Residential Construction Lot Grading Approval Process Optimization: Case Study of City of Edmonton

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Abstract: Rapid growth of residential construction in the city of Edmonton, Alberta, Canada has led to an increased demand for lot grading (LG) inspectors. The traditional inspection process has contributed to inspection delays, backlog, and decreased customer satisfaction. The aim of the research presented in this paper is to study, evaluate, and optimize the existing LG approval process. Data from past years were collected and analyzed to establish a baseline performance level. Flowcharts were developed to visualize the process and a survey was conducted to determine potential areas of improvement from the perspectives of different shareholders. Lean thinking principles were applied to identify and reduce the nonvalue added activities and improve performance. The final phase of the research involved the simulation of the process to evaluate the impact of the implementation of various recommendations. Based on the simulation results, final recommendations were made and later implemented with the help from the city's Information technology department. These modifications to the existing process produced significant gains in quality and productivity, as predicted by the simulation model.

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CE Database subject headings: Buildings, residential; Computer aided simulation; Automation; Canada; Case reports.

Introduction

Residential construction in Edmonton has increased rapidly in recent years, riding the wave of strong economic growth in the region. As an indication of this growth, 7,762 new single-family dwelling units were constructed in 2004 compared to 2,372 units in 2000 (CANSIM II 2005), representing a three-fold increase within the given time frame. One of the responsibilities of the city (Lot Grading Division, Asset Management, and Public Works Branch) is to inspect and approve the lot grading (LG) for these new facilities. 12,646 inspections were performed in 2004, as compared to 6,044 inspections in 2000. For residential construction, LG must comply with the requirements outlined in the citiy's Surface Drainage bylaw (No. 11501). Continued growth of the city has exerted a large strain on the Drainage Services Section's LG approval process. This increased demand, coupled with inefficiency in the process, has led to an increase in the number of complaints. Consequently, the University of Alberta's Construction Engineering and Management Group was retained to analyze and optimize the LG approval process.

Traditionally, lean concepts have been associated with manufacturing operations. The lean production philosophy was developed by the manufacturer Toyota, under the supervision of engineer Taichi Ohno (Howell 1999). Extensive research has been conducted on the possibility of applying lean concepts to nonmanufacturing projects. Koskela and Leikas explored the benefits and the potentials of lean thinking and lean production theory in the construction industry (Alarcon 1997). Lean thinking considers the dependency of supply and assembly chains as well as the potential variation within them. "Lean works to isolate the crew from variation in supply by providing an adequate backlog or tries to maintain excess capacity in the crew so they can speed up or slow down as conditions dictate." (Howell 1999). Ballard and Howell (2004) also illustrate the difference in management styles between the traditional and lean approach. Rather than focusing on production, lean principles focus on efficiency. Reducing or eliminating nonvalue added tasks makes the process more efficient and therefore increased production is achieved. The new management principles improve the quality with an outset in improving flow of work. Ballard and Howell (2004) and Ballard (1999) looked at improving workflow reliability and showed that the application of traditional management techniques resulted in, on average, a 54% failure rate of inspections to complete assignments on weekly work plans as a result of variability in workflow.

The complex nature of construction processes restricts the use of simulations. AbouRizk and Hajjar (2000) defined computer simulation as a process of designing a mathematically logical model of a real-world system and experimenting with the model on a computer. Agbulos and Bowen used the simulation in the improvement of the crew and system efficiency (Agbulos et al. 2005; Bowen et al. 2002). A discrete-event simulation technique, especially suited to construction operations, provides an inexpensive way to test and evaluate different control strategies for operational systems (Hamad et al. 1999). Halpin and Riggs (1992)

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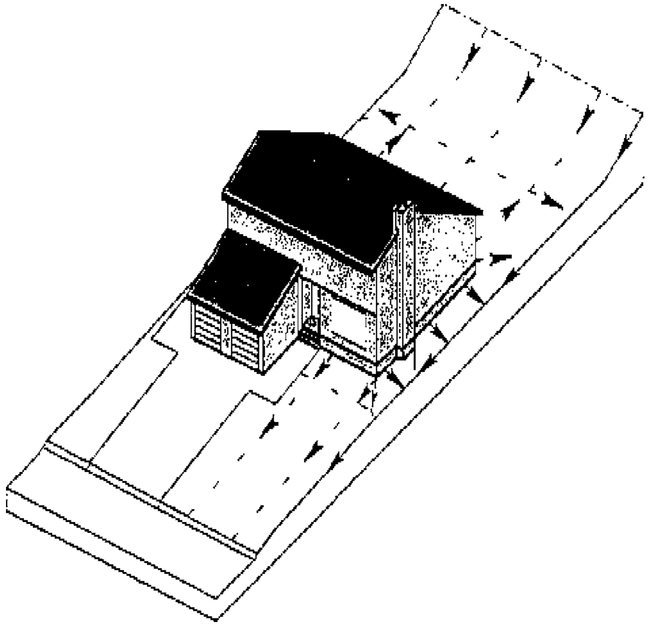

Fig. 1. Illustration of back to front drainage

found simulation to be effective for improving construction process planning. Various simulation and modeling tools have been developed for construction operations, including CYCLONE (Halpin 1977), COOPS (Liu and Ioannou 1992), CIPROS (Tommelein and Odeh 1994), STROBOSCOPE (Martinez and Ioannou 1994), and SIMPHONY (Hajjar and AbouRizk 2002). Oloufa and Ikeda (1997) have studied the various library-based simulation models.

This paper focuses on the evaluation of the criteria used by the LG inspectors with the goal of optimization and automation of the LG process. A combination of lean principles and simulation was used to optimize the process and answer the "what if" scenarios. The research was completed in four primary phases. The first phase involved preliminary and detailed planning of the work analysis study, including the development of the research methodology and approach, and acquiring background knowledge of the LG approval process in place. The second phase involved work measurement and data collection. City staff involved with the LG approval process where interviewed, and the applicable information was documented. A baseline performance level was determined in order to measure any improvements in the modified process. Flowcharts were also developed to illustrate each of the subprocesses involved in the LG approval process. A pilot study and survey were conducted to determine the potential areas of improvement from the perspectives of different stakeholders. The third phase of this research involved the application of lean thinking and lean principles to improve the performance of the operations by identifying the nonvalue added activities. The final phase of this study was the simulation of the process to evaluate the impact of the implementation of the recommendations and answer the what if scenarios. Based on the simulation results, final recommendations were made, which were later implemented by the city.

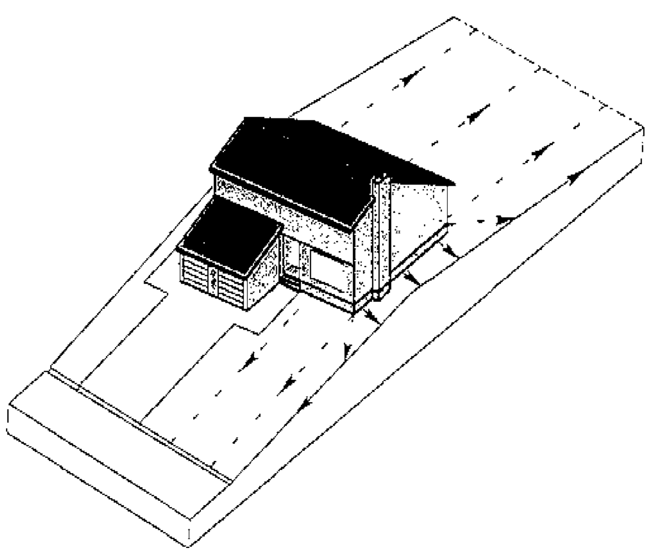

Fig. 2. Illustration of split surface drainage

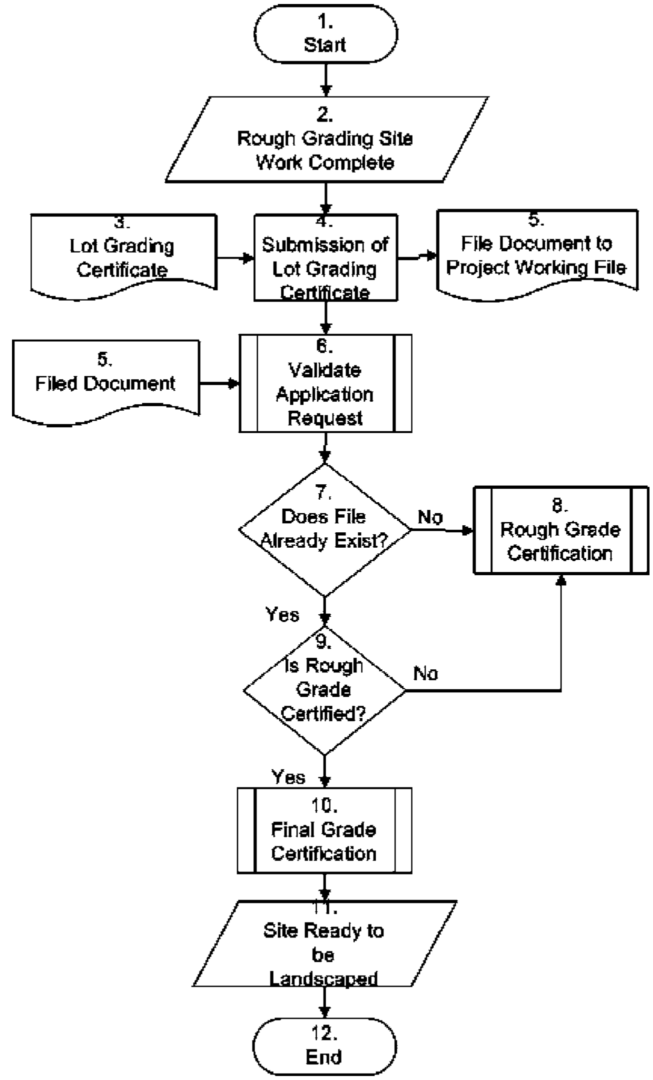

Fig. 3. Process flow for the lot grading approval process

Current Practice

The city has adopted a two-stage LG approval process. The first stage involves the rough grade being inspected and approved for conformance with the Surface Drainage bylaw. The second stage

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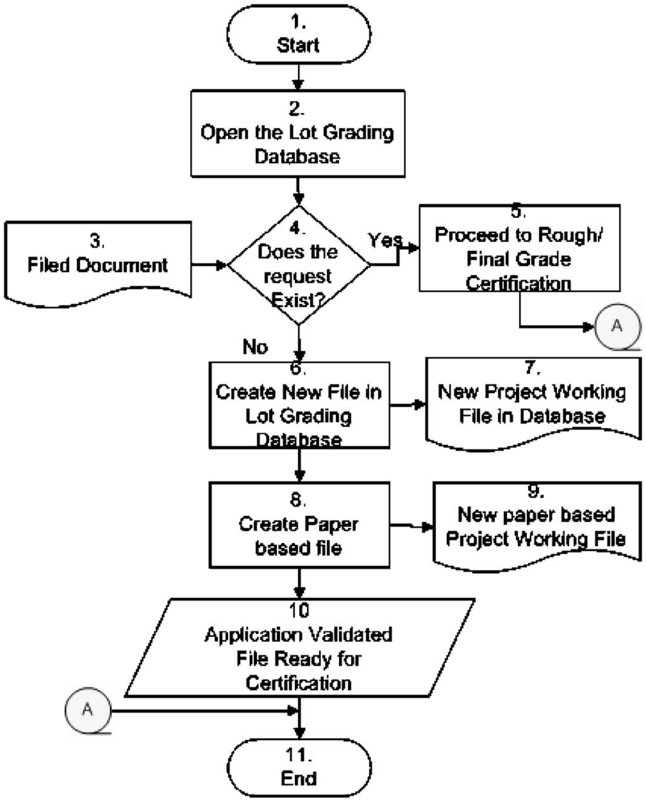

Fig. 4. Process flow for the application validation subprocess

consists of the final grade being inspected and approved. Rough grading includes backfilling the foundation walls and shaping the lot to conform to the design of the approved surface drainage plan. Figs. 1 and 2, respectively, illustrate the back to front and split surface drainage schemes adopted by the city. Final grading involves spreading and smoothing the topsoil so that it is ready for landscaping. For research purposes, the LG approval process has been broken down into three distinct subprocesses: validating the application request, rough grading certification, and final grading certification. A flowchart illustrating the overall LG approval process is shown in Fig. 3. Upon completion of the rough grading site work, the homebuilder/contractor contacts a registered Alberta land surveyor to produce a "Plan of Certification of As-built Grades" (henceforth referred to as the LG Certificate), which is sent to the LG division as a part of the LG approval application. Upon reception of the certificate, the division validates the application following the process illustrated in Fig. 4. The LG division transfers the accepted application's certificate for rough or final grading approval. The submitted LG is manually checked for five criteria: Comparison of grades, direction of drainage, lot grades of neighbor's property, surface conditions, and on-site services. The variation between the as-built elevations and the approved drainage plan are manually computed at defined locations within the lot. The design grades shown on the LG Certificate are also compared with the grades shown on the approved LG plan. The status of the neighboring lots are checked and are indicated on the drawing to ensure that neighboring lots will not be affected by runoff from the lot in the application. Upon completion of the site inspection, the inspector can either approve or fail the rough grading depending on the assessment criteria. In the case of failure, once the deficiencies have been corrected, the division is contacted to perform a reinspection of

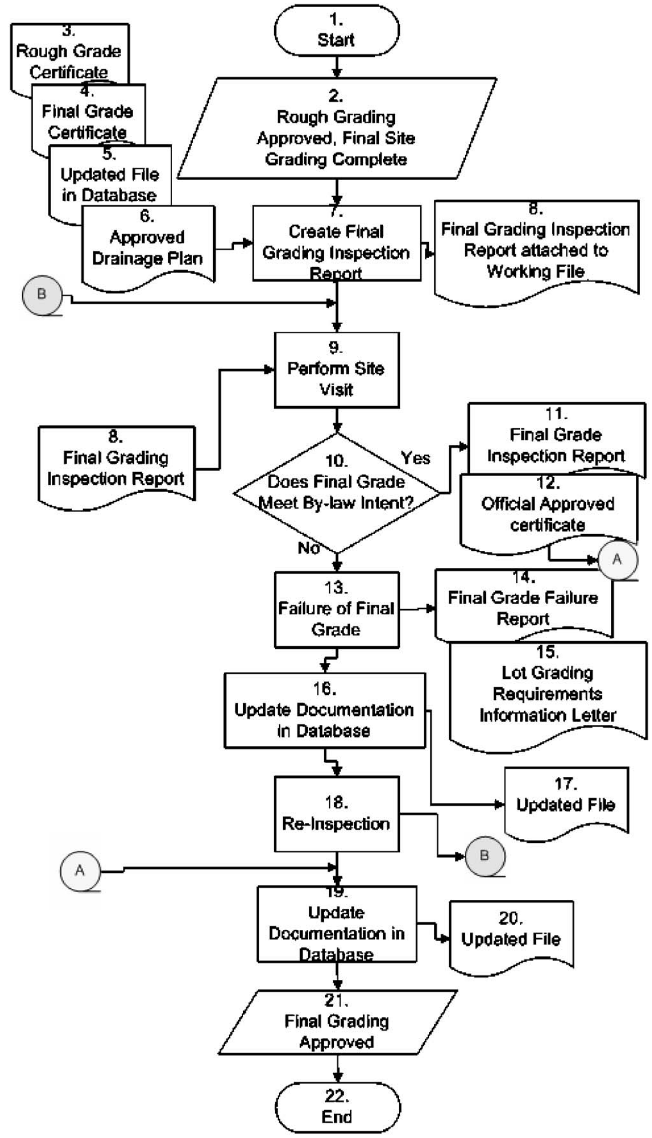

Fig. 5. Process flow for the final grade certification subprocess

the lot grading, thus repeating the whole process and contributing to inefficiency.

The final grade approval subprocess, illustrated in Fig. 5, is much like the rough grading approval subprocess. It is initiated when the final grading is completed and the client (homeowner or contractor) submits a copy of the as-built grades certificate to the LG division. Upon receipt of the certificate, LG division personnel again review the submitted document for the aforementioned criteria including: Surface elevations, status of neighboring lots, direction of drainage, surface conditions, and storm sewer connections. Upon completion of the initial final grading certificate assessment, the working file is forwarded to one of the inspectors to conduct a site review. A copy of the inspection report is left on-site for the homeowner. An official approval of LG certification is sent to the homeowner to indicate that they may proceed with landscaping. The LG database and the subdivision site plan are updated, irrespective of the final grade approval. This is done in the same manner as that of the rough grading.

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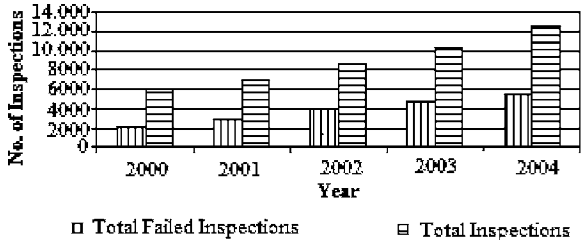

Fig. 6. Total number of failed inspections

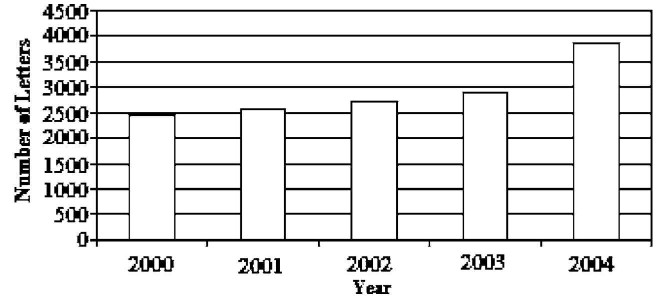

Fig. 8. Number of noncompliance letters issued per year

Data Collection and Analysis

Data analysis of past years' performance shows the large number of rough and final grading inspection failures each year, as shown in Fig. 6. Inspectors frequently reinspect lots due to noncompliance, and the extensive paperwork involved makes the process inefficient and applications difficult to track. The average number of inspections per application is 3.64. Fig. 7 shows the percentage of cases approved in the different numbers of inspections. Fig. 8 shows the number of noncompliance letters issued per year. It is noted that there is steady increase in the number of noncompliance letters issued each year. As is illustrated in Fig. 9, more than 50% of the failure can be attributed to the poorly defined swale and the inadequate grade from the foundation walls. Various factors underlying these failure modes are analyzed and eliminated using the lean tools and other process improvement techniques.

Both rough and final grading inspections also appear to have a high number of failures involving the minimum slope away from the foundation walls. To further investigate the reasons for the inspection failure, 50 cases were taken on the priority bases. Fig. 10 shows the number of inspections performed per case, and the time lag between the application received and the inspection performed. 20 cases were cleared on the first inspection, while 27 cases were cleared on the second inspection. Stakeholders (builders) attributed these failures to the time lag between the submission of the application for inspection and the actual inspection. The city acknowledged the stakeholders' concerns and conducted a pilot study in conjunction with four members of the Edmonton Regional Homebuilders Association. This involved the LG inspectors visiting the site within 1 or 2 days of the initial inspection request. The aim of the pilot study was to evaluate the effect of speedy rough grading inspections on the efficiency of the LG approval process. The pilot project also studied the number of inspections needed for LG approval for participating builders.

The pilot study identified various problems and issues in the LG approval process. One major problem with the current process relates to the large number of inspection failures. This is likely a contributing factor to the large backlog of inspections carried into the coming years. In the peak season, inspectors usually work 10 to 12 h to clear the backlog, which may affect the quality of their work. Anther factor contributing to this inefficiency was the extensive paper-based procedure. There are a number of issues related to the paper-based administrative work including: (1) It is time consuming to update the database; (2) the paper-based search process is inefficient; (3) the only way for customers to check their application status is through a telephone, which generates a large number of phone calls; (4) survey results indicated the presence of a communication gap between the client and the city officials, hence the level of service provided by the LG division did not meet clients' expectations; (5) It is noted that in most cases, inspectors were unable to convey the reason for the failure to the client resulting in additional phone calls for clarification; and (6) This lack of communication also increased the number of failed inspections as clients applied for reinspection without fixing the actual reason for failure.

Application of Lean Principles and Simulation

Lean thinking principles were applied to each process step to identify the value and the nonvalue added activities. As previously mentioned, lean principles address improvements to the entire production system by focusing on reducing waste. As illustrated in Fig. 11, in the application validation subprocess, 50% of the process steps are identified as nonvalue added activities. As shown in Fig. 4, the application validation subprocess has four

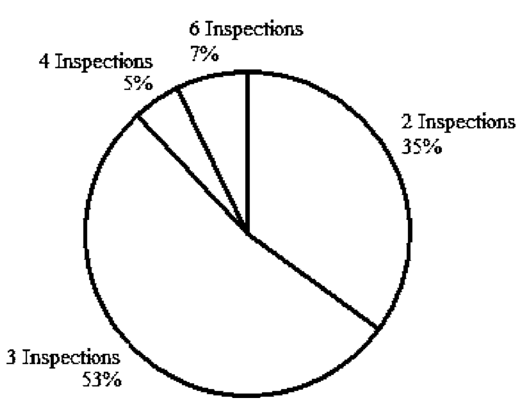

Fig. 7. Inspection based percentage approval

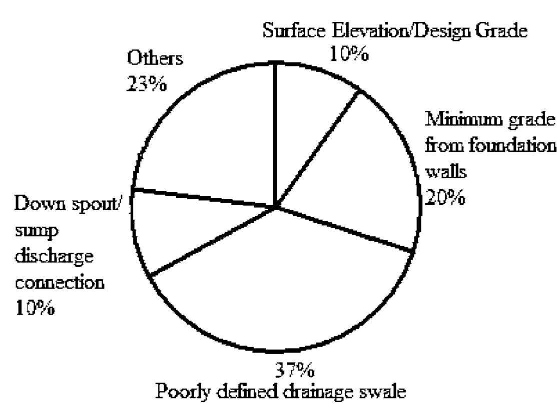

Fig. 9. LG failure distribution according to assessment criterion

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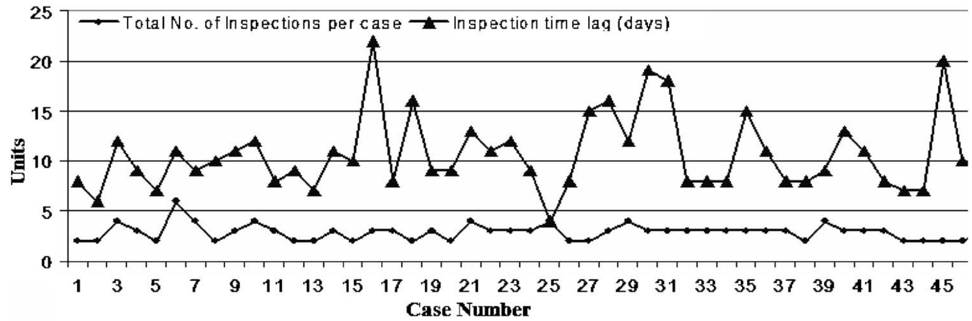

Fig. 10. Inspection time lag (days) per LG approval case

process steps and corresponding outputs. These process steps are represented by the activities numbered 2, 4, 6, and 8; activities numbered 6 and 8 are nonvalue added activities. Process Step No. 6, *creation of new file in the database*, will be automatically performed by the system, once the requisite parameters are in place. Process Step No. 8, *create paper-based file*, will be eliminated through the automation of the system. As demonstrated by the simulation results in the succeeding section, the elimination of these nonvalue added activities reduced required resources by half and increased productivity.

For the rough/final certification subprocess, 42% of the process steps are identified as nonvalue added activities (Fig. 12). Referring to Fig. 5, process Step Nos. 7, 16, and 19 were found to be nonvalue added activities. Process Step No. 7, *creation of final grading inspection report*, can be eliminated through real-time access to the city database. Similarly, process Step Nos. 16 and 19 can be eliminated through the automation of the process.

Various alternatives were generated and, using the simulation model, their impacts were analyzed. Simulated results of the old and the new processes were compared to identify the most appropriate modifications in the process. The following section presents the simulated results of automating the LG approval process. For the simulation purpose, it is assumed that the staff will work for 8 h a day with an efficiency factor of 0.8. The project data for the last 3 years, compiled by the LG division, is used to establish the various simulation input parameters.

Simulation Results: Application Validation

The application subprocess was simulated for 1,000 cycles using SIMPHONY, a simulation software. On a typical day, based on historical data, nearly 60 applications are expected to arrive; nearly 60% of which will be for rough grading approval, and remain for final grading approval. As shown in Table 1, the average processing time to validate each rough grade approval application is 9.63 min, with a resource utilization factor of 62.7%. Similarly, the average processing time for final grade approval application validation is 7.93 min, with a resource utilization factor of 50% (based on one clerk).

The application validation subprocess was modified and simulated, and the results were analyzed. With the modified process in place, process Step Nos. 8 and 9 (see Fig. 4), are eliminated. This will allow the inspectors to reduce the daily paperwork time by 90 min, which can then be used on-site for inspection. In the modified subprocess, it is assumed that only 10% of the applications (certificates) will be paper based. Rough and final grading applications will have the same validation time. In the simulation model of the modified subprocess, two new validation modules are introduced; namely, the paper-based validation process and automated validation process. To decide upon the optimum allocation of resources, various scenarios were analyzed. Allocating one resource each to the paper-based and automated subprocess, it is observed that the resource allocated to the paper-based process is only utilized by 18%. On the other hand, the resource allocated to the automated process is utilized by 66%. Resource utilization suggested that a single resource can be used for both the paper-based and the automated subprocesses, reducing the workforce allocated to the application validation subprocess by 50%.

Table 2 lists the comparative results between the current and modified application validation subprocess. In the current application validation subprocess, the simulation showed that 48 applications were processed using two resources with 56% utilization. In the modified application validation subprocess, 51 applications were processed using one resource with 84% utiliza-

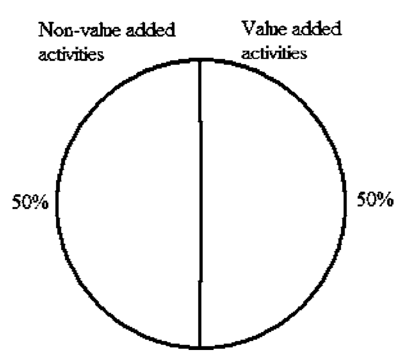

Fig. 11. Percentage of nonvalue added activities in the application validation subprocess

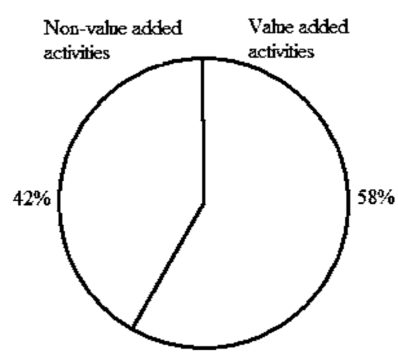

Fig. 12. Percentage of nonvalue added activities in the rough/final grade certification subprocess

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Table 1. Simulation Results for Current Application Validation Subprocess

Results	Rough grade certifications	Final grade certifications
Number of applications received	32	21
Average length of queue	0.627	0.50
Average completion time (min)	9.63	7.93
Resource utilization	62.7%	50%

tion. In the modified subprocess, the average application processing time is reduced to 6.33 min from 8.81 min. Figs. 13 and 14 illustrate the cumulative density function for the rough and final grade certifications, respectively.

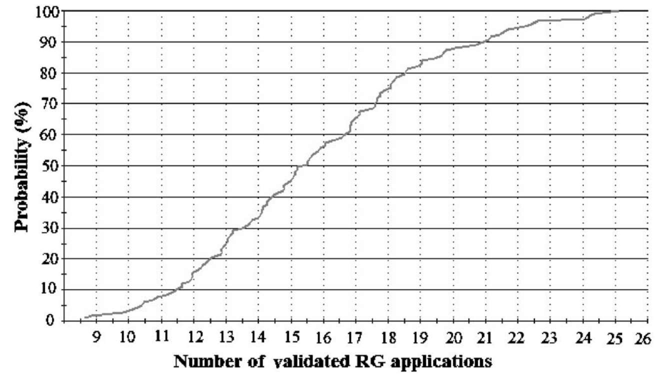

Fig. 13. Cumulative density function for LG certification validation

Simulation Results: Rough/Final Grading Inspection Subprocess

When an inspector visits a site for inspection, he/she may carry out one of both types of inspections. Hence, for the purpose of the simulation, both of the processes are combined. In 2004, the LG division performed nearly 12,704 inspections for rough and final grade approval, with an average of nearly 98 inspections per day. Based on the past trend of an increasing number of applications, it is projected that, in 2006, the total number of applications will be nearly 19,000. One possible solution to handle the increased number of applications and, therefore, inspection visits is to increase the number of inspectors. The effect of an increased number of inspectors on efficiency was studied by changing the resource allocations in the current simulated process, as shown in Fig. 15. Assuming that each inspector spends an average of 4.5 h on site, the simulation showed that in the present scenario of employing five inspectors, they are expected to make a total of 67 visits a day. By increasing the number of the inspectors to seven, the total number of visits per day by all the inspectors increased to 87. Fig. 16 shows the current inspection time for each visit, and the total number of inspections made at a given time of the day based on seven inspectors. Fig. 17 shows the inspection time and the total number of inspections for the modified rough and final grading inspection subprocess, based on the current resources (i.e. five inspectors).

The current process was modified and simulated. Automation is expected to reduce the amount of paperwork performed by the inspectors, thus increasing the number of inspections they are able to perform. It is projected that the automation of the process will save 1.5 h of inspector's time—spent on daily paper work—which can be utilized for site inspections. Also, real-time access to the database will eliminate the need to make an inspection report before going to the site; saving additional time. Referring to Fig. 5, the modified process will eliminate the subprocess (i.e., Step No. 7). Subprocess Step Nos. 16 and 19 will be reallocated to supporting staff. Simulation of the modified process shows that the current team of five inspectors can potentially inspect 139 sites per day as compared to 70 sites per day; nearly doubling the number of inspections per day. Table 3 lists the comparative data for the simulation results. It can be inferred that the automation of the process and the elimination of the nonvalue added activities would double the rough and final grading inspections.

Table 2. Simulation Results for Current and Modified Application Validation Subprocesses

Results	Current application validation subprocess	Modified application validation subprocess
Number of resources	2	1
Number of applications processed	48	51
Average length of queue	0.56	0.59
Average completion time (min)	8.81	6.33
Resource utilization	56%	84%

Implementation of the Automated Modified Process

A modified process was developed and implemented in the LG division, featuring improved workflow and automation compatibility. As shown in Fig. 18, in the current LG process, interaction between the office support staff and site inspectors is solely paper based. In the new automated system (see Fig. 19), the division database is linked to the city database, POSSE (Planning One Stop Service), enabling the division to integrate the LG approval applications with the building permit applications. POSSE is based on the Oracle database that contains information about each lot within the city. To make the process paperless, inspectors are provided with a tablet-personal computer that can be carried on-site. Before going to the site, he/she downloads all jobs and plans in the inspection sequence based on proximity. Inspectors need not carry all the paper-based reports and certificates. They can access the city database on a real-time basis, and download a copy of the LG certificate(s). The inspection reports are filed electronically (see Fig. 20), and all the reports are uploaded instantly

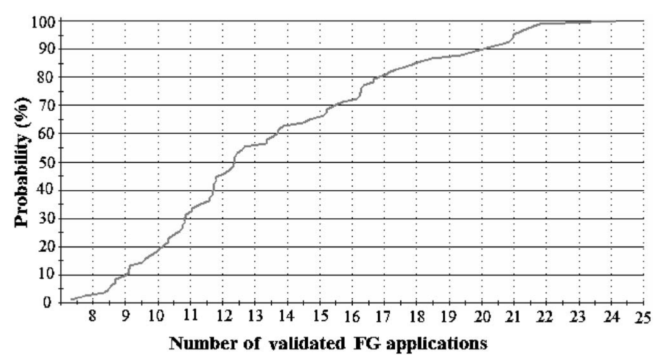

Fig. 14. Cumulative density function for LG certification validation

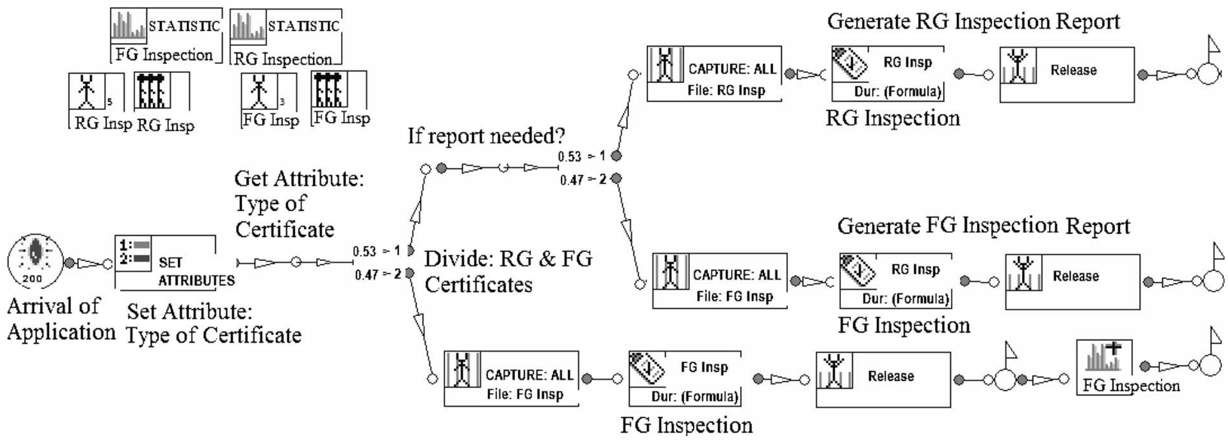

Fig. 15. Simulation model for the rough and final grading inspection subprocess

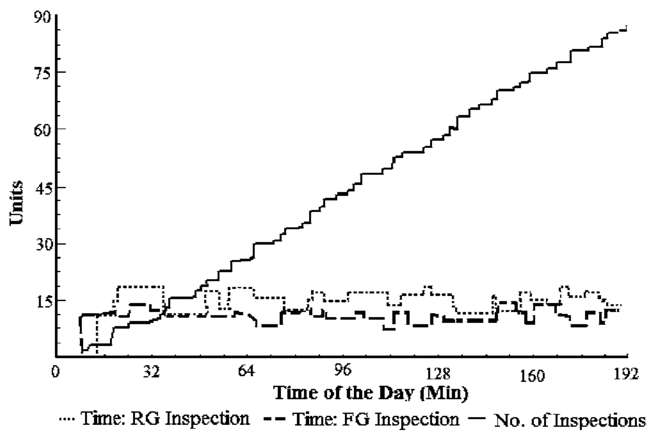

Fig. 16. Inspection time using increased resources (nine inspectors)

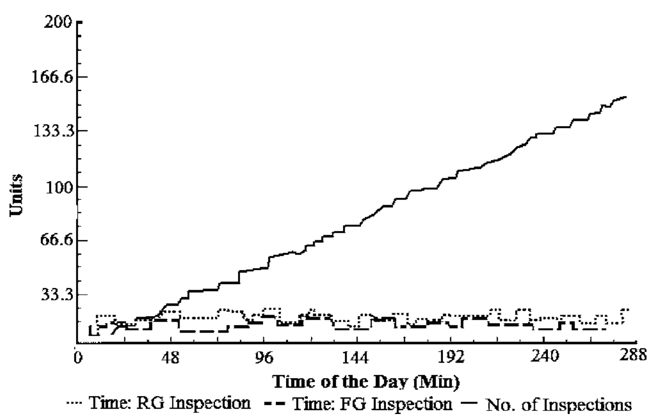

Fig. 17. Inspection time using current resources (five inspectors)

Table 3. Comparative Simulation Results for Rough and Final Grading Inspection Subprocess

	Rough grade inspection		Final grade inspection	
Results	Current process	Modified process	Current process	Modified process
Number of inspections	34	81	36	58
Average length of queue	2.33	3.98	1.96	2.15
Average completion time (min)	12.88	13.77	10.11	10.39
Resource utilization	0.77	0.78	0.981	0.71

online in the POSSE database. The stored procedure in the database allocates the reports to the clerk(s) for printing and mailing/e-mailing to the clients.

By adopting the automated system, the validation time has been significantly reduced. The LG division is connected with the central database system, POSSE, which is maintained by the city. As soon as an applicant applies for the building development permit, a trigger is fired to generate the LG certification application for that particular lot. Based on the parcel number, the system automatically groups the applications under the various city zones. An inspector can log in to the POSSE database system and download the LG jobs assigned for his/her zones. In the new system, the surveyors can e-mail the certificates to the LG division, hence reducing the time spent in the traditional mailing of the paper-based documents. E-mailed documents are uploaded into the central database, and can be downloaded by the inspector on real-time basis.

Conclusion

This paper describes the methodology used to improve the efficiency of the existing LG approval process. Data were collected and analyzed for the existing process to find any inherent deficiencies and problems. A pilot project study was carried out to pinpoint the problem areas and to evaluate the effect of speedy rough grading inspections on LG approval process efficiency. Process flowcharts were developed to represent the existing LG process. These flowcharts were studied to identify the nonvalue added activities. The elimination of nonvalue added activities, coupled with the automated and modified process, has considerably improved the process efficiency and quality. Contemporary decision analysis tools, such as lean thinking and simulation, were used to analyze the existing process, identify the nonvalue added activities, suggest the various scenarios, and choose the best one. Due to the suggested modifications, stakeholder satisfaction has been enhanced resulting in a major reduction in telephone calls. The LG division has been able to cope with the increased demand with the same number of resources. Due to time limitations and limited data availability, only data from the past 4 years is used for the simulation model. This research paves the way for the setting of LG process standards for other municipalities. The baseline performance of the existing process has been documented and can be used to measure future improvement and for the purpose of benchmarking. Further research can be carried out

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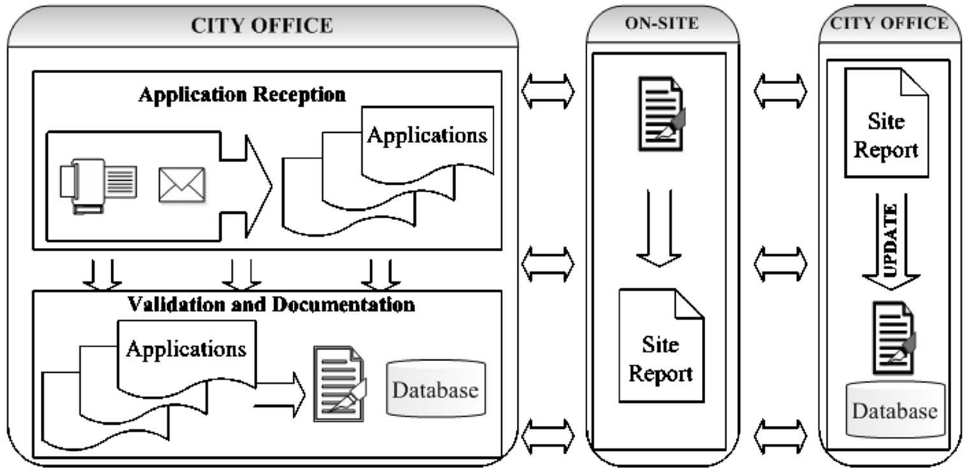

Fig. 18. Schematics of current LG approval process

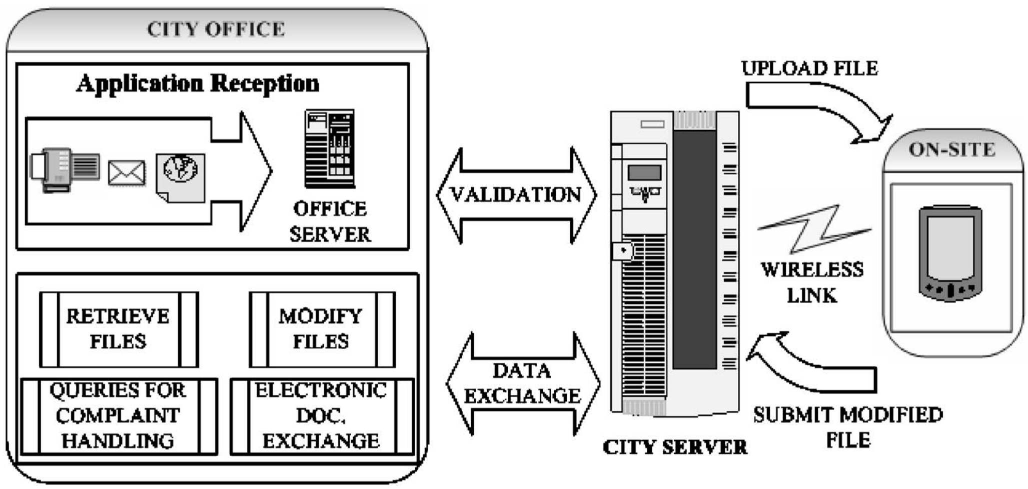

Fig. 19. Schematics of modified LG approval process

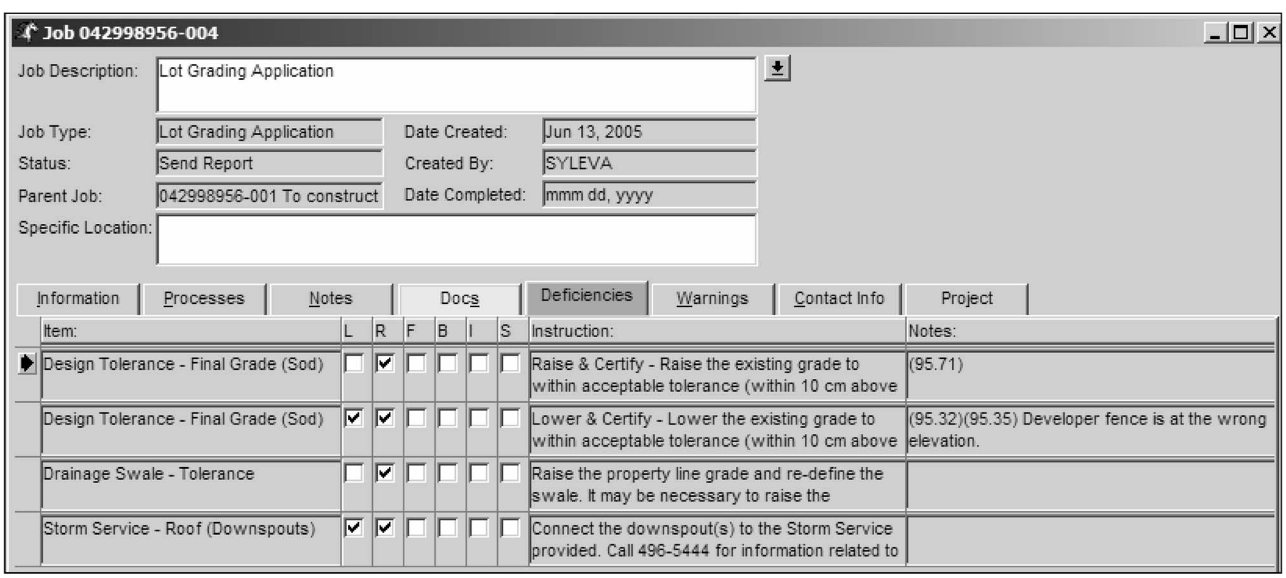

Fig. 20. Screen shot of electronic inspection report

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for the development and integration of three-dimensional illustrations depicting the various failure modes so stakeholders can gain a better understanding of how and why a lot of inspection failed. Customer satisfaction was measured by taking informal feedback from the LG staff and the grading contractors and builders. The engineering challenges were to identify the parameters' contribution to the LG inspection failure and to modify the process; eliminating those failures. The process improvement recommendations have been implemented in the City, resulting in a zero application backlog without increasing the staff strength. The LG staff reported a reduced number of telephone calls related to general queries and complaints. Grading contractors and builders were more satisfied with the quick inspections and approvals.

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