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A Cloud-based Framework for Smart Permit System for Buildings

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***Abstract*— In this paper we propose a novel cloud-based platform for building permit system that is efficient, user-friendly, transparent, and has quick turn-around time for homeowners. Compared to the existing permit systems, the proposed smart city permit framework provides a pre-permitting decision workflow, and incorporates a data analytics and mining module that enables the continuous improvement of a) the end user experience, by analyzing explicit and implicit user feedback, and b) the permitting and urban planning process, allowing a gleaning of key insights for real estate development and city planning purposes, by analyzing how users interact with the system depending on location, time, and type of request. The novelty of the proposed framework lies in the integration of the pre-permit processing front-end with permit processing and data analytics & mining modules, along with utilization of techniques for extracting knowledge from the data generated through the use of the system.**

Keywords—building permit; data analytics; data mining; urban planning; cloud computing; smart city

I. INTRODUCTION

Currently in cities across USA the process for obtaining building permits is often complex, non-transparent, and inefficient, involving a significant amount of "legwork". It is often very difficult for a permit-applicant to determine whether a permit is required, even after multiple visits to the City Hall. Furthermore, the application process is unclear. If a property owner decides to obtain a permit, the permit application process involves filling out several forms, providing many supporting documents, and then waiting anxiously for a decision on the permit application. This lack of clarity often results in frustrated property owners who end up making unauthorized improvements to their properties, thereby increasing public health and security risks. At the city-government-end, the permit-application-generated workflow is slow, difficult to track, and requires coordination spanning several departments (for example, building inspection, public works, and fire).

In this paper, motivated by the above problems and the shortcomings of most existing permit systems, we propose a smart, cloud-based CMS platform to make the permitting process more efficient, user-friendly, transparent, and with quick turn-around time for property owners. The proposed framework benefits both the end user and the city government. For the end user, it streamlines the process, introducing a pre-permitting system that is built on business rules and that includes a recommendation engine that allows permit applicants to identify, through a user-friendly intuitive interface, whether they need a permit, and what is the necessary paperwork needed.

The majority of available systems focus on automating the permit process starting with the submission of a permit request. However, there is little or no work in the areas of pre-permitting, and of employing data analytics and data mining techniques to improve the end user experience as well as the process itself.

Our main contribution in this paper is a smart permit processing framework that integrates pre-permitting processes and analytics with the permit process and incorporates various permit-related functionalities to achieve usability, reliability, transparency, performance guarantee, and a reduction in processing time—characteristics that are extremely important for both city governments and property owners.

The rest of the paper is organized as follows: In Section II we provide a brief overview of the building permit process. In Section III we discuss related work in the field of on-line permitting. In Sections IV and V we discuss the high-level architecture and functionality of the main modules of the proposed framework, namely the pre-permitting process, the permit functionality, and the data analytics and mining processes. We conclude in Section VI.

II. BUILDING PERMIT PROCESS OVERVIEW

This section describes the three major phases—pre-permitting, permitting and post-permitting—of a building permit process from an on-line, cloud-based, permit system design perspective.

During the pre-permitting stage, the following needs to be ascertained: a) whether a building project needs permits; b) if yes, what kinds of permits; c) what application forms and supporting documents need to be provided; d) availability of sample application forms and supporting documents as exemplars; e) the specific steps (including the fee) for obtaining permits; and f) how change in the design or scope of the building project would impact points a) through e). Providing the above-described information to the applicant in an on-line, user-friendly platform that provides answers customized to each building project would help the permit issuing city government department reduce the time and resources needed for in-person interactions with the applicant at the pre-permitting stage. Further, the data gathered at the

pre-permitting stage could provide city governments leading indicators of the demand for permits by various classifications such as permit-type and geographical location of the building projects. However, success of such an on-line platform hinges on strong linkages between the front-(user)-end of the system with the back-(city government)-end of the system. For example, the system should be able to link the data provided by an applicant (such as the project address, building type, and project type) to ascertain the permit requirements based on a project's zoning, applicable building code, and design.

During the permitting stage, an applicant submits the permit application, including the fee. A permit is issued once the application is reviewed and approved by various city government departments. When the building project is underway, inspectors may visit the project site periodically to verify the project's adherence with applicable building regulations and other rules. The inspectors issue a completion certificate once the entire project is completed as per rules. During this phase, an applicant is typically assigned a city staff (often from the permitting department) as the contact person.

At the city-government-end, a complete application is desired in a format that is compatible with the application review systems of the various reviewing departments (such as planning, police, fire, and public works). Further, the back-end system should enable: a) the reviewing departments to view the application and to comment and adjudicate upon it; b) the building inspectors to schedule visits; c) the coordinating staff to track the application status and to communicate with the applicant and the municipality staff; d) automatic generation of notifications (such as assigning a project case number); and e) the coordinating staff to receive notifications, for example, regarding application updates such as an applicant's queries and feedback.

During the post-permitting phase, an applicant desires to: a) review his history of past permit applications, including the submitted applications and supporting documents; notifications from the municipality, including notes and approvals from the building inspectors; and b) have an ability to reference past permits when applying for permits in the future. Additionally, a city's residents might be interested in understanding the real estate development trends in their city and use permit data to gauge these trends.

III. Related Work

A recent survey of 524 cities in the US found that only 21% cities offered an on-line permitting platform [1]. The increased focus on public sector efficiency and transparency - recently with the open data and open government initiatives - is bound to lead more cities to offer the ability to apply and obtain building permits on-line. However, a systematic review of the capabilities of these on-line systems is lacking, especially in the USA. If studies from Europe are any indication, cities' on-line permitting systems are very limited. For example, apart from England and Wales, no other European country offers, on a large scale, the ability to submit building permits electronically [2].

In the absence of an existing systematic review of online-building permit systems, we conducted such a review of on-line permitting systems of three large cities in the US: Chicago, Cincinnati, and San Jose. We found that among these three cities, Cincinnati's on-line system is the most advanced. During the pre-permitting stage it describes the common types of building permits; through a hard-coded permit guide, provides answers to commonly asked questions such as whether a building project needs a permit and if yes, which supporting documents are needed. Further, samples of such supporting documents, including project drawings, are available on-line. Finally, through a simple address search, applicants can identify the types of projects for which permits applications can be submitted on-line.

During the permitting stage, Cincinnati's system allows applicants to upload the application form and project drawings, pay application fees, and track the permit application status through a simple address search or by permit/case number. During the post-permitting stage, Cincinnati's system allows review of permit records. The permit application database is linked to the city's Geographic Information System (GIS), allowing easy spatial analysis of the permit data. For example, maps showing the permit issuances across the city by major permit types are available on-line. Indeed, the city's on-line e-permit system—ezTrak—is hosted within CAGIS—the city's GIS portal [3].

Finally, Cincinnati's on-line permitting system includes various desirable features identifid in Section II. These features include ability to: upload permit application and supporitng data; pay fee; review good examples of filled application forms and supporting documents; and query permitting data. However, the system has limitations. For example, the pre-permitting guide consists of a set of "one size fits all" instructions and is not a smart, customized process as the one we propose in this work.

Our proposed conceptual framework employs state-of-the-art design principles and technologies to implement the various components of the permitting process. The novelty of the proposed framework lies in the use of data analytics and data mining techniques, in combination with business process modeling, to improve both the process itself, as well as the user experience. There is little work done in this area. Huaiming et al. [4] proposed the use of agent technology to assist several administrative permit operations such as filling forms, auditing material, and deciding on permits. While the authors provide a very high-level description on what primary characteristics the agent should have (including residence, autonomy, responsive, pro-active, social), they don't provide any technical details on how these agents will be implemented and what will be the underlying algorithms that will enable them to perform the suggested functionality.

Ye et al. [5] proposed modeling the administrative permit businesses using business objects. Their focus is on describing the business rules and proposing the general business process of one-stop administrative permit system to increase the flexibility of the system. In this paper, we adopt a very high-level workflow, assuming that it will be refined further after performing requirement analysis with the city who's going to implement the permit system. However, as mentioned previously, the main focus of this paper is to highlight how the permit application system can become "smarter" by

integrating data analysis and data mining/machine learning technologies in various steps of the process.

IV. A Conceptual Framework for Smart Permit System

The proposed system will have a pre-permit submission module that will guide the end user (property owner) through a step-by-step process for obtaining a building permit. Through a series of questions, supported by a rule-based decision tree, the system will automatically determine if and what permits are needed and the documents and fees that must be submitted. This will reduce the permit processing time, eliminate operational inefficiencies, and improve customer satisfaction. When a building plan is submitted electronically, the system will also do an automated, preliminary check to make sure that the plan meets the city's permit requirements. The system should have the following features - both for the end-user (property owner) and the system users (city government) - as part of its permit processing module:

a. Provides an automated tool to make sure that the plan meets the permit requirements
b. Allows online submission of plans
c. Provides easy access to guidelines and procedures
d. Streamlines permit processes and reporting
e. Maintains auditable historical compliance records
f. Facilitates monitoring all permit data and dates
g. Provides quick turnaround, notification and alerts
h. Monitors task tracking and follow-up activity
i. Allows for rating-based user feedback

In addition, the web-based smart permit system will have a user-friendly Graphical User Interface (GUI) to enable users to manage contact information for property owners, locations, contractors, architects, and engineers; and track all applications, permits, inspections, and corrections for building, electrical, mechanical, and plumbing projects.

This smart permit system will also allow the city governments to manage complaints, violations, corrections, building licenses, and fees; schedule appointments and inspections; manage tasks and activities; and query and generate customized reports.

The proposed system will interface with a variety of systems such as a city's GIS, and integrate the following processes to improve efficiency: Planning and Zoning; Building Permit-Plan Review and Inspection; Code Enforcement Case Management; Engineering Permits, Fire Prevention Plan Review and Inspection; Special Events; and Customer Relationship Management.

From a technical perspective, this system is cloud-based, which means the user does not need to install any software on the client machine to run the system. The Smart Permit system will be deployed as SaaS application delivery model, that utilizes the cloud computing infrastructure of a cloud service provider such as Amazon Web Services or Azure.

Our software framework consists of Pre-permit & Permit System Front-end, Permit Processing Module, and Data Analytics & Mining Module that are integrated together to coordinate and streamline all business processes.

The Pre-permit & Permit System front-end, shown in Figure 1, is one of the novel components of the proposed framework and will determine whether a user needs a permit or not. It consists of various questionnaires and forms, dynamically customized based on the user's input, and supported in the back end by a rule-based decision tree. It also includes a smart chatterbot, a computer program that will interact with the users via auditory or textual methods [6, 7]. This module acts like a gateway to the Permit Processing module.

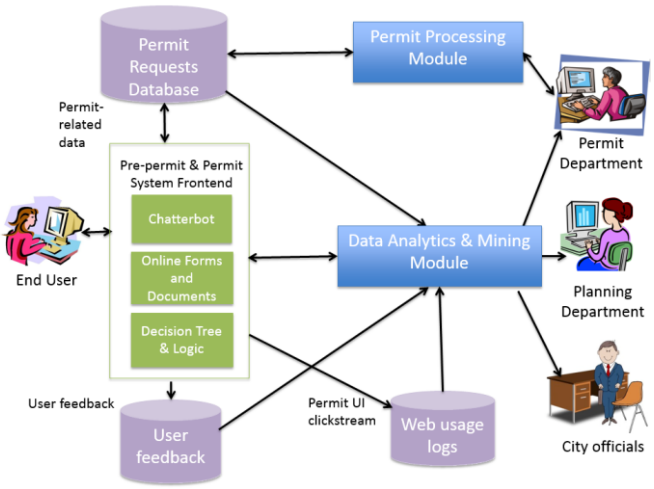

Figure 1: Pre-permit & Permit System Frontend

The Permit Processing module will have all the features described earlier and will process all the plans after the pre-processing has been done. Our Data Analytics & Mining module is quite innovative and provides key insights to the overall permit process. We describe it in detail in the following section.

V. Analytics For Smart Permit System

The novelty of the proposed framework lies in the improvements to both the end-user experience, as well as to the permit and planning processes through the utilization of techniques and algorithms for data analytics and data mining, and the use of recommendation methodologies and algorithms to extract knowledge from the data collected through the use of the system. Accordingly, the Data Analytics & Mining module functions in two layers, namely the permit and planning process layer, and the user experience layer, as discussed next. Figure 2 provides a high-level architecture, highlighting how the various sub-modules of the Analytics module interact with the other modules and data repositories of the framework.

A. Improving the permit and planning processes

The proposed system architecture includes a data repository where all permit-related interactions, including permit requests, types, location, date, etc., are stored. Using predictive analytics and data mining techniques, the city can gain useful insights on the needs of its permit applicants and more efficiently plan its resources and manpower. Some examples of applying data analytics on the permit data set, along with possible use of the results, include:

- Spatiotemporal visualization of permit requests: The city officials and the public will be able to visually explore which types of permits are often requested in what parts of the city during which period of time.

- Statistical analysis and predictive modeling on permit request data: The data will be fed to algorithms, such as a linear regression, to generate a predictive model that will enable early identification of spikes in demand for different types of permits and different calendar periods, such that the city can allocate resources appropriately to avoid long wait periods (e.g. allocate two more employees in March to process kitchen remodeling permits filed in District 9).
- Data analytics and predictive modeling on permit processing data: Data related to permit approvals or denials will be analyzed to identify possible bottlenecks in the workflow and provide insights on how the process can be more streamlined (e.g. discover that a specific type of permit has higher than average rate of denial).

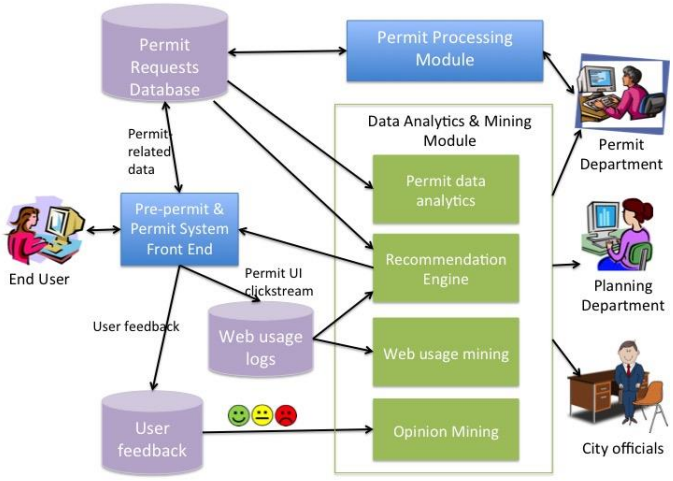

Figure 2: Permit System Architecture - Data Analytics & Mining module

B. Improving the end-user experience

The design of the proposed permit framework is user-centric. The goal is to improve the user experience both in terms of improving the process, but also in terms of improving the interactions of the users with the system itself. To this end, we apply data mining and collaborative filtering techniques to permit application data, web usage data, as well as explicit user feedback:

- Web usage mining: The web usage logs will be mined using clickstream analysis to identify possible bottlenecks in how users interact with the user interface of the system. This knowledge will subsequently be used to redesign the workflow of the interface to minimize the number of dropped (i.e. unfinished) sessions.
- Explicit feedback and opinion mining: At the end of each session, the end users will have the opportunity to provide feedback both through numerical rating of their experience, as well as through textual comments. Opinion mining and sentiment analysis techniques will be applied to the textual comments to automatically identify issues that concern the users, as well as features that they liked. This knowledge can be used to improve the user experience.
- Permit Recommendations: The permit-related data, stored in the data repository discussed previously, can be used as an input to a permit recommendation process. The premise behind recommendation systems is simple: if user A and user B have similar preferences (expressed, e.g. in terms of ratings or purchases), then if user A likes item x, user B is likely to enjoy item x as well. We transfer this paradigm to the permit process, based on the assumption that similar users (for example, with similar houses and past permit requests), might have similar permit needs in the future as well. Based on this assumption, we propose the implementation of a permit recommendation system. Similar to web-based recommendation systems, we will employ collaborative filtering techniques in order to generate recommendations for the active users, in the form of "other users who submitted permit X also submitted permit Y". For example, if a user is installing a new roof, the system may suggest installing solar panels on the roof for energy savings.

VI. CONCLUSIONS

In this paper, we have presented a cloud-based online smart permit system that is efficient, user friendly and that reduces operational inefficiencies through a smart pre-permitting process and the integration of data analytics and data mining techniques, including a recommendation engine. The proposed framework would benefit the city governments as well as the permit applicants and citizens, by improving the end-user experience and the permit process. Finally, the proposed framework provides a descriptive approach based on the best of the breed technologies that can help move toward the vision of Smart Cities. We are currently working on a prototype system that implements most of the aforementioned smart functionalities, using real-life permit data from the City of San Jose.

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