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A building permit system for smart cities: A cloud-based framework

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ABSTRACT

In this paper we propose a novel, cloud-based framework to support citizens and city officials in the building permit process. The proposed framework is efficient, user-friendly, and transparent with a quick turn-around time for homeowners. Compared to 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 both the end user experience and the permitting and urban planning processes. This is enabled through a data mining-powered permit recommendation engine as well as a data analytics process that allow a gleaning of key insights for real estate development and city planning purposes, by analyzing how users interact with the system depending on their location, time, and type of request. The novelty of the proposed framework lies in the integration of a 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. The proposed framework is completely cloud-based, such that any city can deploy it with lower initial as well as maintenance costs. We also present a proof-of-concept use case, using real permit data from New York City.

1. Introduction

Construction projects typically require a building permit, a plan check, and inspections. Building permits are required when any type of construction is planned that will change or add structure to an existing property or land parcel. Often, more than one permit is required even for a simple construction project, such as updates to a bedroom or a bathroom. Further complications arise because even after multiple visits to a city's permit office it is often very difficult for a permit-applicant to determine whether a permit is required. The type of permits, rules and regulations vary significantly between cities, making the process for obtaining building permits complex, non-transparent, and inefficient, often involving a significant amount of "legwork" for the citizens (Barker, 2008; May, 2005; Meijer & Visscher, 1998). Furthermore, the application process itself 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 often a long wait for a decision on the permit application (Lee, Lee, Park, & Kim, 2016; Wahed, 2017; Wahed, El Barmalgy, & Haggag, 2012). Due to this lack of clarity, frustrated property owners often end up making unauthorized improvements to their properties, thereby increasing public health and safety risks (Agyeman, Abeka, & Assiamah, 2016; Lee et al., 2016; Wahed, 2017; Wahed et al., 2012). At the city-government-end, the permit-application-generated workflow is slow, difficult to track, and requires coordination spanning several departments (for example, departments of building inspection, public works, and fire protection) (Barker, 2008; Massachusetts Municipal Lawyers Association, 2015; Riggs, Chavan, & Steins, 2015).

While many parts of everyday life have been largely automated, including various city services (e.g., filing complaints for illegal dumping), a recent survey of 524 cities in the US found that only 21% cities offered an on-line permitting platform (Riggs et al., 2015). This proportion is likely to increase due to a renewed focus on public sector efficiency and transparency, especially with the recent open data and open government initiatives. However, a systematic review of the capabilities of these on-line systems is lacking, especially in the US. If studies from Europe are any indication, on-line permitting systems are very limited (Bellos, Petroutsatou, & Anthopoulos, 2015). In this work, we attempt to address the above issues and shortcomings, by proposing a "smart permit" framework that any city can implement to streamline and facilitate the permit request process.

As noted in (Taewook et al., 2014), smart city represents one of the

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most promising, prominent, and challenging Internet of Things (IoT) applications. According to a recent survey (Riccardo, Valeria, & Nathalie, 2017) the smart city services should be user-centric, ubiquitous, and highly integrated from the end user's perspective, while being highly interconnected, cost-efficient, and energy-efficient from the point of view of the administrators, and this can be enabled by a "Cloud of Things" (CoT) infrastructure. While this cloud-based approach is broadly accepted as the optimal way of implementing such applications (Sharmin & Al-Amin, n.d.; Jin, Gubbi, Marusic, & Palaniswami, 2014; Khan, Anjum, Soomro, & Tahir, 2015; Yang, Manzhu, Fei, Jiang, & Li, 2017; Ye, Na, Wang, Li, & Han, 2009), this is the first work that focuses on the smart building permit application domain.

Briefly, this work has two objectives:

a) To develop a cloud-based architecture to support the permit process and address the shortcomings of most existing permit systems by making it more transparent, efficient, user-friendly, and with quick turn-around time for property owners. As further discussed in Section 3, contrary to the majority of existing systems that automate the permit process starting with the submission of a permit request, this work focuses also on pre-permitting. The novelty also lies in employing data analytics and data mining techniques to improve the permit applicant's experience as well as the process itself. Therefore, this paper develops a framework that streamlines the permitting process by introducing a business-rule-driven pre-permitting system that allows permit applicants to identify, through a user-friendly interactive interface, the exact permits and the associated paperwork. Additionally, the framework incorporates a recommendation engine that inputs past permit requests to a collaborative filtering process in order to generate permit recommendations to new users. For the city government, the framework provides an analytics module that incorporates various permit-related functionalities to achieve usability, reliability, transparency, performance guarantee, and reduction in processing time—characteristics that are extremely important for both city governments and property owners. Finally, the proposed framework is completely cloud-based, meaning that the system does not need to be installed on a local server, but instead is managed by a cloud service provider (like AWS, Azure, etc.). Our proposed technology stack is completely new, highly scalable, and based on emerging open source technologies. This design decision is significant given the budget constraints many cities face, allowing any city to deploy the framework faster and with much lower cost, making it easier to maintain (no need to install software, additional hardware, or do the necessary updates), and enabling access from everywhere given Internet connection.
b) To present a proof-of-concept implementation, using real-life permit data (this paper uses permit data collected by the New York City (NYC Open Data, n.d.; Zip codes states & GasLamp Media, 2016)). The prototype showcases the novel functionalities of the proposed framework and highlights ways in which both the public and the city officials can benefit from such a system.

The rest of the paper is organized as follows: In Section 2 we provide a brief overview of the building permit process. In Section 3 we discuss related work in the field of on-line permitting. In Sections 4 and 5, 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. The proof-of-concept prototype using real-life data from New York City is presented in Section 6, and we conclude with our plans for future work in Section 7.

2. Building permit process overview

Viewing the building permit process from an on-line, cloud-based, permit-system-design perspective, we identify three major phases: pre-permitting, permitting, and post-permitting. In this section, we outline permit process workflow, introducing important concepts. In the sections that follow, we focus on the pre- and post-permitting phases, proposing how these can be streamlined, enhanced, and improved.

The following needs to be ascertained during the pre-permitting stage: a) whether any permit(s) is (are) required for a building project; b) if yes, the kinds of permits required; c) the required application forms and supporting documents; d) whether sample application forms and supporting documents are available as exemplars; e) the specific steps to be undertaken and fee to be paid for obtaining permits; and f) how changes in the design and/or scope of the building project would impact points a) through e). If the applicant is provided above-described information through an on-line, user-friendly platform that provides answers customized to each building project, it would help the permit-issuing city government department reduce the time and resources devoted to in-person interactions with the applicant at the pre-permitting stage. Furthermore, this data could provide the city government leading indicators of the demand for permits across various dimensions such as permit-type and geographical location of the building projects. Success of such an on-line platform hinges on strong linkages between the front-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 the applicant (such as the project address, building type, and project type) to the project's zoning, applicable building code, and design in order to ascertain the permit requirements.

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

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

During the post-permitting phase, the applicants could desire to: a) access history of past permit applications, including the submitted applications and supporting documents and notifications from the city government; and b) have the ability to reference past permits while applying for new permits. Additionally, city residents might be interested in understanding the real estate development trends in their city and use permit data to gauge these trends.

3. Related work

According to a recent survey of 524 cities in the US, only 21% cities offered an on-line permitting platform (Riggs et al., 2015). Unfortunately, a systematic review of the capabilities of these on-line systems is lacking, especially in the US. Studies in Europe identify a similar trend. For example, no other European country, apart from England and Wales, offers the ability to submit building permits electronically on a large scale (Bellos et al., 2015). In the absence of an existing systematic review of online-building permit systems, we