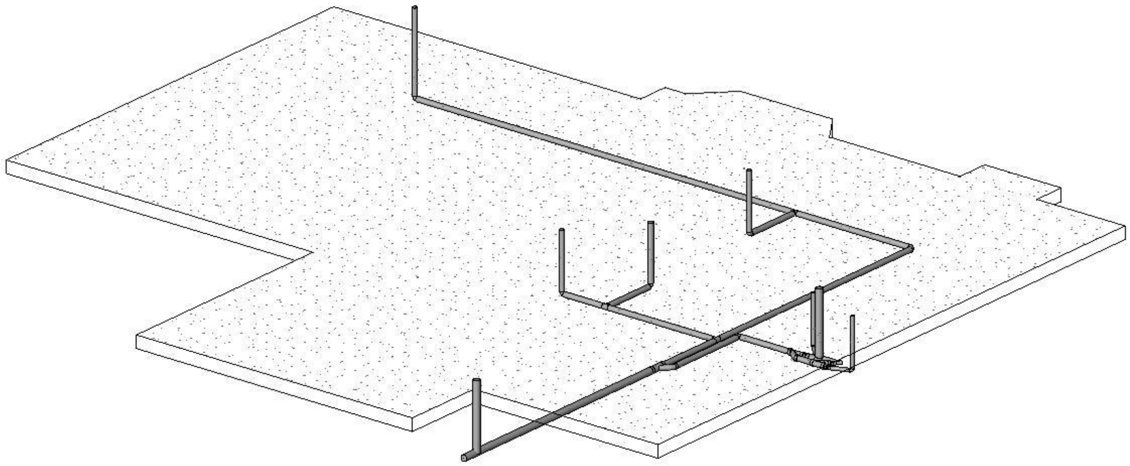

Figure 3: Plumbing 3D as-builts

Development of 4D as-built model

The traditional practice has been to use CPM based networks and bar charts to show the actual schedule, to use the 2D as-built drawings to show the spatial aspects and to capture the project progress through photographs taken at regular intervals. These CPM based networks and bar charts help to coordinate the activities of the construction project but do not provide any information pertaining to the spatial context complexities of the project. These traditional methods do not depict the relationships between the actual construction schedule and various activities. Therefore, to understand actual progress of the project the users must look at 2D as-built drawings for spatial aspects of the project and identify the activity from CPM networks and bar chart and mentally visualize the relationships between them. In this project, to depict the actual construction progress a 4D as-built model was developed by integrating the 3D as-built model with the actual construction schedule. A screen shot of the 4D as-built simulation is shown in Figure-4. The typical wall objects available in the Revit software are useful to represent the finished component but cannot serve to depict the actual construction progress. For example, an interior partition wall is constructed in stages which include stud installation and drywall installation. This interior partition wall can be represented directly by using “Basic Wall: Interior 4-7/8 partition” object available from the wall object library. When this object is used, during 4D simulation the construction of the interior partition wall will be reflected as single entity construction since the studs and drywalls cannot be ungrouped to reflect as separate components. Due to this reason, the wall object component cannot be used to directly to depict the actual construction process. In this project, to depict the actual construction process the various components of the wall are represented as individual components. The actual construction schedule was developed by using Suretrak scheduling software. The necessary information for developing schedule was collected by making regular site visits. Photographs taken at regular intervals were also used for documenting the construction progress.

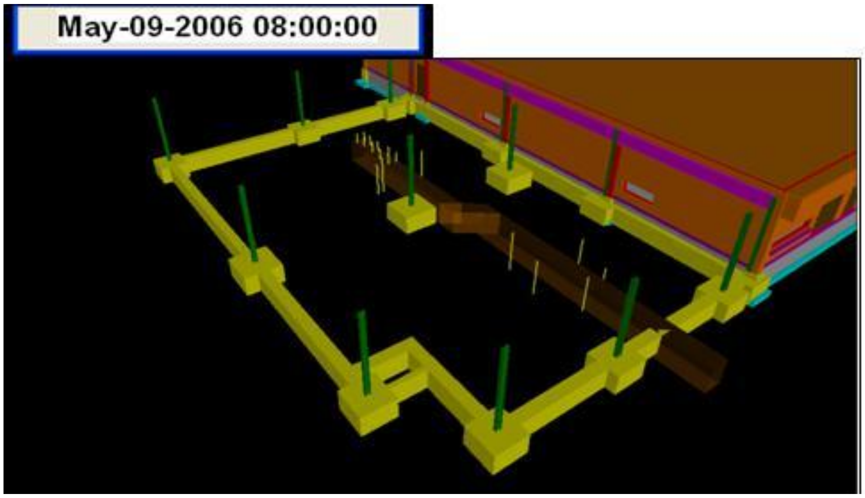

Figure 4: 4D as-built model

Integration of Construction Documents

The different types of documents exchanged during the construction process are classified into five data types. They are structured data files (estimate, and schedule files), semi structured data files (HTML, and XML files), unstructured data files (word or text files), unstructured graphic files (drawings in binary format), and unstructured multimedia files (photographs, audio, and video files) (Caldas et al. 2002). In this study, unstructured data files, unstructured graphic files, and unstructured multimedia files are integrated to the 3D as-built model. Most of the exchanged documents of this case study were in paper format. The paper based documents were scanned and converted into digital documents. The information was then attached to the 3D as-built model. This integration allows the constructor to hand over a data rich digital 3D as-built model to the owner for the BIM implementation. Figure-5 shows the details of manufacturer name, manufacturer website, color, edge finish, and lead time of the selected granite countertop. It also displays picture showing the texture and color of the granite retrieved by clicking the link given in the Color Picture parameter. The advantage of BIM implementation can be explained by considering a renovation scenario. For example, consider owner wants to renovate the kitchen by changing the locations of the appliances from Figure-6 to Figure-7. The actual location of the existing drain pipes can be obtained from the plumbing 3D as-built model. The documents linked to the drain pipe provide specifications, size, and manufacturer information and help the owner for placing the purchase orders from the supplier. Similarly the documents linked to the counter top and casework provide the required information for placing orders from the suppliers. The quick and easy access to information facilitated by BIM implementation helps the owner in expediting the renovation process.

Conclusion

The building industry considered BIM as a means to provide an integrated and coherent information management strategy. BIM eliminates industry fragmentation and provide seamless flow of facility information among the planning/design, construction, and operation and maintenance phases. Implementation of BIM offers benefits in all the phases of the project life. It gives any time access to digital data to the owners, clients, engineers, architects, contractors, facility managers, maintenance and operations engineers, safety and security personnel and many others involved in the building life cycle. Existing practices facilitate the implementation of BIM only up to the pre-construction phase. The unavailability of a 3D as-built model and lack of integration of the construction process documents to the 3D as-built model are barriers impeding the extension of BIM further into the lifecycle of a project. The methodology discussed in this paper serves as initial step to extend BIM beyond the pre-construction phase and facilitate seamless flow of information from initial stage to the final stage of the project life cycle

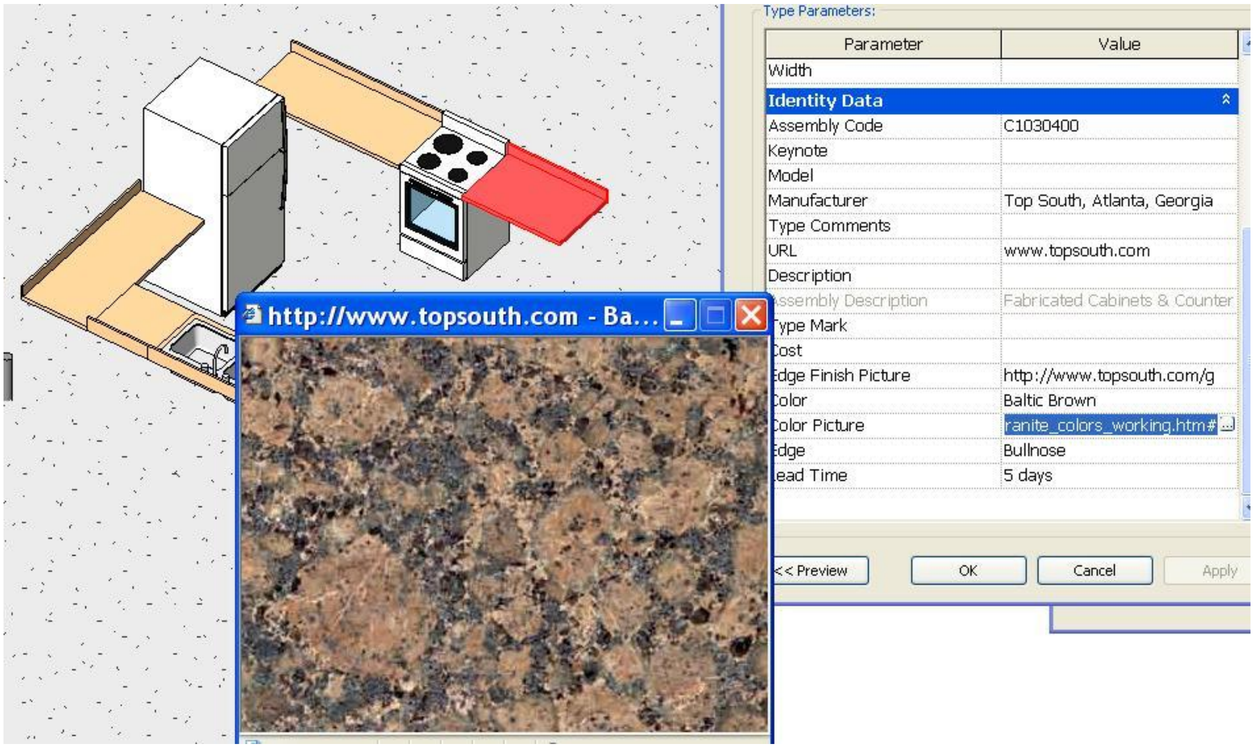

Figure 5: Integration of information to the countertop in the 3D as-built model

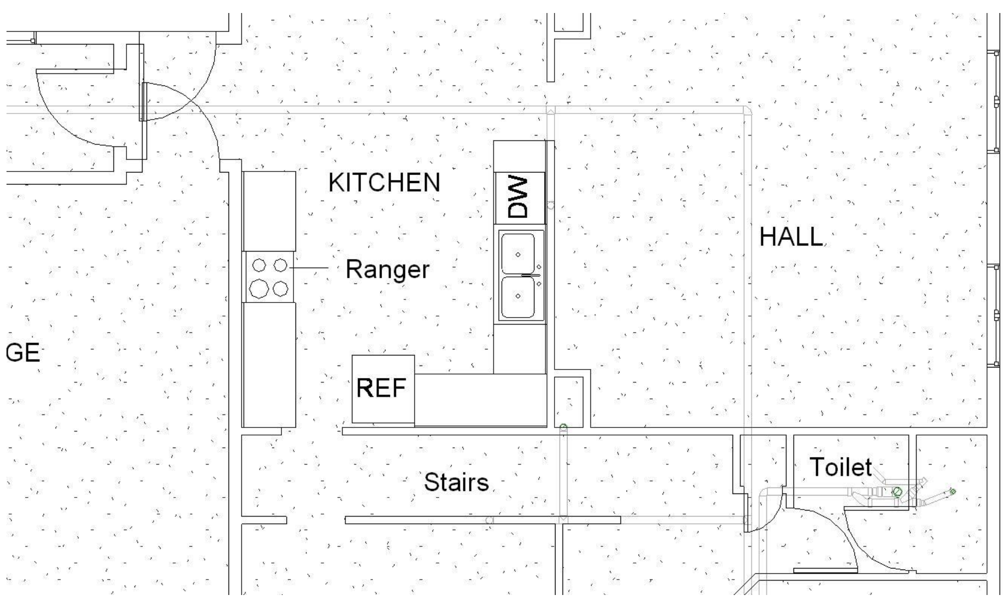

Figure 6: Existing layout of appliances in the kitchen

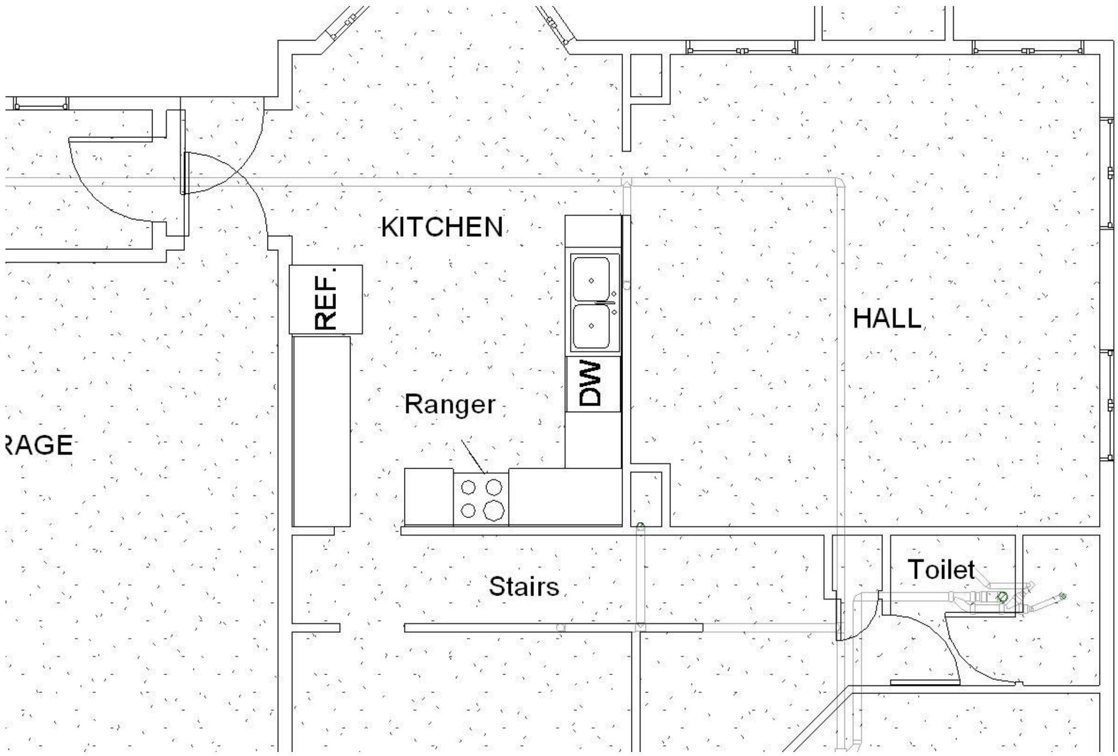

*Figure 7:*Renovated layout of appliances in the kitchen

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