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Smart management of the reconstruction process of post-conflict cities

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Abstract

Purpose – Cities lying within conflict zones have continually faced hardships of both war aftermath and long-term sustainable reconstruction. Challenges have surpassed the typical question of recovery from post-conflict trauma, preserving urban heritage and iconic elements of the built environment, to face issues of critical decision making, rebuilding effectiveness and funding mechanisms, leading to time-consuming processes that lack adequate consistent long-term management. Some approaches have explored methods of effective long-term city reconstruction management but have not fully developed comprehensive approaches that alleviate the management of such complex processes. The paper aims to discuss these issues.
Design/methodology/approach – The authors devise an approach for the smart management of post-conflict city reconstruction. The authors focus on evaluation, strategic planning, reconstruction projects and implementation. The authors integrate building information modeling and geographic/geospatial information systems in a platform that allows for real-time analysis, reporting, strategic planning and decision making for managing reconstruction operations and projects among involved stakeholders including government agencies, funding organizations, city managers and public participants.
Findings – The approach suggested a smart management system for the reconstruction process of post-conflict cities. Implementing this system was shown to provide a multi-objective solution for post-conflict city reconstruction based on its interlinked modules.
Research limitations/implications – Results may lack generalizability and require testing on several cases to provide rigorous findings for different case studies.
Practical implications – Implications include developing smart management systems for use by city managers and government authorities in post-conflict zones, as well as bottom-up decision making by including participant citizens especially populations in the diaspora.
Originality/value – The approach offers an integrated platform that informs city reconstruction decision makers, allowing for strategic planning tools for efficient planning, monitoring tools for continuous management during and after reconstruction, and effective platforms for communication among all stakeholders.

Keywords Reconstruction, Building information modelling, Geographic information systems, Smart city management, Post-conflict cities

Paper type Research paper

Introduction

Post-conflict zones have typically faced the hardships of man-made disaster. Many cities lying within these zones, such as Aleppo, Baghdad, Beirut and Sarajevo, which were formerly perceived as cultural, economic and political hubs, have continually been torn by regional and international conflicts, facing the challenges of not only war and disaster aftermath, but more

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substantially long-term and sustainable reconstruction. For many of these cities, emerging reconstruction efforts only present more questions than answers, typically pertaining to economic revitalization and the return of refugees and internally displaced persons.

An incessant cause of failed reconstruction efforts classically results from poor planning and poor coordination strategies, or lack of engagement of the effective group of stakeholders in the decision-making process. Most efforts focus on the reconstruction of specific iconic buildings without clear justification or without a clear urban planning strategy, vision or prioritization for revamping specific institutions or public spaces or for adequate planning and funding, due to fluid political situations in such post-conflict zones (Badescu, 2014). It has typically been the case with post-conflict cities that reconstruction is such a time-consuming process that lacks adequate and consistent long-term management.

Not only is it becoming a question of preserving the very precious historical monuments, conserving urban heritage in such iconic cities, or a physical reconstruction of buildings and infrastructure (Al-Saffar, 2018), but also a reconstruction of sustainable economy, governance structure, civil society and public participation. One of the pressing questions is as follows: Can city reconstruction be managed more efficiently? Does such an integrated platform exist that can strategically manage the process of post-conflict city and community reconstruction?

As stated by Lloyd-Jones (2006), there exists "a gap – in funding, management and delivery – between the short-term, effective humanitarian relief, and long-term reconstruction." His everlasting questions about funds being paralyzed in the bank accounts of major agencies and governments, and post-conflict survivors being stranded in the process, remain largely unanswered. Along with the magnitude of post-conflict trauma and recovery efforts comes as powerful and harsh the millions displaced from their homes, the hundreds of buildings damaged or deteriorated, the effectiveness of aid and rebuild; in short, the main question is as follows: Where and how is the best way to start? Which decisions are most critical? Which projects should be funded first? What exactly should be funded and why? How can a long-term process of reconstruction be sustained? How can affected populations including those in the diaspora be engaged in such a process?

Several agencies, institutions and researchers have explored methods of effective long-term city reconstruction, including the work of Harding (2007) and Al-Dahash *et al.* (2014) who argued for social development strategies and grounded approaches to mitigate the effects of such disasters. One of the significant efforts was the work of Barakat *et al.* (2008) who investigated potential applications of spatial methodologies in the design and implementation of decision support systems in an effort to aid post-war community reconstruction. Their planning tool integrated geographic/geospatial information systems (GIS), public participation, spatial decision support systems and natural language processing to offer a web-based planning tool and application that supported both agencies in the field and members of the diaspora, in addition to other representatives of the general public, to contribute effectively to the reconstruction process, aided by multinational humanitarian agencies. Other efforts aim to exploit the concepts of the Intelligent City and internet-based public participation geographic/geospatial information systems (PPGIS) applications in augmenting the role of public participation in decision-making efforts (Kingston, 2011).

Our aim is to extend such an integration to include a comprehensive approach to city reconstruction that alleviates the management of such a complex and long-term process, and includes continuous monitoring and real-time data acquisition and archival of reconstruction efforts, smart assessment of existing conditions, strategic planning and management of efficient reconstruction, and effective communication among all involved stakeholders, including both ends of the spectrum of the decision-making process.

Stakeholders in the reconstruction process typically involve funding agencies such as the World Bank, a key sponsor that aims at revitalizing societies and playing a major role in peacekeeping. However, many approaches of post-conflict city reconstruction have tended to discard the public as a major player but rather a spectator in community reconstruction, therefore lying at the non-participatory end of Arnstein's (1969) ladder of citizen participation which describes citizen manipulation as opposed to citizen control. Kingston *et al.* (2000) and Barakat *et al.* (2008) delineate citizen participation to include key issues in the reconstruction process such as the public right to know, informing the public, public participation in risk assessment, solution recommendation and final decision, information dissemination regarding the intentions of external agencies, consultation of local populace, collaborative decision making, cooperative action and the external support of local initiatives.

Since then, there have been considerable developments in two separate fronts: developing cloud applications, software-as-a-service web-based platforms and GIS online tools on the one hand; and augmenting the role of public participation in decision making through public participatory spatial decision support and multi-criteria analysis on the other. Using argumentation maps (Rinner *et al.*, 2008), Boroushaki and Malczewski (2010) developed an online participatory decision support tool using participatory GIS and multi-criteria analysis. Arciniegas *et al.* (2013) developed maps for decision making in participation groups. Significant efforts have also been done to utilize natural language processing to engage participation of different entities in decision making (Ballatore *et al.*, 2013; Delgado *et al.*, 2013; Eldrandaly, 2013).

Crooks and Wise (2013) experimented with agent-based systems, crowdsourcing and GIS to inform involved agencies such as multinational humanitarian aid organizations with the extent of damage on affected populations in conflict zones. Other efforts targeted the process of modeling individual behavior and validation of collected data using expert systems and agent-based modeling and generating dynamic models by combining agent-based modeling and GIS to aid decision making in spatial contexts (Gimblett, 2002; Leszczynska, 2011). These efforts primarily focused on the effective utilization of available support in pre-reconstruction phases rather than sustainable long-term reconstruction.

Other approaches such as those developed by Cinderby *et al.* (2008) tend to focus on utilizing physical maps for the use and annotation of public participants, which makes it often less practical or appropriate in some post-conflict zone scenarios where multiple parties are involved that do not necessarily engage easily in direct interaction or confrontation such as populations in the diaspora or parties formerly engaged in combat.

There appears to be, however, no systematic approach that addresses the comprehensive management of reconstruction of post-conflict zones from both a spatial data-driven perspective and a multi-participatory decision-making perspective during all phases of the reconstruction process. This paper proposes a smart city reconstruction management system for an effective and informed decision-making process to all involved stakeholders using a web-based application.

Approach

This paper aims at devising an approach for the smart and effective management of the post-conflict city reconstruction process. Our approach primarily involves post-conflict city evaluation, where the existing condition is thoroughly assessed; reconstruction planning, where strategic planning is involved through the integrated decision making of all stakeholders to make informed decisions based on credible data and sources; reconstruction projects, where strategic plans are executed effectively; and project implementation, where reconstruction projects are conducted with an eye on long-term sustainability of projects and their ongoing cycle of management of operations, tasks and resources.

Figure 1 illustrates our approach for managing the reconstruction process, hereafter coined the smart city reconstruction management system. Our process is implemented through a web-based application that utilizes building information modeling (BIM) and GIS technology for effective and informed decision making.

BIM open standards, data structure specifications and GIS technologies have currently facilitated the streamlining of building and city information to management phases and are

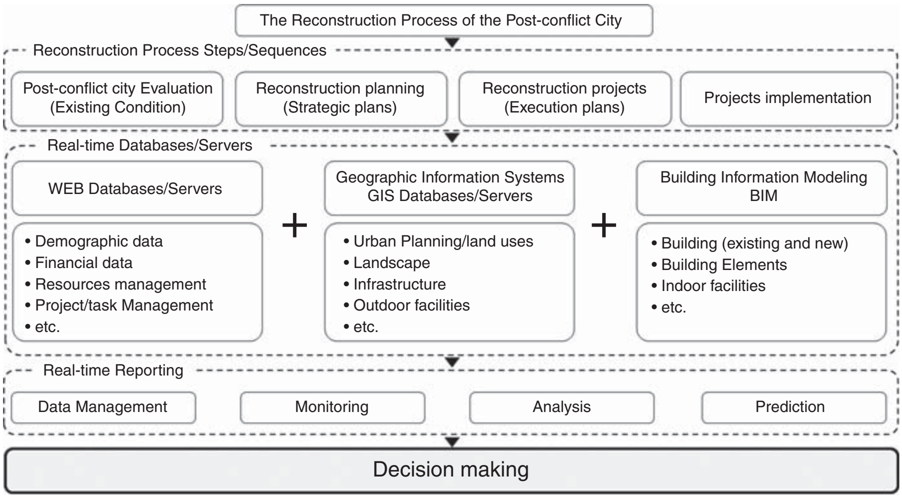

Figure 1.
The proposed approach for the smart city reconstruction management system

increasingly being prescribed both as credible sources of data delivery and exchange, and as repositories for supporting project operation throughout post-occupancy stages of lifecycles of the built environment (Volk *et al.*, 2014). Several industry-wide solutions have explored the increased role of BIM, GIS and data structure specifications in supporting management workflows and systems, by focusing on improved workflow and efficiency (Kassem *et al.*, 2015), knowledge acquisition and management (Motawa and Almarshad, 2013), spatial relationships, visualization and analysis (Akcamete *et al.*, 2010; Motamedi *et al.*, 2014), and information integration and decision support (Shen *et al.*, 2012).

The added value in our approach is threefold: data archival on the city scale, where the history of the city, its planning mechanisms, the old and the new, its heritage sites and monuments are all digitally archived and documented in real time with versioning mechanisms; a platform for communication between the multitude of stakeholders involved in the reconstruction process including but not limited to funding agencies, governments, city managers, local authorities, etc.; and a dynamic, interactive and real-time tool for analysis, reporting and decision making, where all short-term and long-term planning for a post-conflict city can be justified with credible data.

We capitalize on the power of data, represented in both BIM and GIS, to visualize, analyze and manage information within the city, including but not limited to demographic data, financial data, resources, projects, tasks, land uses, buildings, building components, systems, facilities, utilities and infrastructure, etc., within a web-based, integrated and interactive platform that affords seamless communication among its different users and stakeholders. Figure 2 illustrates the proposed phases of management in our approach.

These phases include the pre-reconstruction process, involving preliminary evaluation and planning of reconstruction projects; during the reconstruction process, involving the management and reporting cycle of project progress and implementation; and the post-reconstruction process, involving continuous management and re-evaluation of project lifecycle. This entails the cyclic process of continuous post-conflict evaluation of the existing condition, strategic planning for reconstruction, executing reconstruction projects and implementing projects. Our approach links data from different stakeholders including the city management team, local authorities and implementing entities, government agencies, and funding organizations, in addition to participant citizens and populations in the diaspora, to manage the efficient reconstruction process of post-conflict cities.

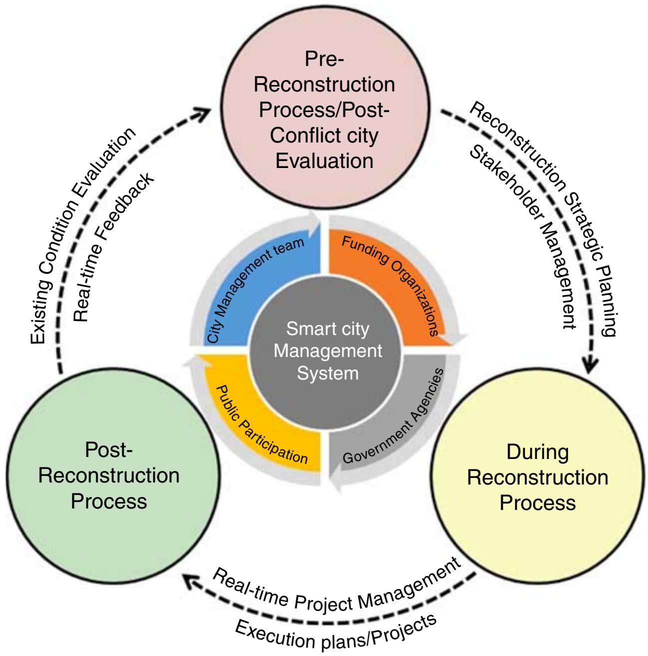

Figure 2.
Proposed phases, structure and stakeholders involved in the reconstruction management process

This approach allows city managers to view, analyze and manage city operations and ongoing reconstruction projects efficiently via an interactive database. It also allows local authorities and implementing agencies to discuss available options, seek necessary funding and execute city reconstruction operations effectively in consultation with the public. Government agencies can perform regular monitoring of city reconstruction operations through a dynamic and interactive interface, in addition to the benefit of efficient budget allocation based on an informed and collective decision-making process. Funding organizations can identify districts, buildings, heritage buildings, ancient monuments and other assets in immediate need of financial support or in deteriorating conditions based on the continuous evaluation of a real-time mechanism of city operations assessment.

System modules and features

The proposed smart city reconstruction management system hosts a variety of key features using its extensive modules and databases, including city management, building management, project management, navigation, task and process management, file management, funding management, stakeholders, reporting, human resources, in addition to a chatroom and messaging system. A brief description of these modules is shown below.

City management module

This module allows government agencies, local authorities and public participants concerned with city reconstruction planning to monitor reconstruction efforts at the city level, and to manage and streamline daily tasks related to the oversight and status of expenses, revenues, rentals, requests, operations, control and performance within these efforts. With its BIM/GIS navigation and database technology, the module is designed to suit a variety of levels and services, including the capability of managing reconstruction efforts at the level of districts, road networks, utilities and infrastructure. City managers can browse interactively between

GIS maps of reconstruction sites worldwide representing post-conflict zones and countries at the macro level, and micro sites of their specific cities and areas that require intervention, together with all the designated assets, services, infrastructure and utilities. Key features of this module include interactive dashboards for continuous monitoring of expenses, revenues and reconstruction status, 3D navigation through reconstruction sites worldwide, and tracking of reconstruction project work orders and staff performance.

Building management module

This module allows building and facility managers in city municipalities to manage the different facility management systems within the reconstruction efforts for specific buildings, including earthworks systems, structural systems, wall and barrier systems, roof systems, damp proofing systems, heating and cooling systems, electrical systems, communications systems, security and safety systems, control and protection systems, ventilation and air conditioning systems, process engineering systems, fittings, furnishings and equipment, disposal systems, transport systems, general finishing systems, stair and ramp systems, and others.

Building and facility managers can browse through these systems per system and per building level by navigating through the building 3D BIM operational model, which represents all building data and systems interactively and three dimensionally. They can also visualize and manage all the detailed 3D components and subsystems for each system that requires repair, maintenance or inspection, based on the status of the building and the priority of reconstruction determined through the city reconstruction strategic plan or funding allocation. Facility managers can navigate through extracted views of specific systems to a high level of detail, e.g. air conditioning systems, with all their details, rather than generic views of the whole building. They can also navigate interactively though extracted 2D plans of selected building levels and inspect and manage different spaces using the powerful visual representation of all building spaces and systems. Upon the inspection, maintenance and repair operations of building managers for the buildings to be reconstructed, these are automatically recorded within the history of the reconstruction process, and the system is updated in real time to reflect the overall status of completion.

Task and project management module

This module allows stakeholders to add different tasks and projects and assign them to other users, therefore contributing to the smart lifecycle management and planning of tasks, projects and operations. The definition of a reconstruction task or project outlines the specific priority of operation, in addition to real-time feedback concerning the percentage of completion. For each added task or project, a detailed illustration of the percentage of completion, user role, and start and end date is demonstrated. The real-time feedback of task completion is reflected automatically. Upon clicking on each task, a detailed editing can be conducted, outlining a detailed description, log hours and activities, in addition to any documents and comments.

Navigation module

Building on the BIM/GIS integration within the system, different stakeholders, including mayors, local authorities, building managers and government agencies, can navigate through different sites and facilities and create, edit or manage their specific requests in an interactive, visual and user-friendly format. This includes a GIS navigator which allows users to visually monitor and manage different reconstruction sites, including all assets, utilities and infrastructure. The BIM navigator allows the user to visualize, monitor and manage detailed elements of the specific building to be reconstructed, as well as navigate freely through by level or by building system.

Process management module

Upon selecting any asset, building or object to perform or request a specific operation within the reconstruction process, such as maintenance, repair, renovation, etc., a specific ticket is issued and the system automatically detects the object ID, location coordinates and other necessary metadata. The designated authority personnel can then manually add other data such as a description of their request, preferred date and duration of performing the request, or upload an on-site image using their cell phones for more detailed description. They can also track the full history of all issued tickets and query tickets by type, status, detailed steps and actions, in addition to the visual management, monitoring and resolution of all requests. For each ticket type, the city or building manager can detail the types of actions and steps within the workflow of that ticket, with details of specific roles, time durations and relations to other steps and actions, and therefore can interactively and dynamically design and modify their workflows.

File management

This module allows city and building managers to view, archive, edit, sort and maintain all files and documentation related to a given reconstruction project, including images, drawings, reports, certificates, specifications, forms, etc. For each file, different stakeholders can add comments on each of the exchanged files to allow for a customized level of communication among all involved stakeholders.

Funding/Ledger management module

This general ledger module allows city and building managers to manage all financial information related to reconstruction projects, and to have access to a database linked to the project database including a wide variety of aspects related to typical ledger and accounting modules, such as invoices, expenses, payments and other vendor and product information.

Stakeholders module

This module defines the basic settings and configurations related to interactions among all different stakeholders involved in the reconstruction process, including mayors, city councils, municipalities, building managers, local vendors, public participants including those in the diaspora, etc. Each stakeholder has a different view of the district, site or building, and the type of associated tickets and permission of requests. Using the system's flexible and integrated database technology, the city manager can assign different roles and relations within a given project, e.g. assigning relations between designated facilities and the different stakeholders, assigning different building managers to designated properties, assigning the role of public participation and the contribution of different citizen participant groups within a given project, assigning relations between a given building and the different facility management systems so that service provider relations can be easily integrated, etc.

Reporting and analysis module

This module allows city and building managers to generate customized on-demand reports for their projects using the system's dynamic reporting engine. A multitude of report types can be generated, including reconstruction status, revenues and expenses, task completion, and many others. PDF reports can be generated from different queries, whereby different aspects can be defined to provide a customized report, including type of report, type of ticket, ticket step, etc. Major reports, analysis and prediction models for designated reconstruction projects are represented in the project dashboard for quick and easy visualization. The displayed reports in the dashboard demonstrate basic information and current statuses for all types of requests, tailored per stakeholder view. The displayed reports show real-time data for requests, while the notification panel shows the needed actions for all stakeholders.

Human resources module

This module is linked to the reconstruction project database and tasks and allows city and building managers, and government agencies and local authorities and other involved stakeholders to manage and track staff data and performance. It includes all aspects related to staff data, leaves, jobs, recruitment data, timesheets, competencies and other data.

Chatroom and messaging module

This module allows for easy communication between all stakeholders, and is especially designed to engage concerned citizens in public discussions regarding planning and management of the reconstruction process, whereby their continuous engagement leads to bottom-up decision making rather than imposed and authoritarian agendas. The module facilitates an interactive forum for real-time communication and data sharing. It is also used for technical support purposes, for keeping records of events and inquiries. A notification system is also included, whereby the city manager can select actions that require instant notification and users who should be notified. Users instantly receive notifications of requests and actions based on their different privileges.

Technology infrastructure

The proposed smart city reconstruction management system is comprised of three technology layers: the BIM model layer, GIS database layer and web-based application layer (Figure 3). Each layer has a unique characteristic that gives the system its overall value and comprises categories of data sets that are relevant to reconstruction projects, which collectively contribute to the comprehensive framework of the smart city reconstruction management system.

GIS database layer

This layer allows for scalability, positioning, server integration, geospatial analysis and modeling through its relational database structure, and therefore facilitates the viewing, management and planning of projects at the city, district and neighborhood level, in addition to the ability to visualize and manage data related to building site data such as outdoor utilities and infrastructure. It allows for visualizing, managing and analyzing data related to infrastructure, buildings, real-time data and zone boundaries. This facilitates the retrieval, display and management of demographic data and environmental data, for example, as well as identifying different building types including ancient monuments,

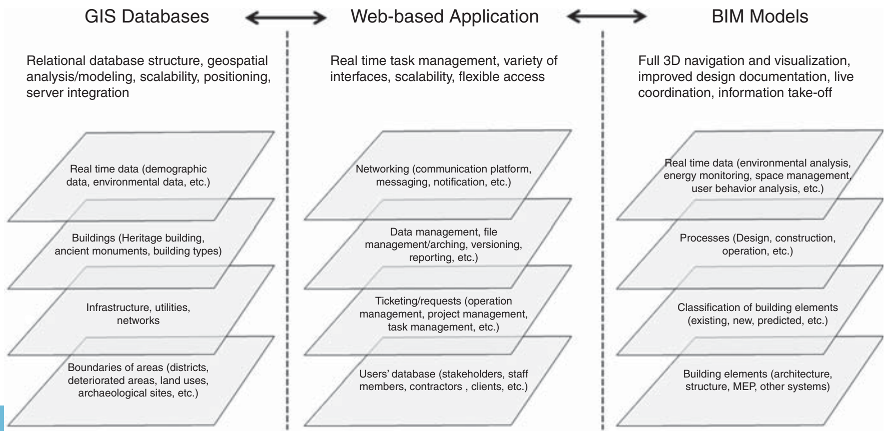

Figure 3.
Categories of data sets in the technology infrastructure of the reconstruction management system, including the GIS database layer, web-based application layer and BIM model layer

buildings of value or heritage buildings that require restoration or renovation. At a larger scale, this layer provides a comprehensive reading of infrastructure, utilities and networks on the city geographical and geospatial map, in addition to identifying and tagging different areas such as districts, deteriorated or damaged areas, zones of conflict, land uses, and archeological sites.

Web-based application layer

This layer allows for real-time task management, scalability, flexible access, in addition to providing a variety of interfaces. It allows yet for another level of management, as it widely facilitates networking via communication platforms, and allows for messaging capabilities and mobile notifications for all involved stakeholders in the reconstruction process by means of its extensive database technology. This layer also provides a dynamic ticketing mechanism, whereby different types of requests are exchanged among all stakeholders, including operation management, and project and task management. All data are managed through this dynamic interface using archiving, file management, versioning, and reporting mechanisms to allow for a coherent and comprehensive data management system among all stakeholders involved in the reconstruction process, including contractors, facility managers, clients, service providers, staff members, as well as concerned participants from the public.

BIM model layer

This layer allows for full 3D navigation and visualization of building projects, enhanced design documentation, live coordination, and information and quantity take-off of all building data at the operational level. It allows for the visualization, analysis and display of real-time data related to reconstruction projects, such as indoor environmental analysis, space management, indoor energy performance monitoring and user behavior analysis. It also contains data related to processes of design, construction and operation, allowing for a full documentation and real-time archiving of ongoing reconstruction processes. Another added value is the identification of different trades and systems including architecture, structure, mechanical, electrical and plumbing, and other systems. This allows for a thorough study of procedures, cost, operation, phasing, logistics and visualization per system. Furthermore, the classification of building elements allows for archiving different states of buildings within reconstruction projects, including newly constructed projects, existing buildings, and projected and planned buildings based on the city reconstruction plan, allowing for informed decision making and integrated planning.

The system infrastructure for the proposed smart city management comprises the following servers: main platform server, GIS server and BIM server (Figure 4). It is built on a Linux-based operating system. The main server has Apache running as a web server with PHP7. The main framework which runs the core application is Laravel, which is a free open source PHP web framework, and it is connected to MySQL database through drivers. The main server communicates with other servers, such as BIM and GIS servers, to analyze and process data requests. The outputs of the main server are served through API calls to serve any type of devices and users such as Desktop, Android and iOS users.

The back end of the software comprises several cloud servers and databases, including MySQL database, Google Maps (for general map navigation), BIM server (for managing the translation of data from 3D BIM models) and GIS server (for creating and managing GIS data, web services and applications related to city maps). These servers and databases communicate together through an intermediate database, and with the core application, which uses PHP7, Python, Java and CentOS for the main software and web development. This is managed at the front end using a dashboard management and administration platform. Through the API gateway, all server outputs are communicated to serve any type of devices, including desktop applications (using HTML, CSS3, JavaScript and Vue.js), in addition to mobile applications (both Android, using Java, and iOS, using Swift, Apple's programming language). The following components are used for the development of the system: Apache (licensed under Apache 2 open source license), PHP7 (open source software distributed under the PHP License v3.01), Laravel Framework (open source software licensed under the MIT license), MySQL (licensed under the GNU Public License GPL), CentOS7 (licensed under the GNU Public License GPL) and Vue JS (licensed under the MIT license).

System overview

The reconstruction of post-conflict zones, especially major cities like Damascus, Sarajevo, Baghdad and Aleppo, requires a scale of management that extends beyond just the building or project level, but rather the whole city, including all reconstruction projects, all stakeholders, all documents and drawings of new, existing and completed projects, human resources, allocations of funds, and many other complex processes and tasks. The proposed smart city reconstruction management system hosts a wide variety of key features that address these challenging processes and needs using its extensive modules and databases, including city management, building management, project management, process management, task management, file management, reporting, human resources, chatroom and messaging. Figure 5 shows the main system overview, outlining the basic city manager dashboard. At the entry level, this dashboard outlines the main countries comprising active reconstruction projects and their status, in addition to basic reporting and analysis of the current projects. The purpose of this high-level view is for government agencies and funding organizations to continuously monitor affected areas and populations and the effect and status of active and ongoing reconstruction projects.

Figure 6 shows a typical city manager dashboard for the city of Baghdad, Iraq. This is the dashboard a city manager would use to oversee all city operations and projects. It includes basic data pertaining to the current number of reconstruction projects, the total amount of funds allocated, the number of stakeholders involved in a given number of projects, and a brief notification of the number and type of requests involved in the process. It also contains a GIS map of the city, highlighting current reconstruction projects, and showing the status of those projects, including pending projects, completed projects and in-progress projects. These are color-coded based on status and are clickable such that each leads to a detailed model view of that specific reconstruction project. Using this interactive interface, the city manager can visualize in real time all operations, processes and project progress taking place for the entire city and can assign tasks and projects to specific

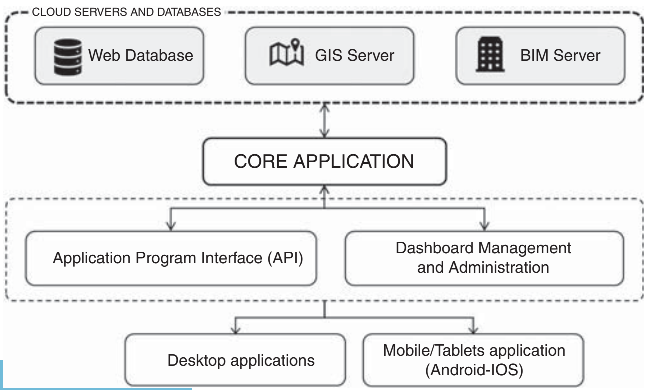

Figure 4.
Technology stack diagram of the smart city reconstruction management system, including cloud servers and databases, core application, application program interface, dashboard management and administration, and desktop and mobile applications

Figure 5.
City management dashboard illustrating status of active reconstruction projects using GIS

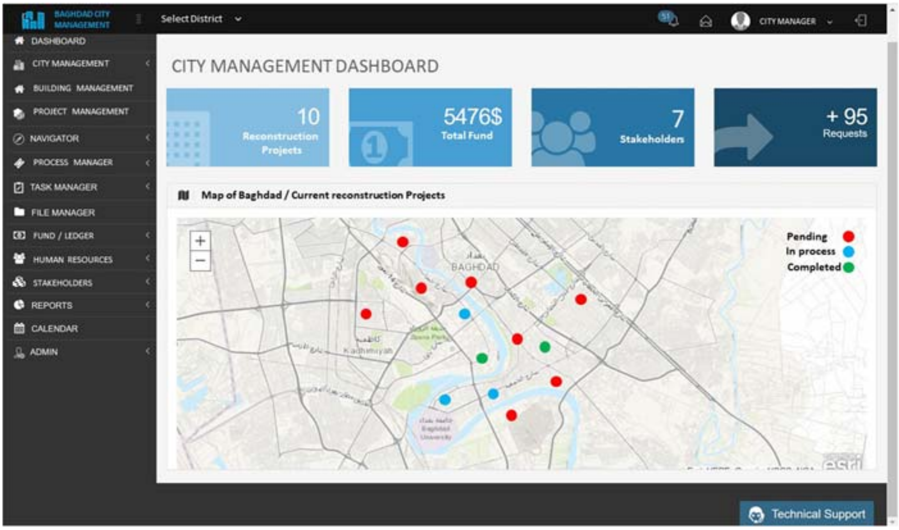

Figure 6.
City management dashboard illustrating status of reconstruction projects within the city of Baghdad using GIS (pending, in-process and completed reconstruction projects)

contractors and service providers from the system database based on availability of funds, all while being notified in real time as well of all requests among different stakeholders.

Based on the viewing portal, each stakeholder would have a different view of the system, as well as different access and privileges depending on their participation and contribution. Regarding reconstruction projects, for example, city managers have access to all building 3D model data and the status of building operations, whereas funding agencies and public participants have access to high-level data including budgets and operations. Facility managers would have yet further access to model data at the highest level of detail.

Another level of detail involves visualizing the status of reconstruction projects at the district level (Figure 7), where GIS capabilities allow for a zoomed in view of a certain

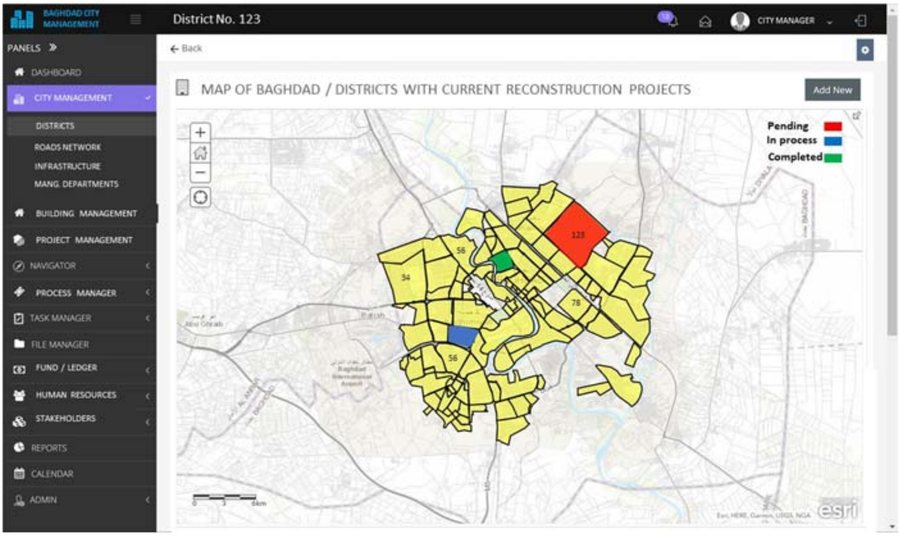

Figure 7.
Status of reconstruction projects in the city of Baghdad at the district level using GIS

district in order to visualize all reconstruction projects within that geographic zone. The city manager can view and assess the status of projects at the district level and can select a specific land plot within the chosen district to view yet another level of detail. At the infrastructure level, the city manager can visualize and manage another level of detail of reconstruction projects using the GIS capabilities of the system, such as street networks, utilities, fences and gates, water and sewage systems, electric generators, power plants, public services, etc.

Figure 8 illustrates the status of a given reconstruction project at the infrastructure level. All the infrastructure systems and their detailed components typically contain data pertaining to their status of operation, maintenance, installation date, etc., allowing the

Figure 8.
Status of reconstruction projects in the city of Baghdad at the infrastructure level using GIS

city manager to assess the current situation in real time, seek feedback from other stakeholders, residents, contractors, clients and staff, and make informed planning decisions accordingly for new projects or modifications to existing reconstruction projects. This communication can be easily conducted using the system's messaging and chatroom capabilities, where all stakeholders can communicate through the messaging application, exchange documents, sign off important decisions, allocate funds and assign tasks or human resources.

While capitalizing on GIS capabilities in the system to visualize and manage networks and geospatial data, the city manager can also select a specific reconstruction project that involves a new or existing building. Upon clicking on a project with building data, the system interface displays a detailed 3D BIM operational model of that building with visualization and navigation capabilities. This seamless transfer from the city-level mode to the building-level mode allows different users to navigate easily and to monitor and assess the status of specific reconstruction projects to the highest level of detail depending on the scope and privileges assigned to each of the stakeholders.

Figure 9 shows the status of a reconstruction project at the building level in the city of Baghdad. Using the system navigator, the city or building manager can explore all building details including building systems (such as HVAC systems, finishing, equipment, doors, windows, stairs and ramps, etc.) using a custom view of those systems. They can also choose to view the building by level, where the system displays a 2D interactive view of each floor level, highlighting all building spaces for further visualization and management at the space level. For each of these views, the status of tasks and operations is reflected in real time, along with system notifications of any updated tasks and live communication exchanges among different stakeholders including participants from the public. The discussions resulting from these exchanges are moderated by local authorities and are used to initiate or guide the reconstruction process of a given project.

The system can also be used to manage the status of heritage buildings and buildings of unique historical value such as the partially destroyed Taq Kasra monument in Baghdad (Figure 10), where different restoration and renovation data can be visualized, archived and managed through the system's historic record and file versioning capabilities.

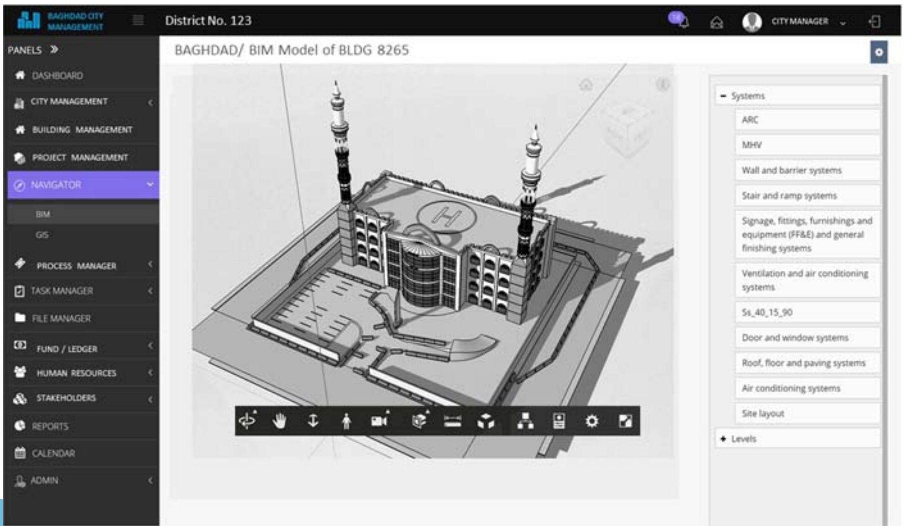

Figure 9.
Status of a reconstruction project for a building in Baghdad using BIM, illustrating all building systems and levels

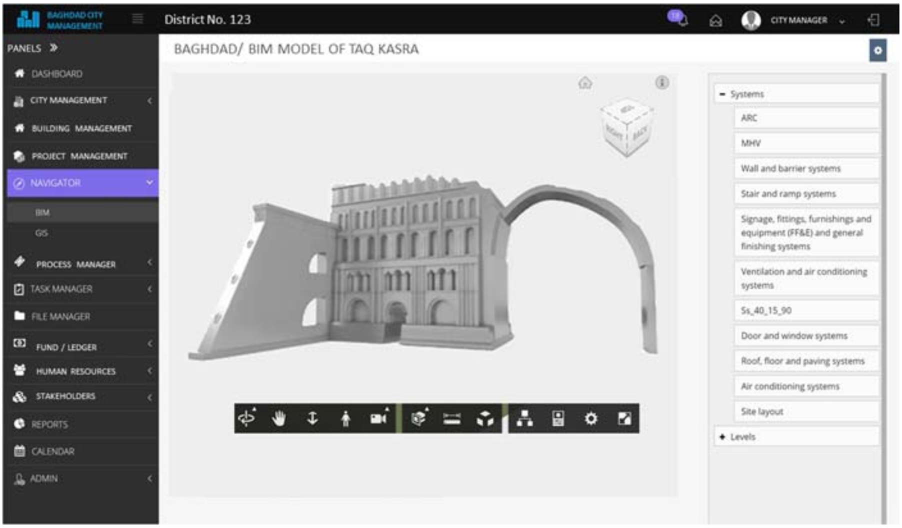

Figure 10.
Status of a reconstruction project for a heritage building in Baghdad using BIM (reconstruction of the Taq Kasra monument)

Discussion

Our approach suggests a smart management system for the reconstruction process of post-conflict cities. This approach builds on – rather than a mere representation of existing conditions and planned reconstruction activities – a comprehensive and integrated platform that aims to inform planners and decision makers concerned with post-conflict city reconstruction. This platform uses BIM, GIS and web-based technology to develop a smart system comprising a number of interlinked modules that aim to provide a multi-objective solution for post-conflict city reconstruction, including effective data archival, assessment of existing city conditions, strategic planning, management and decision making of reconstruction efforts, continuous monitoring of reconstruction operations, and effective communication among different stakeholders. Below is a brief description of the added value and potentials addressed by the proposed smart reconstruction management system.

Real-time and live reconstruction data repository

For an effective data archival at the city and building scale, the system uses its city management, building management module, task and project management module, and its BIM and GIS navigation and database technology to monitor reconstruction efforts and systems at the level of the city, district, road networks, utilities and infrastructure, as well as the building level. These are continuously updated and recorded using the system file management module which documents all states at the city and building level in the form of drawings, model data, certificates, forms, contracts, standards, etc.

This allows for a permanent record and live status of tasks, operations, activities and building and city reconstruction data which are all accessible in real time for all stakeholders based on their access privileges. This is especially significant for reconstruction projects, where the discrepancies between existing and newly introduced conditions, and different stages and states of reconstruction, are all highly important to distinguish, monitor, record and visualize during the overall duration of any given reconstruction project.

Flexibility of model viewing, representation and level of detail based on available data and stakeholders

One of the key outputs of the proposed smart city management system is the building information model, or the digital description of every aspect of the built asset established through the process of BIM, which is a process for creating and managing information on a project across its lifecycle. This model draws on information assembled collaboratively and updated at key stages of a project. Creating this model enables those who interact with the building to optimize their actions, resulting in a greater lifecycle asset value. The system utilizes dynamic scaling regarding model level of detail and development based on the viewing requirement of the different stakeholders involved, where BIM LOD 100 or 200 is introduced to user groups like government agencies and public participants who do not require a high level of detail in viewing and navigating through BIM models of a given project, while higher levels such as BIM LOD 300 or 400 are provided for facility managers and service providers and other parties requiring a degree of detail that delineates building systems and infrastructure necessary for conducting detailed operations and tasks required during the reconstruction of that project.

Our approach recognizes the challenges of managing the different reconstruction operations for a given building, asset or utility, which can vary dramatically using different buildings references including: no references at all, manual drafting and 2D CAD, or 3D BIM, while the communication requirements of information remain constant. The application of standards supported by technology, however, manages more determined and efficient information with less inherent risk, providing improved building operations for an efficient reconstruction process. The reconstruction process using BIM helps obtain the maximum benefit of building data with multi-layered interaction for different stakeholders including designers, contractors, facility managers, service providers and many others.

BIM models may typically have different graphical representations and data entry for the different levels of implementation and scale of using BIM. Our system has a strategic approach for each application using the Construction Operations Building Information Exchange data and model geometry, providing accurate data and graphical representation. We use a BIM viewer, which is a WebGL-based, JavaScript library for 3D and 2D model rendering. 3D and 2D model data may come from a wide array of applications and is based on Autodesk Forge development. The viewer communicates natively with the Model Derivative API to fetch model data, complying with its authorization and security requirements. The system comprises a unique reference for each component of any given project, providing reliable tracing for component development and reconstruction and maintenance history, data set availability for maximum use and recall whenever required, therefore supporting integration with other collaboration platforms.

BIM/GIS integration

A key strength of the system is the integration between BIM and GIS. This integration aids to control macro processes, where GIS increases the value of BIM design data through the analysis and management of infrastructure and other elements in the built project. It also supports the improvement of communication and data retrieval. Using the analytical power of both BIM and GIS, all stakeholders in the reconstruction process can better understand the issues and impacts of their decisions. The seamless navigation between BIM and GIS viewing portals was specifically designed to view both lightweight BIM models using Autodesk Forge and GIS city models using ESRI interchangeably through the system's web-based interface.

Continuous assessment and monitoring

The system uses its analysis and reporting module and navigation module to continually evaluate and report on reconstruction efforts with regard to reconstruction status, revenues and expenses, task completion, and many other customized and on-demand reports. Advanced reporting and analysis allow for a strategic planning tool for efficient reconstruction by means of the system process management module, funding and ledger module, stakeholder module and human resources module. This is manifested in the prediction models enabled by these modules which are related to strategic funding allocation, priorities of reconstruction projects and projection of incurred costs.

This is especially significant in post-conflict zones, where priorities of reconstruction are always problematic and questionable, and where funding is limited and requires strategic planning. This applies to prioritization of projects involving essential infrastructure and utilities, and projects related to providing basic human needs such as residential and commercial projects, as well as projects involving reconstruction of significant historic and heritage sites. The proposed system allows for informed decision making in terms of funding, construction and phasing of these different projects.

Platform for communication, discussion and decision making among stakeholders

Regarding an effective platform for communication among all stakeholders involved in the reconstruction process, the system uses its stakeholder module and chatroom and messaging module to provide a highly interactive communication mechanism during all reconstruction operations between mayors, city councils, municipalities, building managers, local vendors and service providers, funding organizations and agencies, and many other stakeholders including public participants. This mechanism allows for seamless communication and discussion among all stakeholders to manage a variety of complex projects and operations without the need for complicated, disjoint and lengthy methods of correspondence, thus resulting in significant time and cost savings per project.

An added value in the system is the potential to utilize its communication modules as an open discussion forum and platform for bottom-up decision making, where citizen participants can use this platform to discuss and express their opinions regarding reconstruction efforts and offer valuable input in terms of planning and city re-energizing through real-time feedback and live debates and discussions, especially among populations in the diaspora and the interested public, rather than top-down authoritarian decisions from government agencies or funding organizations solely.

System evaluation and future work

As it stands, the system offers a comprehensive approach for the effective reconstruction management process. As opposed to other systems that utilize solely heritage BIM techniques or public participation geographic/geospatial information systems (PPGIS) technology, our system adopts a comprehensive multi-scalar and integrated approach that utilizes both the relational database structure and the geographic and geospatial analytic power of GIS tools in addition to the granularity and level of detail of BIM modeling and the navigation, visualization, coordination, design documentation and information take-off capabilities in a back-and-forth seamless navigation environment.

Apart from the continuous development and extended features in each of the system's modules, there are currently a variety of potentials for future development, including developing the system modules to incorporate live discussions and exchange of ideas among its different stakeholders, especially public participants and populations in the diaspora. The documentation, structuring and curation of these valuable discussions and inputs that currently exist in the system can be transformed through a developed version of its chatroom and messaging module and file management module to think tanks, where different ideas for reconstruction projects emerge for a wider discussion among decision makers, and where continuous monitoring and feedback regarding the validity and performance of reconstruction projects can be addressed based on their lifecycle which can be easily tracked through the historical record readily available for each project and its tasks and operations.

Regarding the visualization and monitoring of live data from buildings, utilities and assets on reconstruction sites, this can be further augmented using hardware equipment related to IoT and sensor networks (currently under development in the system), where physical equipment attached to existing and reconstructed facilities can be used to provide real-time feedback that would give stakeholders a more informed idea concerning the monitoring and control of existing facilities and systems. The integration of the smart city management system and existing IoT systems including smart systems and sensor networks gives the system a further competitive edge, where real-time data and feedback from existing reconstruction operations are detected, monitored and processed by the system's data analysis, management and reporting tools to provide comprehensive and accurate real-time data representation and prediction models of operation and management.

Conclusions

Reconstruction efforts for post-conflict cities such as Baghdad, Aleppo, Sarajevo and Damascus typically face significant challenges related to economic revitalization and the return of refugees and internally displaced persons. A primary cause of failed reconstruction efforts typically owes to poor planning and poor coordination strategies, where most efforts focus on the reconstruction of specific iconic buildings without clear justification or without a clear urban planning strategy, vision or prioritization for revamping specific institutions or public spaces or for adequate planning and funding, due to fluid political situations in such post-conflict zones.

In this paper, we presented an approach for the smart city management of the reconstruction process in post-conflict cities. The primary objective of the proposed approach and system is to empower all parties and stakeholders concerned with the efficient management of the reconstruction process for post-conflict zones. The proposed system integrates BIM and GIS technology with a web-based application that allows for a real-time analysis, reporting and decision-making tool for the management of reconstruction processes involving a multitude of stakeholders.

Our approach primarily involves multiple levels and dimensions of the reconstruction process, including: post-conflict city evaluation, where the existing condition is thoroughly assessed; reconstruction planning, where strategic planning is involved to make informed decisions based on credible data and sources; reconstruction projects, where strategic plans are executed effectively; and project implementation, where reconstruction projects are conducted with an eye on long-term project sustainability and the continuous cycle of management of operations, tasks and resources for those projects.

We claim that our approach provides an effective tool for data archival at the city scale, an assessment tool for existing city conditions, a strategic planning tool for efficient reconstruction planning, a monitoring tool for continuous management and operation during and after reconstruction, and an effective platform for communication among all stakeholders involved, including city managers, local authorities, government agencies and funding organizations.

One of the added values of the proposed system includes offering a real-time and live reconstruction data repository for continuous assessment and monitoring by all stakeholders, including especially public participants, aiming toward a bottom-up decision-making process through think tanks and discussion platforms. Future work will augment this capability to include a structured process for the involvement of public participants and bottom-up development and monitoring of reconstruction projects.

Another added value includes the flexibility of model viewing, representation and level of detail based on available data and stakeholders, where different BIM levels of development and detail standards are tailored to address different users and are adapted to work with different modes of available data for reconstructed buildings. The integration between BIM, GIS and the web-based approach is a key factor in addressing the comprehensive platform that the proposed system offers, based on the combined benefit of geospatial analysis, server integration, live database integration, 3D navigation and visualization, live record of 3D building data and operations, real-time feedback, and information take-off. Future work will integrate IoT systems including smart systems and sensor networks, where real-time data and feedback from existing reconstruction operations are detected, monitored and processed by the system to provide comprehensive and accurate real-time data representation and prediction models of operation and management.

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