



WPI **BARCLAYS**

Development of an Operational Process for Continuous Delivery

A Major Qualifying Project Report
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Abstract

This project, sponsored by Barclays Bank PLC, focused on improving the continuous deployment process and developing the guideline for onboarding new applications for the Prime Financing group. We identified that Jenkins is the better tool for Prime Financing, and explored and created a few plugins, which could enhance the use of Jenkins and provide management information system details. Our recommendations aim to eliminate manual steps within the continuous delivery process and save time on adopting new applications.

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Executive Summary

The technologies and software development strategies are vital for the competitive nature of most industries and organizations. To deliver new features and get feedback rapidly would increase the reputation of an organization and furthermore lead the company in the specific industry (Kim, 2014). In order to do so, it is essential to release software more often with low risk. To fulfill this demand, the concept of Agile Software Development has been established. From Agile, DevOps, previously known as “Agile Operations” was born. DevOps is the collaboration of development and operation teams throughout all stages of the development lifecycle to ensure code quality and to release software at any given time (Mueller, Wickett, Gaekwad, & Karayanev, 2011). Continuous Integration tools and Continuous Delivery platforms have been created to implement the DevOps initiative.

For Barclays Prime Financing, they have considered several initiatives to adopt an Agile Software Development approach which would be widely pushed within the organization. Even though some teams in Prime Financing are using some forms of Continuous Integration tools or a Continuous Delivery platform, it would be better to standardize the toolset in order to manage related applications. The strengths and weaknesses of each tool were not clear, so it was hard for Prime Financing to choose a tool. They were investigating a better DevOps tool that could be used as a standard tool in their team, and also standardized guideline for onboarding projects to the specific tool.

The goal of our project was to improve automated deployment in the continuous delivery process. Our first objective was to evaluate the advantages and disadvantages of two continuous delivery tools: CA Release Automation and Jenkins Promoted Builds Plugin. We conducted background research to understand concepts within DevOps and their importance. Through

interviewing several experienced employees, we collected the subjective responses regarding the advantages and disadvantages of each tool. We also identified some objective strength and weaknesses via sample implementations for each tool. After that, we did a comparative analysis to reach our conclusion of each tool and provide recommendations. Our second objective was to implement three volunteer applications from Prime Financing, which enabled us to catalog detailed functionalities within the chosen tool. We discovered the missing functionalities of the tool and provided our suggestions to promote the use of the tool. The research and implementations guided us to form a standardized guideline for the onboarding process for applications onto the tool. Our final objective was to generate data reports about the chosen tool's continuous delivery processes. We retrieved raw data from Jenkins and manipulated them in order to show useful information.

We concluded that Jenkins satisfied Barclays Prime Financing's requirements, but the automated deployment of its continuous delivery process can be improved from several aspects. We suggested adopting Jenkins Promoted Builds based on our comparative analysis of Jenkins and CA Release Automation. We developed an easily extensible Jenkins Plugin for automatic Jenkins' configuration with regards to job creation and cleanup from SVN branching. Moreover, we created a management information system plugin that can extract build and promotion information into a SQL database and CSV files, and then import into a reusable Excel template we created to show reports. Our recommendations can help to improve automated deployment of continuous delivery process within Prime Financing group and to generate reports of continuous delivery process.

1.0 Introduction

The technologies and software development strategies play essential roles in many industries and organizations. In order to achieve higher performance in technology, it is necessary to release software more often. To deliver new features and get feedback faster would increase the competitive nature of an organization and furthermore lead the company in the specific industry (Kim, 2014). The concept of Agile Software Development has been established to fulfill this demand, and DevOps developed naturally from the concepts of Agile Software Development. DevOps is the collaboration of development and operation teams throughout all stages of the development lifecycle to ensure code quality and to release software at any given time. Important concepts for Agile and DevOps are Continuous Integration (CI) – the process of continuously merging and “integration” the code base of different developers so as to avoid pain when having to manually combine widely diverging code bases, and the bugs associated with combining changes that haven’t been tested with each other – and Continuous Delivery/Continuous Deployment (CD) – the process of continuously deploying the product to test and “production like” environments (and eventually production environments) and running appropriate tests for all builds. In Continuous Deployment every build that passes tests will be deployed to production, whereas in Continuous Delivery, every build has the potential to be deployed to production, but may only particular chosen builds are actually deployed.

Barclays IB is currently adopting Agile, and as part of that initiative teams are adopting CI/CD practices and automation tools. Already most teams are using CI practices and tools, and have processes to deploy to and test in Quality Assurance (QA) testing environments and “production like” User Acceptance Testing (UAT) environments. However, most teams do not have automated deployment to Production environments, and often the actual deployment process

differs between testing and production environments which risks unknown factors impacting deployment to Production.

For the automated deployment process there are many different products that may be used. Within Barclays Prime Financing two specific tools were identified for evaluation – CA Release Automation (formerly known as Nolio), an automated deployment tool identified by the wider IB organization as recommended, and Jenkins, a primarily continuous integration tool that has extensions that enable automated deployment and managing of a continuous delivery process. The strengths and weaknesses of each tool were not made clear, so it was hard for Prime Financing to choose a tool. Barclays Prime Financing was investigating a better DevOps tool that could be used as a standard tool in their team, and also desired to have a standardized guideline when onboarding projects to the specific tool.

The goal of our project was to standardize the guideline to adopt the selected tool on applications. By conducting research, interviews with experienced employees and comparative analysis, we concluded that adopting the Jenkins Promoted Builds Plugin is the better option for the team, which also takes away many manual steps. Based on our implementations of three volunteer applications, we identified possible improvements to the workflow currently being used. Moreover, we generated data reports on Jenkins Promoted Builds Plugin's continuous deployment processes and managed them to show useful information. Our recommendations can help to improve the automated deployment process of the Jenkins within Prime Financing and to develop the guideline for the group to integrate more candidate applications.

2.0 Background

Nowadays, many more industries rely significantly on technologies and software. For high performing technological organizations, it is vital to release their software more frequently to upgrade new features and receive feedback faster to plan for the next deployment (Kim, 2014). In order to reduce errors and speed up deployments, the concepts of Agile Software Development and DevOps aim to fulfill the technology demands. The major areas to implement in regards to DevOps are Continuous Integration and Continuous Delivery, which allow developers to ensure code quality throughout the software life cycle and release software at anytime. Jenkins is the Continuous Integration tool being used by many IT teams, and CA Release Automation is the Barclays standard Continuous Delivery tool.

2.1 Barclays

Barclays Bank PLC, founded in 1690, is one of the largest multinational banking and financial services companies in the United Kingdom, and its headquarter is in London. Barclays provides different financial services in retail, wholesale, investment banking, wealth management, mortgage lending and credit cards, which all operate in multiple countries across Europe, the Americas, Asia, and Africa. There are four core business sectors of Barclays: Personal & Corporate (Personal Banking, Corporate Banking, Wealth & Investment Management), Barclaycard, Investment Banking and Africa. Barclays has a primary listing on the London Stock Exchange and a secondary listing on the New York Stock Exchange. At the end of 2011, Barclays' assets achieved US\$2.42 trillion, and it ranked the seventh-largest bank worldwide.

Their purpose is “helping people achieve their ambitions – in the right way”, and their values are “respect, integrity, service, excellence and stewardship” (Barclays, 2015). Their purpose and values guide them on how to measure and reward people, “not just on commercial results, but on how they live our Values and bring them to life every day.”

As for Barclays in New York, during the 2008 financial crisis, Barclays announced its agreement to purchase the investment banking and trading divisions of Lehman Brothers. In the end, Barclays PLC paid US\$1.35 billion to acquire the core business of Lehman Brothers, including Lehman's US\$960 million midtown Manhattan office skyscraper and the responsibility for 9,000 former employees.

2.2 Agile Software Development

Agile software development is a set of software development methods based on iterative and incremental development, through software developer self-organizing, cross-functional team communication and collaboration to complete the development work (Highsmith, 2002).

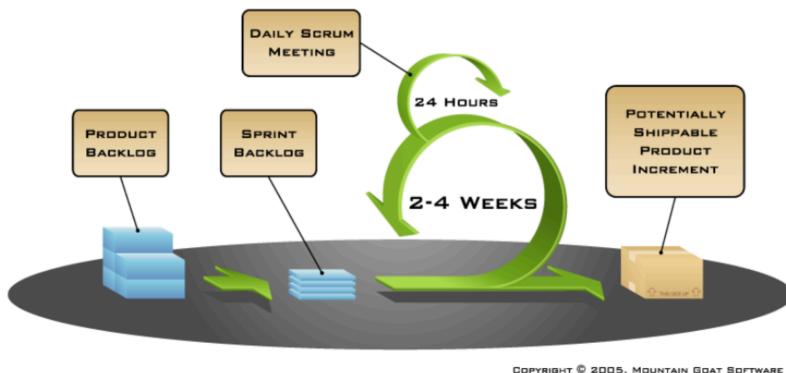


Figure 2.1: Process of Agile Software Development (Mountain_Goat_Software, 2005)

Software development teams normally set two to four weeks per iteration, as seen in Figure 2.1(Mountain_Goat_Software, 2015). They usually have daily scrum meetings, which are basically standup meetings, to ensure they are on the same page in order to continuously make progress.

Agile methods sometimes are misunderstood as unplanned and undisciplined approaches. As a matter of fact, agile methods emphasize adaptability rather than predictability (Cohen, Lindvall, & Costa, 2003). An adaptive approach focuses on quickly adapting to changing realities. When the requirements of a project change, the adaptive team should change as well. However, it might be difficult for the team to predict what would happen in the future.

Agile development, a new development model to avoid the shortcomings of the traditional waterfall model, emphasizes on delivering features as soon as possible and doing continuous improvements and enhancements throughout the project cycle, which helps the team continuously adapt its plans so as to maximize the value it delivers (Highsmith & Cockburn, 2002).

Compared to iterative and incremental development methods, agile methods put more emphasis on high collaboration of the team, which in turn can create a shorter development cycle. Both software development methods emphasize shipping software in a relatively short cycle.

2.2.1 The Agile Manifesto

We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value (Beck et al., 2001)¹:

Individuals and interactions over Processes and tools

Working software over Comprehensive documentation

Customer collaboration over Contract negotiation

Responding to change over following a plan

That is, while there is value in the items on the right, we value the items on the left more.

2.2.2 Twelve Principles of Agile Software

The following are principles behind the Agile Manifesto (Beck et al., 2001):

Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.

Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.

¹ Kent Beck, James Grenning, Robert C. Martin, Mike Beedle, Jim Highsmith, Steve Mellor, Arie van Bennekum, Andrew Hunt , Ken Schwaber, Alistair Cockburn, Ron Jeffries, Jeff Sutherland, Ward Cunningham, Jon Kern, Dave Thomas, Martin Fowler, Brian Marick © 2001, the above authors. This declaration may be freely copied in any form, but only in its entirety through this notice.

Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.

Business people and developers must work together daily throughout the project.

Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done.

The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.

Working software is the primary measure of progress.

Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.

Continuous attention to technical excellence and good design enhances agility.

Simplicity--the art of maximizing the amount of work not done--is essential.

The best architectures, requirements, and designs emerge from self-organizing teams.

At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly.

2.3 DevOps

DevOps is a software development ideology concentrated on communication, collaboration and integration among software development, technology operations and quality assurance (Mueller et al., 2011). Since the software industry has recognized the necessity to integrate

developers and operations engineers in the entire service life cycle, from design to production as seen in figure 2.2, DevOps is aimed at helping organizations rapidly enhance software products and services.

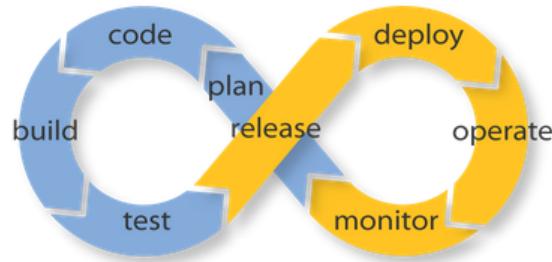


Figure 2.2: The Ideology of DevOps

Generally, releasing an application is risky and relates to multiple development teams. However, in an organization that uses DevOps tools, the risk of application release decreases significantly for the following reasons (InfoQ, 2014):

1. Reducing the scope of change

Compared to the traditional waterfall development model, using agile or iterative development means more frequent releases and each release contains fewer changes. Thanks to the high frequency of deployment, each single deployment would not have a huge impact on the production system. As a result, the application will grow smoothly.

2. Strengthen the coordination of release

It is good to have a strong coordination to bridge skills and communication gaps between development and operation teams; one must ensure all responsible personnel understand the content changes and cooperate well through electronic data sheets, teleconferencing, instant messaging, enterprise portals (wiki, SharePoint) and other collaboration tools

3. Automation

Powerful automated deployment tools ensure the repeatability of task and reduce the possibility of deployment errors. This process takes away the tremendous time and effort required for manual deployment.

2.3.1 Comparison of Traditional IT and DevOps Oriented Team

To understand the differences between traditional IT and DevOps oriented team, it would be essential to instill a DevOps oriented culture within an organization (Logan, 2014). The author of the Article “Fresh Stats Comparing Traditional IT and DevOps Oriented Productivity” surveyed 620 engineers to accomplish this comparison. The survey asked the time spent on improving infrastructure, setting up automation for repeatable tasks, fighting fires, communication and so on, the results of which are shown in figure 2.3.

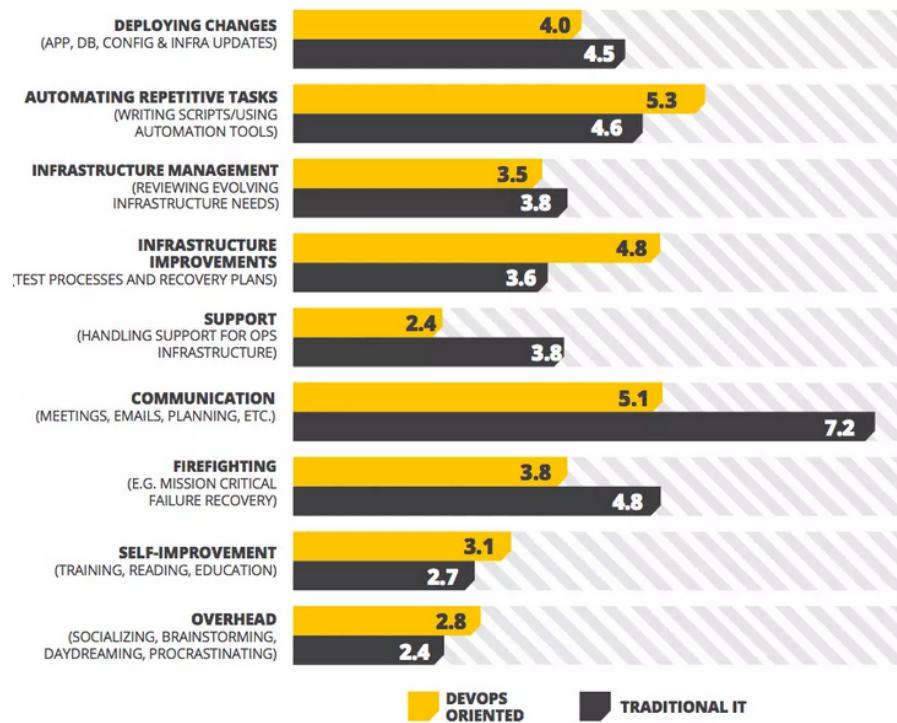


Figure 2.3: Hours spent each week carrying out key activities (Logan, 2014)
This resulted in several conclusions as follows (Logan, 2014):

- DevOps oriented teams spend slightly more time automating tasks
- Both traditional IT and DevOps oriented teams communicate actively

- DevOps oriented teams fight fires less frequently
- DevOps oriented team spend less time on administrative support
- DevOps oriented teams work fewer days after-hours

2.4 Continuous Integration

Continuous Integration (CI) is a software engineering practice, used by many software development teams, to ensure code quality throughout the software build life cycle. The practice was first named and proposed in 1991 by Grady Booch and was adopted by Extreme Programming (XP), a type of Agile Software Development (Wikipedia, 2015b). The practice was suggested to avoid large integration issues that arise when integrating large sets of changes with each other. In XP as well CI was intended to be used along with automated unit tests, which should be designed to ensure functionality. The major role of CI is to control and react to problems immediately. It is a practice designed to ease and stabilize software development processes.

CI would bring the following benefits (Martin, 2006):

1. Software Build Automation: Once a configuration is completed, a CI system can build the target software in accordance with a pre-established schedule.
2. Sustainable Automated Inspection: A CI system can continuously obtain added or modified source code. When the software development teams need to periodically check added or modified code, the CI system can check whether the added code could destroy the original software build.
3. Sustainable Automated Testing: Once the code is built, pre-established tests would run, and the CI system would automatically trigger real time notifications via RSS, Email or Instant Messaging to appropriate developers.
4. Automated Follow-up Processes: After the automated inspection and tests complete, there may be some additional required tasks in the software build cycle, including generated

documents, packaged software, and deployed components, in order to improve the speed of release for project.

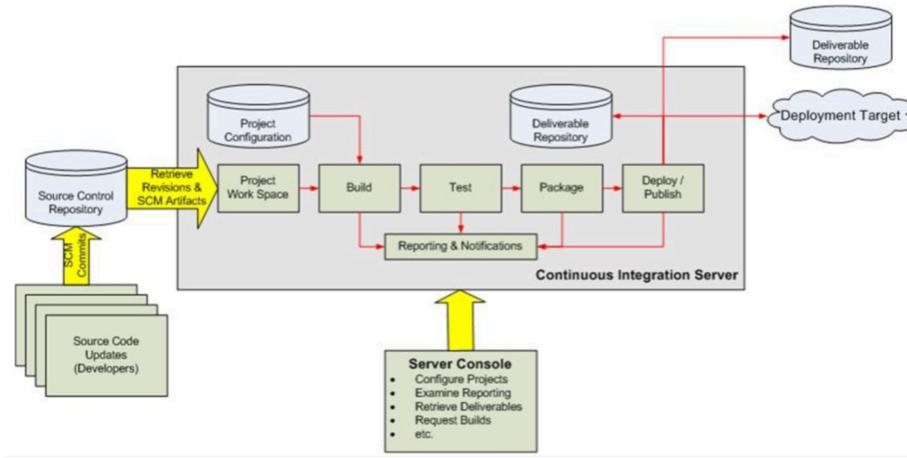


Figure 2.4: Basic Structure of CI System (Trimios, 2012)

The figure 2.4 shows the workflow of a CI system, which would react and reflect the build problem or integration problem. The main role of the CI system in the whole development process is control: when the system detects a change in the code repository, it will entrust the task of running build to the build process itself. If the build fails, the CI system will notify the relevant personnel, then continue to monitor the repository. While it seems passive, the CI system does reveal problems immediately.

2.5 Continuous Delivery

Continuous Delivery (MacDonald, 2005) is a software engineering approach for automating software release at any time. CD is an extension of CI; it uses the concepts and frameworks of CI, unit testing, and acceptance testing to streamline software delivery (Wikipedia, 2015a). CD is an important part of the DevOps ideology. In CD code is compiled and tested every time it is changed, and is frequently deployed to test environments and run through automated acceptance tests. Moreover, code may pass through manual acceptance tests as well. Only code that passes all

automated and manual tests/approvals is marked as “releasable,” ensuring that even though the system automates much of the process, code is only “released” once it is ensured to be valid.

Continuous Delivery allows anyone to receive fast, automated feedback regarding any changes made to their code, and furthermore people can perform push-button deployments of any version to any environment (Farcic, 2014).

2.6 Automated Deployment

Automated deployment means automatically deploying every change to production, and the main concept of automated deployment is deployment automation (Smith, 2015). Deployment automation is a solution to deliver applications faster and more efficiently (XebiaLabs, 2015). Even though there are some difficulties in implementing the fully automated deployment process, such as the overhead of creating, setting up, configuring and maintaining an automated deployment mechanism, the benefits of using automated deployment are significant in comparison to the difficulties.

Automated deployments make the application deployment processes become much less error-prone and much more repeatable, which eliminates manual steps and avoids delivering incorrect versions (XebiaLabs, 2015). Once the automated deployment process is set, if it works the first time, it will work many more times afterwards. The knowledge of the automated deployment process is captured in the system, independent from an individual, and thus anyone in the team can deploy software. Furthermore, rather than spending time on performing and validating manual deployments, the software development teams can spend their time on developing the next set of quality features and enhancements to the software. The target environments and machines can be changed easily, which simply requires configuring the existing setup and then relying on the new release automation. The system allows frequent releases in order to ship valuable features to users more often and to get continuous feedback to enhance the software.

2.7 CA Release Automation/Nolio

CA Release Automation, formerly known as Nolio, is an enterprise-class, multi-release, continuous delivery solution which automates complex release deployments (CA_Technologies, 2015b). This software is aimed to ease and streamline the deployment process.

CA Release Automation enables to design, manage, and automate application-centric operations across physical, virtual, and cloud environments. It can speed up application release cycles, reduce errors, and achieve higher quality releases. The software also can create more frequent releases, reduce costs and promote collaboration and alignment between developers and operation engineers.

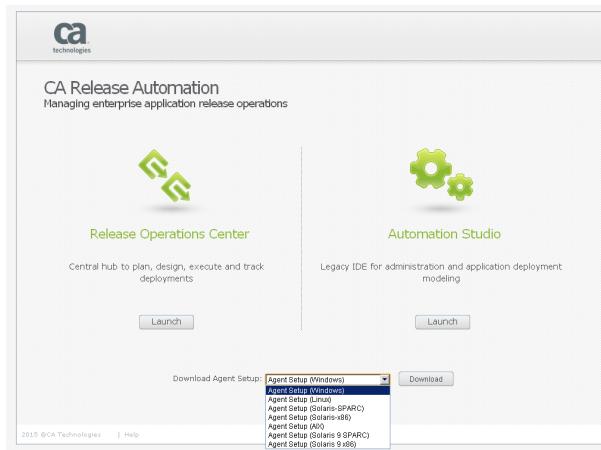


Figure 2.5: Launch user interface of CA Release Automation

In regards to the User Interface for every CA Release Automation system, there are two parts in the launch interface as shown in figure 2.5: Release Operations Center (ROC) and Automation Studios. ROC is a web application for creating release flows and managing their execution in terms of the operational functionality, which is organized into tabs in the dashboard, as seen in figure 2.6. Automation Studio is a legacy client that provides some administrative features, such as administrative tasks, export and import functions, and process scheduling and notification settings. ROC is the main area for most development and operation teams.

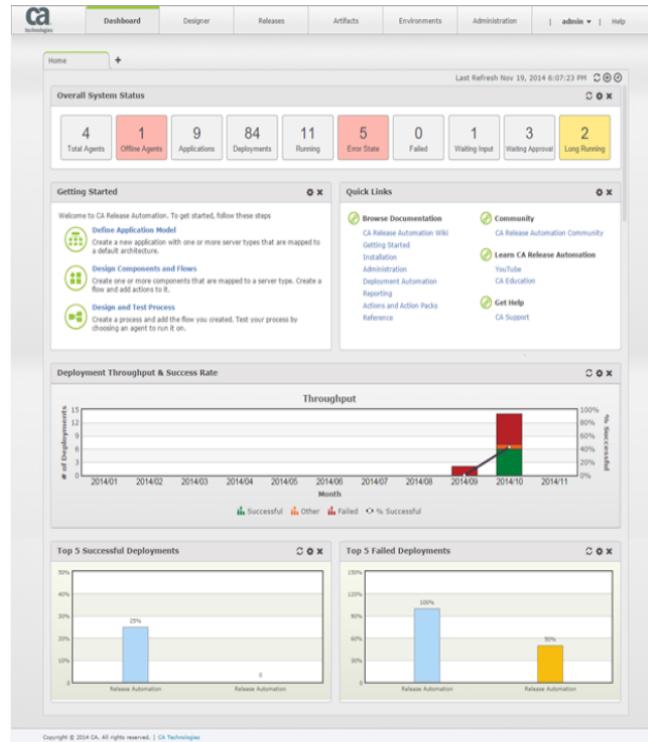


Figure 2.6: Example dashboard of CA Release Automation's ROC

The typical and simplified scenario of deploying an application and promoting that application from integration testing through to production is in figure 2.7.

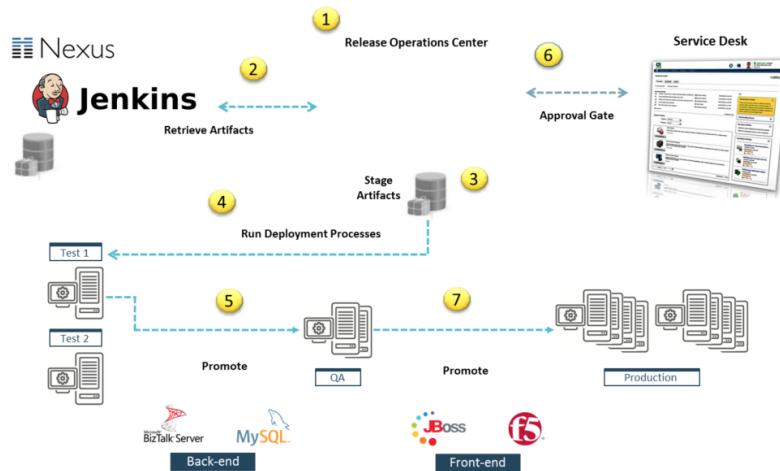


Figure 2.7: scenario of deploying and promoting an application (CA_Technologies, 2015a)

1. Create the release using the ROC.
2. Retrieve the specific artifacts (application files and content) from the repositories.

3. Next, stage the artifacts.
4. The next step runs the deployment, which could have a variety of steps. Here it does a pre-deployment verification and configures a load balancer. It then deploys the application and database and then does some post-deployment verification.
5. If everything was successful, the same deployment can be used (with different environment and release data) to promote the application to the next stage.
6. Prior to the deployment to production, the deployment can go through an approval process with integration to a service desk.
7. If the approval process passes, the deployment is then promoted to production.

Throughout the process above, it shows how to link a repeatable continuous delivery process.

In general, CA Release Automation enables IT operations to centrally manage, automate and control application service operations over a data center, as well as standardize application service operation and application workflows. More terminologies about CA Release Automation are in Appendix A.

2.8 Jenkins

Jenkins is an open source continuous integration tool with an active community and a rich ecosystem of extensions (Kawaguchi & Hayes, 2015). Jenkins is written in Java and works on most operating systems. It is also the world's most popular open source continuous integration software, which is being used in more than 65,000 sites worldwide.

Two critical features of Jenkins are monitoring the software development process and building and testing software projects continuously, which help users to obtain the newest build and code quality (Kawaguchi, 2015).

Jenkins provides functionality to run jobs - predefined tasks - on certain circumstances, such as an update to a source control repository, running a task in a set interval of time, or after a

manual request to run a job (Kawaguchi, 2015). Jobs are versatile as they can be custom defined to do anything - build code, run unit tests, check code quality, deploy code to a server environment, ping a web server, etc. Jenkins provides functionality through its core product and plugin extensions for running unit tests on a source control repository following the practices of CI. It could test integration of development and mainline branches before they are merged in. During testing, it can identify issues ahead of time, automatically run quality assurance, deploy software, create processes to require manual approval, and test to proceed in a step in the deployment pipeline. More Jenkins terminologies are in Appendix A, and the instruction on how to use Jenkins Plugin is in Appendix B.

2.8.1 Jenkins Promoted Builds

Jenkins Promoted Builds Plugin, as shown in figure 2.8, provides a framework for manual approval within the CD pipeline.

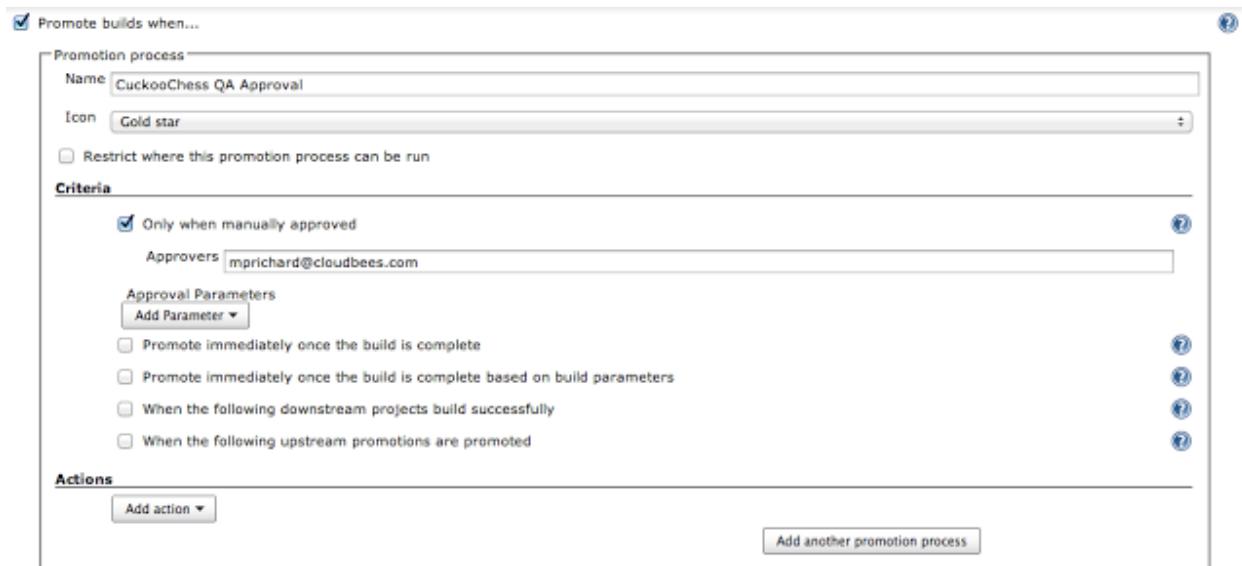


Figure 2.8: Jenkins Promoted Builds Plugin (Inman, 2012)

The plugin creates a User Interface (UI) where automated processes can be run depending on certain circumstances. For example, a build could be automatically deployed to an automated acceptance-testing environment, or it could wait for manual approval to be deployed to a QA testing environment. A final step could also be added to automate deployment to production systems once

all other steps have been completed. Jenkins with this Promoted Builds Plugins is another continuous deployment option besides CA Release Automation.

3.0 Methodology

The goal of this project is to improve automated deployment in the continuous delivery process. Our measurable objectives were:

1. Evaluated advantages and disadvantages of the firm standard tool (CA Release Automation) and the tool used in Prime Financing (Jenkins)
2. Investigated workflow improvements of the chosen tool
3. Generated data reports about continuous deployment processes of the chosen tool

We used online research, case studies, interviews, and sample implementations to achieve our objectives, which we discuss in detail in this chapter.

3.1 Evaluated advantages and disadvantages of two different continuous delivery tools

The first phase of our project was to compare the two tools to decide the proper one to use when implementing applications. We did research online to study the related terminologies, such as Agile Software Development, DevOps, Continuous Integration, and Continuous Delivery. We also did research of each tool and cataloged features of both tools, Jenkins and CA Release Automation. Moreover, to understand detailed information concerning implementation, we did case studies via implementing test applications into the two tools. In order to better understand the two tools, we interviewed several experienced employees in both Jenkins and CA Release Automation. The team determined the advantages and disadvantages of each tool and compared feature by feature to reach a conclusion.

3.2 Investigated Workflow Improvements

Once we had decided to recommend Jenkins with the Promoted Builds Plugin for the Prime Financing group we investigated possible workflow improvements. We investigated plugins recommended for usage in a continuous delivery with automated deployment environment, and compared the different recommended plugins in both their feature set and compatibility with Prime Financing's workflow. As well, we investigated the possibilities for automating Jenkins configuration, and created a proof of concept for managing configuration through Job DSL, and through Jenkins' scripting, and finally created a Jenkins plugin to automate the process of creating and pruning per-release branch jobs. We also explored functionalities of three volunteer applications to identify core strategies of onboarding the applications to the tool.

3.3 Generated data reports about continuous delivery processes

In order to provide a better way to evaluate continuous deployment processes, we developed a process to extract raw data from Jenkins. This raw data, which includes useful statistics such as number of successful/failed builds and promotions, can be saved into a SQL database or CSV file and then managed in Excel. We used the pivot table functionality in Excel to filter and manage data, and created a reusable template. To develop the process for extracting data we first created a rapid proof-of-concept using Jenkins' groovy scripting capabilities and by reading the relevant documentation for identifying the location of the data. By doing so we were able to rapidly identify and test a process for extracting data, and to agree upon a common data format such that the finalized extraction plugin and the reporting excel template could be developed in parallel. Produced were a Jenkins plugin and an Excel reporting template.

3.4 Summary

The methods described above were to fulfill our project goal: to improve automated deployment in the continuous delivery process. The background research helped us to understand

the overall concepts within DevOps and their importance. The experienced employees' interviews provided us subjective responses on the advantages and disadvantages of each tool. We identified some objective strength and weaknesses via sample implementations for each tool, and compared with the information provided by experienced people. The investigations on workflow of automated deployment improves the continuous delivery process our sponsor, Prime Financing, to adopt the chosen tool on their existing application. In order to generate data reports about the continuous deployment processes, we extracted and managed useful statistics to evaluate overall processes.

4.0 Results and Analysis

In this chapter, we discuss our results and analysis on background research, comparative analysis, and implementations. We evaluated the advantages and disadvantages of both CA Release Automation, also known as Nolio, and Jenkins Plugin, determined the better tools for Prime Financing group, and improved workflows of automated deployment within Prime Financing's Jenkins. Based on our research and practices, we successfully achieved our goal to improve automated deployment in the continuous delivery process for our sponsor, Barclays.

4.1 Comparing Tools

To compare Nolio and the Jenkins plugin, we studied extensive online research, both through publicly available resources and Barclays' internal resources, and interviewed several experienced employees regarding each tool.

4.1.1 Investment Bank (IB) Standard Tool and Control Objective

In order to better adopt the DevOps initiative in Barclays, there is a list of IB standard development tools for each DevOps category, such as Continuous Integration and Continuous Deployment. Each approved tool has a different level of Barclays's internal support. In regards to the standard tool for Continuous Deployment, Nolio is the only listed approved tool. The figure 4.1 shows other approved tools for the DevOps initiative within IB.

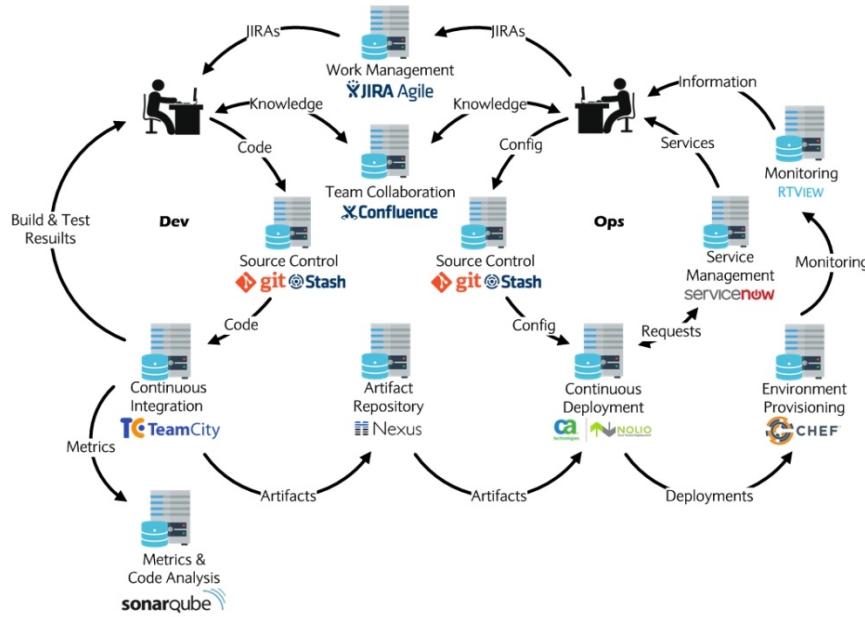


Figure 4.1: The DevOps process with approved tools
 Barclays has set up what are called “control objectives” which are mandatory or optional criteria during an application’s development cycle. One specific mandatory control objective pertaining to Continuous Deployment states that “no change can be made to any technology configuration item without appropriate authorization.” Fortunately, both Nolio and the Jenkins plugin satisfy this control objective.

4.1.2 Level of Support

For Nolio, there is a comprehensive amount of support available within Barclays. There is a designated Nolio support team in Barclays providing approximately 400 pages of support documentation as well as email, chat client, and telephone support. The most useful document, “my first Nolio application,” provides a tutorial on how to implement a “hello world”-esque application into Nolio.

In regards to Jenkins, since Jenkins and the various plugins are open-source, it is easy to retrieve many available resources online to get help. While there is no internal Barclays support for Jenkins, many employees have basic understandings of the tool.

4.1.3 Onboarding Intuitiveness

The Barclays-supported Nolio requires an extensive onboarding process which involves submitting a support ticket onboarding request, requesting to create the Nolio project groups and then following a long detailed process to onboard an application. Through interviews, especially with employees of the support team, we received information that the approximate time to onboard a new application is a week or two. The major reason for the lengthy onboarding time is because of waiting for approvals or assistance from Barclays' Nolio support team.

One example team that we interviewed said that they started to onboard their applications in May 2015 and even today are still working on the Nolio implementation. The team mentioned that the complexity and heavyweight nature of Nolio is part of the reason for the long implementation time. On the other hand, there is a separate team who praised the support of the Barclays's Nolio support team when onboarding their specific applications.

As for onboarding Jenkins, it is easier. If a project team wishes to onboard with the Jenkins Promoted Builds Plugin managed by the Prime Financing team, the project team simply has to fill out a detailed questionnaire, written up by Prime Financing, which asks for most of the necessary configuration information. Then the project team would have to supply appropriate deployment scripts so that the deployments can actually run. In general, the time spent in the onboarding process for Jenkins and the plugin is about only a few hours.

4.1.4 Deployment Process

Nolio and Jenkins plugin are two almost entirely different ecosystems. The main purpose of Nolio is to do deployments via drag-and-drop actions and flows on its web dashboard, which is on the left of figure 4.2. This offers flexibility and robustness for different types of projects, whereas the Jenkins Promoted Builds Plugin handles deployments through approval gates and the deployment scripts written by the application team. As the right of figure 4.2 shows, the main

deployment procedure in the Jenkins plugin is shell scripting, and the complexity level depends on the user's need.

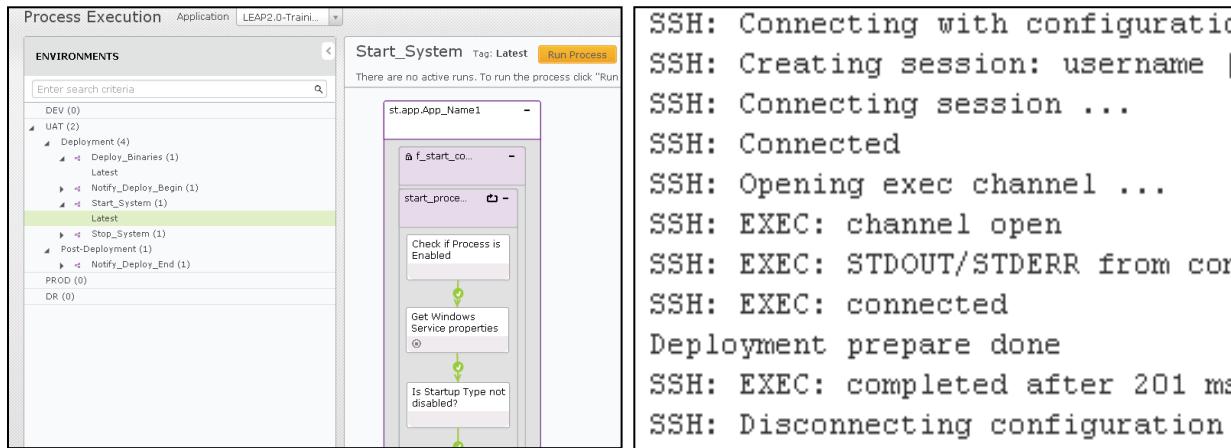


Figure 4.2: (Left) Drag-and-drop actions and flows (Right) Example shell script log

4.1.5 Sample Implementation

On the Nolio front, we followed the tutorial supplied by Barclays's Nolio support team to have a better understanding of the Nolio architecture. However, it was a long and arduous process. Appendix C shows a summarized step-by-step procedure of what the tutorial was asking and how to accomplish a deployment. As for Jenkins, the sample implementation is intuitive. The majority of investigation and results are on the plugins, as seen in section 4.2.

4.2 Improving Workflows

Besides basic functionalities of Jenkins itself, there are various plugins that are able to enhance the use of Jenkins. According to the requirements of Prime Financing group, our team explored some useful plugins within Jenkins in order to fulfill their demands. The major part was to enhance automated onboarding and deployment process.

4.2.1 Automatic Deployment Workflow

Jenkins can be used to build a continuous delivery or deployment pipeline out-of-the-box.

There are numerous plugins that add additional features such as manual approval gates, visual overviews, and custom permissions, to allow users to better fine tune and fit the automated deployment set up to their needs. The plugins evaluated were Promoted Builds Plugin, Build Pipeline Plugin and Delivery Pipeline Plugin.

Promoted Builds Plugin introduces the concept of “promotions”, which have prerequisites and resulting actions to allow fine tuned control over triggering actions related to an individual build in Jenkins. Build Pipeline Plugin is an overview of the promotions, which provides an overview based on built in job relations, as well as providing a new type of relation – a “manual” build step. Delivery Pipeline Plugin also provides an overview based on built-in job relations, as well as supporting the manual steps of the Build Pipeline Plugin and the promotions of the Promoted Builds Plugin.

We evaluated the provided functionality of the plugin, including support for “fan-out-fan-in,” manual approvals, and allowing for specifying build parameters; the look and usability of the overview; and the complexity of setup.

4.2.1.1 Promoted Builds Plugin

The Promoted Builds Plugin provides the ability to mark certain builds of a job as “promoted” if the build has fulfilled a certain criteria, as well as to trigger certain actions upon promotion (Kawaguchi & Hayes, 2015). This plugin extends the functionality of Jenkins to allow triggering of downstream jobs on more criteria than just if the build passed or failed. It also allows requiring multiple previous or triggered jobs to complete successfully, manual approval from a specific set of approvers, and other promotions for the job that have already occurred, in order to allow one to enforce an order of promotion. Moreover, the plugin allows for specifying build

parameters for triggered jobs and allowing a manual approver to provide needed details for a deployment, such as a service desk ticket number or deployment credentials.

The plugin displays the promotion status of every build directly on the job and build pages, as shown in figure 4.3.

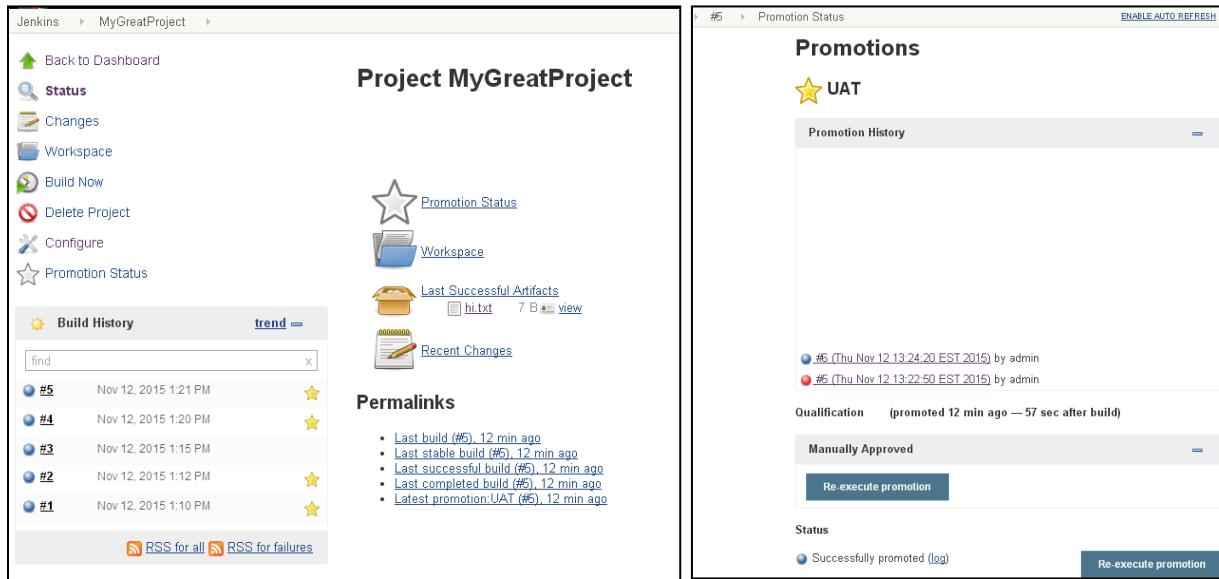


Figure 4.3: Job Page (Left) and Build Page (Right) of Promoted Builds Plugin

Setting up these promotions is quick, as simple as setting up automatic triggers built into Jenkins. However, the plugin does not show the upstream/downstream relationships between jobs, so it can be difficult to see what jobs exactly are triggered and in what order of jobs are related to a promotion. Ordinarily one would have to click through many pages concerning builds and promotions to understand the upstream and downstream relationships. Additionally, while the plugin can require one promotion be completed successfully before another one, one can “approve” a promotion at any time accidentally. However, it cannot disapprove a promotion even if it hasn’t occurred yet, which may result in two sequential manual promotions occurring immediately after one another because of the second out-of-order accidental approval. If, for example, the first promotion was to deploy to a manual QA environment and the second a deployment to a beta/UAT environment, this would not be ideal.

4.2.1.2 Build Pipeline Plugin

The build pipeline plugin provides an overview of a continuous deployment “pipeline” based on an initial “seed” build. The pipeline displays all related downstream jobs triggered by it and their status. The plugin also provides a new type of trigger/relationship to allow manual approving for triggering a downstream job, similar to the Promoted Builds Plugin. However it does not allow for more sophisticated approval requirements, such as restricting who can approve the build, or requiring that multiple upstream jobs have completed successfully before a job is triggered. Furthermore, one cannot supply manual parameters for a manual build; such parameters must be provided at the start of the build cycle, which is not feasible in many cases when builds are deployed several days or weeks later.

The pipeline UI, in figure 4.4, itself is rather difficult to use and look at, and does not integrate well with the Jenkins UI.



Figure 4.4: Pipeline UI of Build Pipeline Plugin

4.2.1.3 Delivery Pipeline Plugin

Delivery Pipeline Plugin fulfills a similar purpose to Build Pipeline Plugin, however with a better UI execution, as in figure 4.5. Similarly to the Build Pipeline Plugin, the Delivery Pipeline Plugin shows an overview based on job upstream/downstream relationships. Additionally, it allows for grouping of related processes in “stages.” It can use the Build Pipeline Plugin manual build relationship to allow for manual builds. Like the Build Pipeline Plugin, you cannot specify parameters for a manually approved build.

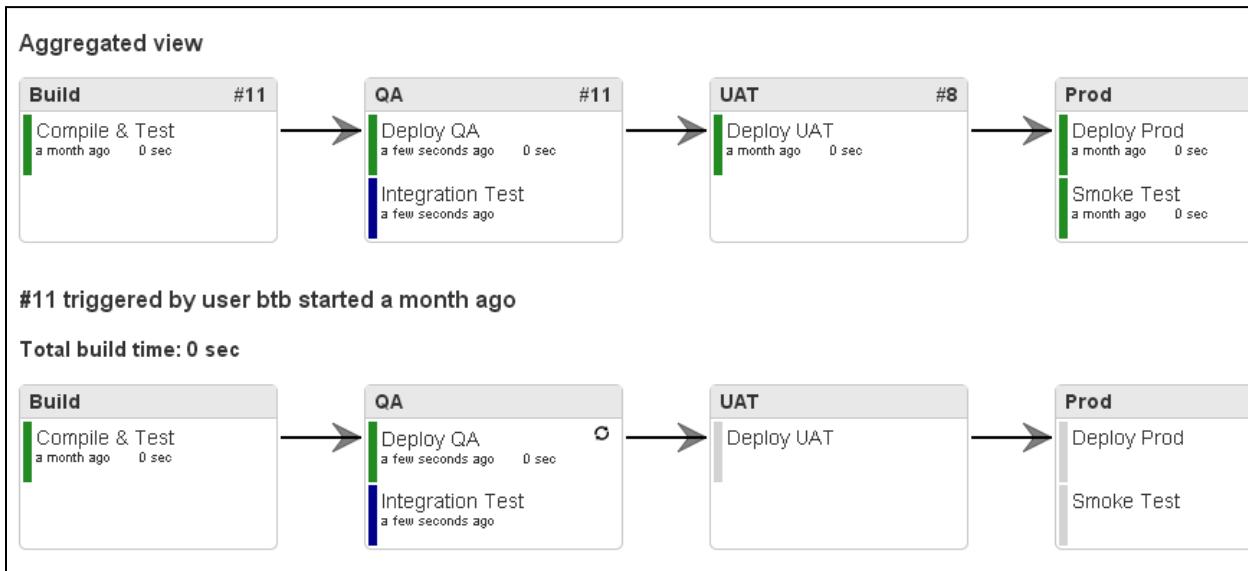


Figure 4.5: Pipeline UI of Delivery Pipeline Plugin

It is also compatible with the Promoted Builds Plugin; however support seems to not be perfect, as multiple promotions on the same build will show as parallel processes, even if the promotions are sequential as seen in figure 4.6. Also, while promotions can be shown on the pipeline page, you cannot promote a build directly from the page.

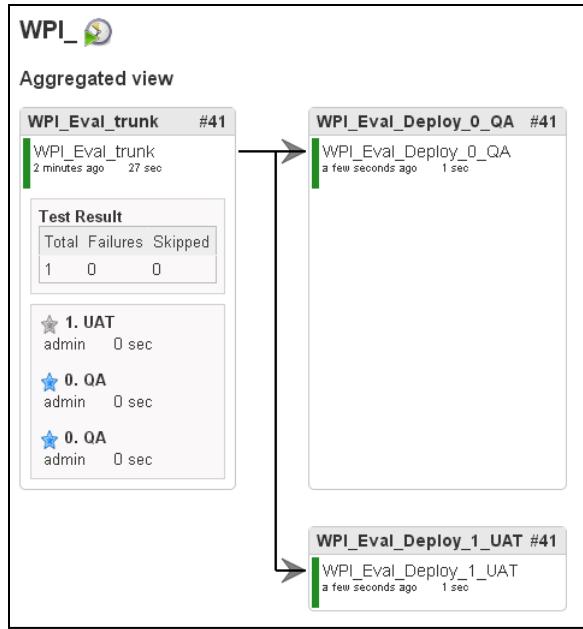


Figure 4.6: Multiple promotions on the same build

The Delivery Pipeline Plugin shows promise for showing a comprehensive overhead view of the jobs related to an initial seed build, and when used with the Promoted Builds Plugin can satisfy the requirements of allowing restricted manual deployment with specified parameters. However, its integration with the Promoted Builds Plugins is lacking. The community in Jenkins and the Delivery Pipeline Plugin has expressed interest in proper integration with the Promoted Builds Plugin, and it is possible that in the soon future there will be full integration. Even without perfect integration the Delivery Pipeline Plugin provides a useful overview to see the status of builds, especially as velocity increases or as more automated test steps are added, such as automated integration tests in QA, or automated assurances in Production. The Promoted Builds Plugin provides all the necessary manual approval requirements and parameters, and the per-promotion overview on the builds page provides sufficient overview for many cases.

4.2.2 Automating Jenkins Configuration

Groovy is a scripting language based on top of Java that runs in the Java JVM, and it can leverage and extend existing Java APIs in a loosely typed, dynamic language. Jenkins is largely based

on groovy and allows for extensions based in this scripting language. Moreover, Jenkins has multiple plugins that allow for executing scripts that can interact with Jenkins' internal APIs to manage job creation and Jenkins management. Additionally, there is a plugin that defines a Domain Specific Language (DSL) for managing job creation and management within Jenkins called the “Job DSL” Plugin, which simplifies the process of programmatically creating Jenkins Jobs. Through using Jenkins' internal APIs, one can automate various aspects of management of Jenkins' configuration for certain applications.

4.2.2.1 Using Job DSL to Script Job Creation

Operations that frequently create a large number of jobs and require keeping the configuration of many jobs up-to-date may benefit from using the Job DSL.

Using Job DSL to create a simple Job:

```
mavenJob("my_job") {  
    description("""My great job""")  
    logRotator {  
        daysToKeep(7)  
    }  
    keepDependencies(false)  
    scm {  
        svn {  
            location("https://svn/project/branch") {  
                credentials(SVN_CREDENTIALS_ID)  
            }  
            checkoutStrategy(SvnCheckoutStrategy.UPDATE_WITH_CLEAN)  
        }  
        triggers {  
            scm('H/10 * * * *') {  
                ignorePostCommitHooks(false)  
            }  
        }  
    }  
}
```

4.2.2.2 Limitations of using the Job DSL / Extending Job DSL

There are several significant issues, however, with using the Job DSL. The first, most obvious issue is the learning required to be able to use the Job DSL effectively. While the Job DSL aims and succeeds at making jobs easier to maintain than by directly using Jenkins APIs, it is still

much less intuitive than using the GUI interface, and some more obscure features may not be supported at all, requiring extending the Job DSL. Furthermore, any updates to Jenkins may be potentially breaking, as was experienced during evaluation. During evaluation, a Jenkins update changed the XML format for a “logRotator” plugin, causing the Job DSL implementation to be broken.

One can use groovy to extend the Job DSL classes to either fix or extend the Job DSL. Groovy provides “mixin” functionality that allows adding methods to existing classes. Due to how the Job DSL is implemented, one can just add methods to the DSL classes and they are available to use in the DSL. This functionality can be used to add implementation specific shorthand or to add new features without having to wait for acceptance by the open source project. However, one must look at an existing, functional XML configuration to identify the required structure, which can then be automated.

Using Groovy Mixins to extend the DSL to support an additional feature (“keep builds forever”):

```
class PromotionActions {  
    static def bind() {  
        javaposse.jobdsl.dsl.helpers.step.StepContext.mixin PromotionActions  
    }  
  
    /**  
     * Promoted builds flag to keep build forever  
     */  
    void keepBuildForever() {  
        stepNodes << new  
        Node(null, 'hudson.plugins.promoted_builds.KeepBuildForeverAction')  
    }  
}
```

Using Groovy Mixins to extend the DSL to repair an existing feature that was broken due to a

Jenkins update:

```
class Job {  
    static def bind() {  
        javaposse.jobdsl.dsl.Job.mixin Job  
    }  
  
    /** New version of jenkins moved the location of this configuration node  
  
     Old version used for inspiration:  
    
```

```

https://github.com/jenkinsci/job-dsl-plugin/blob/master/job-dsl-
core/src/main/groovy/javaposse/jobdsl/dsl/Job.groovy#L203-L216
*/
void logRotator(@DslContext(LogRotatorContext) Closure closure) {
    LogRotatorContext context = new LogRotatorContext()
    ContextHelper.executeInContext(closure, context)

    configure { project ->
        project / 'properties' / 'jenkins.model.BuildDiscarderProperty' /
            'strategy'(class:'hudson.tasks.LogRotator') {
            daysToKeep(context.daysToKeep)
            numToKeep(context.numToKeep)
            artifactDaysToKeep(context.artifactDaysToKeep)
            artifactNumToKeep(context.artifactNumToKeep)
        }
    }
}

```

4.2.2.3 Using Jenkins API to Duplicate Jobs

Another option for the creation of new jobs is to just look at existing jobs and copy their configuration. Since we aren't concerned with the internals of the job structure, the API calls are very simple. This method was used by Prime Financing in a manual process, where a job is structured so that any job-specific configuration is reliant on the Job Title (in this case, the job title matches the SVN branch title), and jobs are duplicated as needed. Automation of creating release branch jobs was straight forward.

4.2.2.4 Using Groovy to Fetch SVN Branches

Jenkins comes with the “SVNKIT” library built in for its base functionality, so we were able to leverage this library to fetch a list of branches. It is also possible to use the command line SVN client and parse the output it gives, which was the original implementation, however using SVNKIT means we are using a library that is always installed with Jenkins. (The SVN command line client may or may not be installed on the Linux server client).

4.2.2.5 Automate what you can – Using Scripting to automate Job creation for branches.

We ended up creating a script, as shown in Appendix D, that polls an SVN repository and ensures that the Jenkins configuration matches what is expected. The script uses the newest

matching branch job as a template for creating new branch jobs. It can delete or disable old jobs, and create new jobs automatically, removing a manual process that required distracting a Jenkins administrator away from their other responsibilities. The frequency of the polling process is configurable, but generally it would be set to check on a regular schedule.

Using the Job DSL was not ideal because the configurations were complicated and used plugins not supported by Job DSL. The jobs were not created with such frequency that using Job DSL would speed things up, and the learning of Job DSL and requirements of extending Job DSL would be as error prone if not more error prone than building/modifying Jenkins jobs manually through GUI. The other benefit of Job DSL over “copy paste” is to keep all jobs with the same configuration. Since branches are generally for release, old branches are just kept for historical purposes and do not need to be kept up to date. Copying the last used branch provides the configuration needed.

4.2.2.6 Jenkins Integration with Plugins

After developing a rapid prototype using Groovy script, the desire for Jenkins configuration integration arose, and a plugin was developed. Jenkins’ plugin framework allows for quick creation of configuration menus with error checking, and the similarity of Groovy to Java (the language Jenkins plugins are by in large written in) allowed for a very quick development cycle (the majority of the time taken implementing new error checking features). Moreover, the integration with Jenkins allowed streamlining some of the process – instead of depending on the Groovy plugin, the EnvInject Plugin, and proper configuration of both, one just installs and configures the Sync Branches plugin we developed. The plugin is used as a build step and the configuration and error checking can be seen in figures 4.7 and figure 4.8. A global configuration area was also added for common configuration, as seen in figure 4.9.

Synchronize Per-branch Jobs

SVN Repository: http://SVN/repos/Project/branches

SVN Credentials: username/******** (username-password)

Branches Selection Regex: Project_.*

Advanced...

Delete

Figure 4.7: Configuration Screen for a Sync Branches Build Step

Synchronize Per-branch Jobs

SVN Repository: http://svn/repos/WPL/branches

SVN Credentials: username/******** (username-password)

Branches Selection Regex: WPL_.*

Invalid Regex

Override Number of Branches to Sync: -1

Must sync at least 1 branch!

Override Number of Branches to Keep in Jenkins: -5

Must keep at least 1 branch in Jenkins!

Delete

Figure 4.8: Configuration Screen with Advanced Options and Error-Checking Visible

Sync Branches Defaults

Number of Branches to Sync: 3

Number of Branches to Keep in Jenkins: 5

Figure 4.9: Global Configuration Screen

4.3 Generating Reports

Metrics and measurements of projects are important to understand whether projects are improving. We investigated available Jenkins reporting plugins, however they did not meet our expectations. We decided to look at the source; Jenkins itself keeps all metrics and statistical information, such as number of successful/failed builds and number of successful/failed promotions. Therefore we investigated ways of extracting information from Jenkins into a consumable format that can be used in reporting software to generate reports.

4.3.1 Dashboard View Plugin

We explored certain Jenkins plugins that might provide functionality to show Management Information System details. The Dashboard View Plugin is one such plugin which can show some straight forward information about jobs and builds.

Dashboard View adds “a new view implementation that provides a dashboard/portal-like view for Jenkins”(Hayes & Ambu, 2015). The plugin allows users to create one or more new “views,” labeled as Dashboard, which is customizable and contains various portlets with information about the selected job(s). Portlets are widgets containing useful charts or statistics. Further explanation on this terminology can found in Appendix A. More information about Dashboard View Plugin can be found in Appendix H.

Even though Dashboard View provides capabilities to visualize some information about jobs and builds within the Jenkins web instance, it doesn’t provide any information regarding promotions. To overcome this limitation we decided to custom implement the ability to access this information. When deciding how to display the information, we chose to extract the data to be used in external reporting software as that would provide more flexibility than what was shown in the Jenkins dashboard for far less work.

4.3.2 Data Extraction Plugin

As part of the project objective to provide MIS reports for Jenkins usage, it was identified that a tool needed to be created to extract Job and Promotion data from a Jenkins server into an easily consumable format that could be then analyzed and transformed into a report.

4.3.2.1 Prototype – Identifying Data Extraction Method

During the initial research phase, we used groovy scripting in the Jenkins console, as seen in figure 4.25, along with documentation to identify where the data we desired resided. The data

identified was the build status and time for every build and promotion information within Jenkins. Jenkins exposes this data through a stable and well defined, albeit internal, API. This method of extracting data is quick and simple, and leverages the usability of the Jenkins code base.

```
All the classes from all the plugins are visible. jenkins.*, jenkins.model.*, hudson.*, and hudson.model.* are pre-imported.

1 import hudson.plugins.promoted_builds.PromotedBuildAction
2
3 for (job in Hudson.instance.items) {
4     for (build in job.builds){
5         println job
6         println build
7
8         def promotionAction = build.getAction(PromotedBuildAction.class)
9         if (promotionAction) {
10             for (promotion in promotionAction.promotions) {
11                 for (promotionBuild in promotion.promotionBuilds) {
12                     println promotionAction
13                     println promotion
14                     println promotionBuild
15                 }
16             }
17         }
18     }
19 }
```

[Run](#)

Result

```
hudson.model.FreeStyleProject@95b412[ADP-Automated-Integration-Test]
ADP-Automated-Integration-Test #1
hudson.model.FreeStyleProject@1237b85[ADP-Build]
ADP-Build #1
```

Figure 4.25: Jenkins Script Console

Alternatives

Also evaluated was the possibility of using the Jenkins REST API – an HTTP API provided by Jenkins and its plugins. However, in our research we discovered that the API does not have an endpoint for mass data extraction of this type, but rather allows for investigation and modification of individual Jobs. It does provide a way to enumerate jobs and builds, however using that endpoint would still require a new HTTP REST API call for every single job. As well, there is no API endpoint to enumerate Promotions for a given build. Given these limitations, and given how simple using a programmatic method is, we chose the latter.

Another possibility is to do manual parsing of the XML files in which the Jenkins configuration is stored, an idea that was brought up by the sponsor. However, this idea was

dropped for a number of reasons: the XML files may be out of sync with the Jenkins instance, and may change while reading. As well, the overhead of writing the code to parse the XML makes little sense when Jenkins itself already has done the trouble of that for us.

4.3.2.2 Prototype – Extracting Data to File

Initially, our prototype groovy script was made to extract the desired data to a CSV File. The next step was to extract into a SQL database. There were three ideas posed: extract the data within the groovy script to SQL, extract the data with groovy to CSV and then create a second application in Java to read the CSV and export to SQL, or create a single Jenkins plugin in Java to extract to SQL.

Hypothetically, one can use a feature of the Groovy Jenkins Plugin to add additional jar files to the classpath of the script VM, allowing for using external jars such as would be required for a database connector. However, this option was dropped for 2 reasons: 1) due to a bug in the plugin, it didn't work, and 2) having to maintain dependencies using complex classpath configurations is error prone and not intuitive to set up.

Having two separate tools to maintain was not ideal. Creating a Jenkins plugin has additional benefits, so this path was chosen.

4.3.2.3 Java Extraction Tool Plugin

Jenkins plugins are all written using the Java programming language. Using Java has a few key benefits: we can structure the project as an actual project rather than a script file and loosely gather dependencies; a more strongly typed and strict language allows for creation of a more robust tool; and dependencies can be managed as part of the project and packaged together for deployment. Furthermore, creating a Jenkins plugin allows for integration with the Jenkins web GUI.

Creating a Plugin

Jenkins has a wide-ranging plugin extension system that we used to develop our plugin. Jenkins provides a template for creating the base of a plugin that can be customized to one's needs. The plugin was implemented as a Jenkins Build Step, which can be added to and configured in a Jenkins Job. The plugin was made in Java using Maven for dependencies, which allows for bundling the required dependencies such as database drivers and helper libraries in the tool distributable in the plugin file.

Configuration Considerations

Parameters are configurable as a part of the standard Jenkins configuration console. The target database and credentials are configurable in Jenkins in the build job. Credentials are encrypted using Jenkins standard methods.

Data Type Considerations

In designing the tool some special considerations were made towards data types for interoperability. Java dates operate using milliseconds since the Unix Epoch. Microsoft SQL Server, as a .NET product, operates on 100 nanosecond “ticks” since the year 1 started. While the .NET DateTime is 10000 times more precise than Java’s milliseconds, in the conversion between .NET and Java we saw errors where the time recorded was 1 millisecond off from the actual time desired to be recorded. To prevent such conversion errors, time was stored as a raw long integer representing the Java Date, in such a way that conversion between different Date styles is not needed. However, MS Excel does not have an easy way to convert Milliseconds to a local time, so the data was denormalized and an additional local date column was added that is precise enough for reporting needs, and in a format that Excel understands.

4.3.2.4 Outcomes

A Jenkins Plugin was created and implemented on Prime Financing's Jenkins server. The configuration screen is shown in figure 4.26, and it has error checking validates credentials and URL, as seen in figure 4.27. The plugin will extract new job metadata to the specified SQL server, as seen in figure 4.28, or to a specified CSV file. The plugin is designed such that it can be run at any interval, and will only append new data.

The screenshot shows the Jenkins configuration interface with two entries:

- Export Jenkins Build and Promotions Data to MSSQL**
 - Destination Server: `jdbc:jtds:sqlserver://server/database;instance=instance1`
 - Username: `username`
 - Password: `.....`
 - Delete** button
- Export Jenkins Build and Promotions Data to CSV Artifact**
 - Delete** button

Figure 4.26: Configuration Screen

The screenshot shows the Jenkins configuration interface with the same two entries as Figure 4.26, but with an error message for the first entry:

- Export Jenkins Build and Promotions Data to MSSQL**
 - Destination Server: `jdbc:jtds:sqlserver://server/database;instance=instance1`
 - Could not connect to server!** (Error message)
 - Username: `username`
 - Password: `.....`
 - Delete** button
- Export Jenkins Build and Promotions Data to CSV Artifact**
 - Delete** button

Figure 4.27: Error Checking validates credentials and URL

	id	buildId	promotionName	promotionBuildNumber	promotionBuildResult	promotionBuildTime
176	2...	708	1.QA	22	SUCCESS	2015-11-18 10:44:31.0000000
177	2...	708	1.QA	21	FAILURE	2015-11-18 10:35:48.0000000
178	2...	709	1.QA	20	FAILURE	2015-11-18 10:32:20.0000000
179	2...	709	1.QA	19	FAILURE	2015-11-18 10:28:32.0000000
180	2...	711	1.QA	18	SUCCESS	2015-09-02 14:34:13.0000000
181	2...	711	2.UAT	10	SUCCESS	2015-09-02 16:25:53.0000000
182	2...	711	3. Prod	5	SUCCESS	2015-09-18 18:15:33.0000000
183	2...	712	1.QA	19	SUCCESS	2015-11-18 10:26:54.0000000
184	2...	714	1.QA	18	SUCCESS	2015-09-09 17:58:42.0000000
185	2...	714	2.UAT	8	SUCCESS	2015-09-14 16:15:54.0000000
186	2...	714	3. Prod	4	SUCCESS	2015-09-18 18:16:30.0000000
187	2...	715	1.QA	15	SUCCESS	2015-09-02 14:32:43.0000000
188	2...	715	2.UAT	7	SUCCESS	2015-09-02 16:27:13.0000000

Figure 4.28: Data in SQL

4.3.3 Reporting with Excel Pivot Table

The Job and Promotion information from the SQL server was then imported into Excel. We decided to use pivot tables to filter and group the very large data set. A pivot table is a data summarization tool that can automatically sort, count, give average, and do other functions on data stored in a spreadsheet or table. The actions and filtering are independent of the original data (MacDonald, 2005). Instructions on how to create a pivot table using a SQL database and CSV file source can be found in Appendix E and Appendix F respectively. The version of Excel we worked on was Microsoft Excel 2007, but the pivot table functionality is available in every version of Excel. Information about the features of our pivot table configuration can be found in Appendix G. The end result can be as seen in figure 4.29 below. The pivot chart is nice in that it shows an understandable visual representation of the number of successful/failed promotions across time.

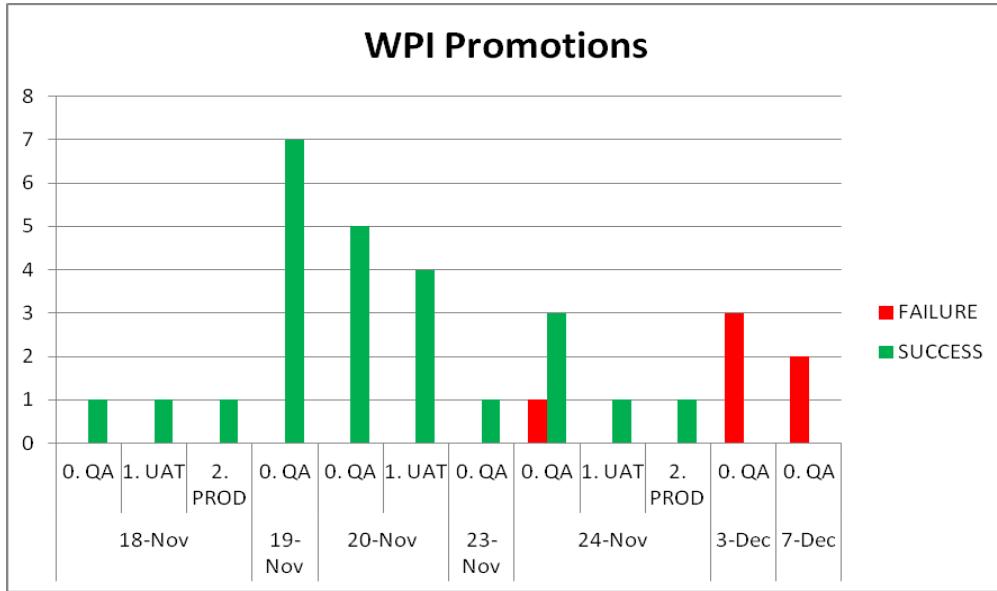


Figure 4.29: Pivot Chart created from sample data.

4.4 Summary

By analyzing the strength and weakness of both CA Release Automation and Jenkins and sample implementations, we determined Jenkins is a better to be widely implemented in Prime Financing. We explored and tested several Jenkins plugins, which could be helpful, such as pipeline view, Job DSL, Groovy scripting, and Dashboard View, and we evaluated feasibility of each plugin. We also demonstrated how to create Management Information System data reports with Jenkins. In the next chapter, we will conclude our findings and provide our recommendations in order to enhance the continuous delivery process of the chosen tool, Jenkins, and the process to adopt candidate applications into Jenkins.

5.0 Conclusions and Recommendations

In this chapter, we provide our conclusions and recommendations to choose the better tool and to develop strategies to onboard applications on the chosen tool. We recommend Prime Financing uses Jenkins based on our comparative analysis of Jenkins and CA Release Automation. We determined several strategies to enhance the continuous delivery process on Jenkins via investigating and developing some plugins. We also provided recommendations on how to show and use management information system details.

5.1 Conclusions

Based on our comparative analysis, both CA Release Automation and Jenkins have their respective advantages. CA Release Automation provides robust and sharable deployment strategies, and allows users to configure environments. Moreover, there is less administrative overhead for frequently changing deployment processes and complicated deployment to many different targets. As for Jenkins, it follows build-your-own deployment strategies, which provides convenient integration with current application configurations. Furthermore, the set-up process is quick for teams with existing deployment scripts or simple deployments.

We explored several plugins that could enhance the automated deployment process. Jenkins has several available pipeline view plugins, which could show upstream and downstream relationships. These plugins are useful, but don't integrate well with the Promoted Builds Plugin or with Prime Financing's configuration. As for Job DSL Plugin, while it is a powerful tool, it has a high learning curve and is heavyweight in general. For Groovy scripting, it can accomplish simple and useful actions, however it has a high learning curve for complicated jobs. In the end, however, Jenkins plugins written in Java that leverage Jenkins' API and tools proved the most useful and

stable for reliably automating these tasks, while Groovy scripting proved to be a useful tool for quickly testing and scripting small things.

As for Management Information System reporting, we discovered that any specified data could be extracted from Jenkins, such as build and promotion information. We created a Jenkins Plugin to extract data either into a SQL database or CSV files. Furthermore, the extracted information can be imported into data reporting software, such as Excel, to create reports; we created a reusable Excel template that creates reports from Prime Financing's Jenkins instance.

5.2 Recommendations

Based on our research and implementations, we recommend using Jenkins over CA Release Automation because of minor overhead and quicker set-up. In order to eliminate some manual steps, we recommend using our Jenkins Plugin 'Sync Branches' to accomplish automatic job creation and cleanup from SVN branching instead of manually copying jobs. Moreover, to provide management information details. We recommend using our Jenkins plugin to extract data into either a SQL database or CSV files. SQL database is the preferred destination rather than CSV files because SQL databases are easier to manage data and has better compatibility with different reporting software. Additionally, we also developed an Excel template to visually show data reports. We highly recommend using Excel with our template, since Excel is widely used and intuitive for reporting.

5.3 Impact of Our Project

Our project results and recommendations can help our sponsor, Barclays Prime Financing, to improve automated deployment in the continuous delivery process, and to generate reports to understand the continuous delivery process. Implementing strategies we developed could eliminate a few manual steps within their continuous delivery process. By using our strategies, we

hope the continuous delivery process could be more efficient and easy, thus helping address the challenges of automated deployment.

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Appendix A: Glossary of Technical Terms

General

Application: A piece of software that is developed and built by a Barclays development team. Application and project may be used synonymously within this paper.

Onboard: This is the configuration procedure necessary for applications to do when being set up to a continuous deployment environment, whether that is Nolio or Jenkins. For the case of Jenkins, the application development team is responsible for filling out the Prime Financing-supplied questionnaire, setting up the deployment scripts which detail out the build sequence, build dependency, and build frequency as well as notification method.

Jenkins (Ramfelt, 2015)

Job/Project: Jenkins seems to use these terms interchangeably. They all refer to runnable tasks that are controlled and/or monitored by Jenkins.

Build: The result of one run of a project.

Plugin: Third-party plugins can extend Jenkins by adding features not present in the core. This allows users to satisfy any need, no matter how niche it is without affecting the core.

Node/Slave: Slaves are computers that are set up to build projects for a master. Jenkins runs a separate program called "slave agent" on slaves. When slaves are registered to a master, a master starts distributing loads to slaves. The term Node is used to refer to all machines that are part of Jenkins grid, slaves, and master.

Promotion: This term pertains to the Promoted Builds Plugin. A build that passed any additional criteria would be marked by promotion icons. This kind of promotion allows triggering of downstream jobs on more criteria than just if the build passed or failed. Users can distinguish good builds from builds that had runtime problems through checking promotions.

Groovy: Groovy is a script programming language based on Java. It is a lightweight language that can run on a Java server. Since Jenkins runs on Java, a Groovy script is directly compilable and compatible with Jenkins.

Jelly: Jelly is a customizable Java and XML based scripting and processing engine. It turns XML script into executable code. Jelly is a component of Apache Commons.

Portlet: This term pertains to the Dashboard View Plugin. Generally speaking, a portlet is a Java-based web component that processes requests and generates dynamic content. They are deployed in a container, Dashboard View Plugin for the case of our project.

View (dashboard status window): In the screenshot shown below, there are two icons that describe the status of the current build. The “S” column represents the “status of the last build”. The “W” column represents the “weather report showing aggregated status of recent builds.” Jenkins use these two concepts to introduce the general situation of a build.

S	W	Name ↓	Last Success	Last Failure	Last Duration
		config-provider-model	1 yr 6 mo - #1367	2 yr 11 mo - #1353	1 min 9 sec
		core_selenium-test	N/A	3 yr 0 mo - #18	12 min

Figure 7.1: Dashboard status window

Status: There are four kinds of status of a build.

- Successful:** Build is completed and considered stable.
- Unstable:** Build is completed, but is considered unstable.
- Broken:** Build is failed during building.
- Disabled:** Build is disabled.

Weather: Jenkins will release a robust value (from 0-100) for build based on some processor tasks, which be implemented through plugins. Those tasks may include unit test (JUnit), coverage (Cobertura) and static code analysis (FindBugs). Higher score indicates the build is more stable. Build stability score less than 80 points is considered as unstable.

Table 7.1: Weather Status

80+	60-79	40-59	20-39	0-19

CA Release Automation (CA_Technologies, 2015b)

Artifacts: the objects that make up the software application being deployed.

Components: a collection of the objects to build a process

Actions: an individual operation in the target deployment environment

Flow: a group of actions with a defined sequence

Process: a set of actions executed in a logical order

Environment: a group of computers to which deployments are deployed simultaneously

Release Template: each template is contained within Category and provides the processes that need to be executed for release along with the order they should be executed

Pipeline: a way to express a sequence of operations over DevOps

Appendix B: Installing Jenkins Plugins

Jenkins is an open-source and extensible continuous integration software. There are more than 1,000 publicly available plugins that are ready to use in any instance of Jenkins. Information and explanation on Jenkins plugins are on the Jenkins wiki website (Kawaguchi, 2015). The actual plugins, as well as their source code, are primarily on Jenkins community repositories on Github. Through this manner, it allows easier contributions from any community developer. So in the circumstance that an original plugin developer leaves behind his/her plugin, plugin development can still continue thanks to the community. After meeting prerequisites and created a plugin Github repository, a plugin developer can message the core Jenkins team to have a dedicated page on the Jenkins wiki.

On a plugin page on the Jenkins wiki, for example in the below figure 7.2 that shows the Promoted Builds Plugin, one can see many details about a plugin: plugin name, release version, release date, required Jenkins core version, dependencies, graph of monthly installations, change log, source code, issue tracking, pull requests, authors, and number of installations by month.

Plugin Information

Plugin ID	promoted-builds	Changes	In Latest Release Since Latest Release																										
Latest Release Latest Release Date Required Core Dependencies	2.24 (archives) Nov 25, 2015 1.554.2 rebuild (version:1.22, optional) maven-plugin (version:2.0) token-macro (version:1.10, optional)	Source Code Issue Tracking Pull Requests Maintainer(s)	GitHub Open Issues Pull Requests Kohsuke Kawaguchi (id: kohsuke) Peter Hayes (id: petehayes)																										
Usage	<p>promoted-builds - installations</p> <table border="1"><caption>Data for promoted-builds - installations</caption><thead><tr><th>Month</th><th>Installations</th></tr></thead><tbody><tr><td>Dec 2014</td><td>6735</td></tr><tr><td>Jan 2015</td><td>7181</td></tr><tr><td>Feb 2015</td><td>7332</td></tr><tr><td>Mar 2015</td><td>7827</td></tr><tr><td>Apr 2015</td><td>7747</td></tr><tr><td>May 2015</td><td>7878</td></tr><tr><td>Jun 2015</td><td>8307</td></tr><tr><td>Jul 2015</td><td>8433</td></tr><tr><td>Aug 2015</td><td>8410</td></tr><tr><td>Sep 2015</td><td>8827</td></tr><tr><td>Oct 2015</td><td>8884</td></tr><tr><td>Nov 2015</td><td>9054</td></tr></tbody></table>	Month	Installations	Dec 2014	6735	Jan 2015	7181	Feb 2015	7332	Mar 2015	7827	Apr 2015	7747	May 2015	7878	Jun 2015	8307	Jul 2015	8433	Aug 2015	8410	Sep 2015	8827	Oct 2015	8884	Nov 2015	9054	Installations	2014-Dec 6735 2015-Jan 7181 2015-Feb 7332 2015-Mar 7827 2015-Apr 7747 2015-May 7878 2015-Jun 8307 2015-Jul 8433 2015-Aug 8410 2015-Sep 8827 2015-Oct 8884 2015-Nov 9054
Month	Installations																												
Dec 2014	6735																												
Jan 2015	7181																												
Feb 2015	7332																												
Mar 2015	7827																												
Apr 2015	7747																												
May 2015	7878																												
Jun 2015	8307																												
Jul 2015	8433																												
Aug 2015	8410																												
Sep 2015	8827																												
Oct 2015	8884																												
Nov 2015	9054																												

Figure 7.2: Promoted Builds Plugin description page.

This appendix assumes you have properly installed and have done the basic configurations for Jenkins. The following are instructions show how to find and install plugins through the Jenkins web dashboard:

1. On the homepage of Jenkins, click “Manage Jenkins”, as seen in figure 7.3:

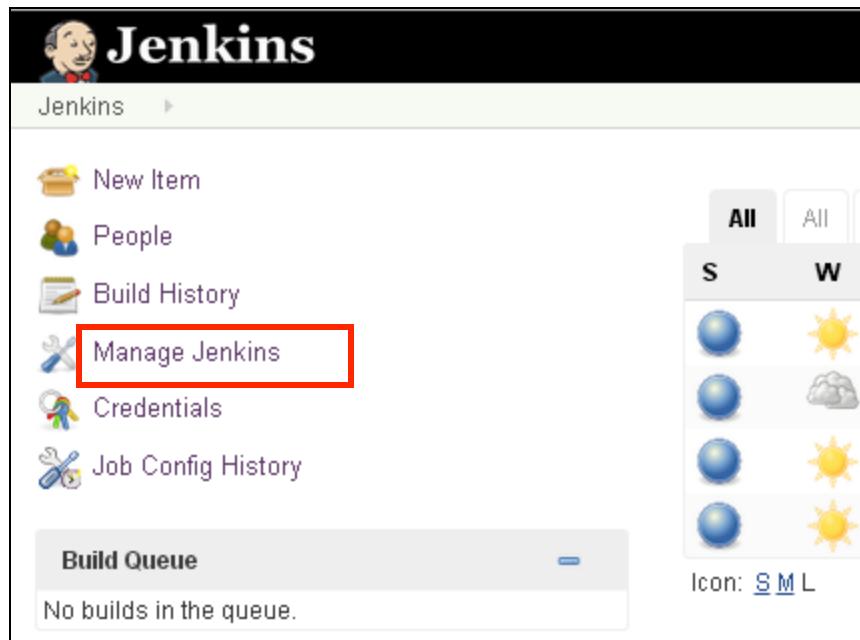


Figure 7.3: Manage Jenkins.

- From the list of configuration options, click “Manage Plugins”, as seen in figure 7.4:

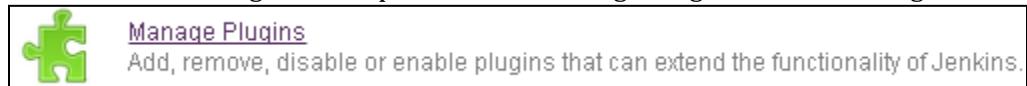


Figure 7.4: Manage Plugins.

- You should see tabs labeled “Updates,” “Available,” “Installed,” and “Advanced”. To find and install a new plugin, click the “Available” tab, as seen in figure 7.5. Select the desired plugin and then click “Install without restart” (you can also click the plugin name to be taken to the plugin description page on the Jenkins wiki):

The screenshot shows the 'Available' tab selected in the Jenkins Manage Plugins interface. A search bar at the top contains the text 'chuck'. Below it, a table lists a single plugin: 'ChuckNorris Plugin'. The table has columns for 'Name' and 'Version'. The 'Name' column shows 'ChuckNorris Plugin' and the 'Version' column shows '0.9.1'. Below the table are two buttons: 'Install without restart' and 'Download now and install after restart'. At the bottom right, it says 'Update information obtained: 17 hr ago'.

Figure 7.5: Installing an available plugin.

- The plugin installation screen should look like figure 7.6. Once complete, you can use the newly installed plugin wherever the plugin can be used, as seen in figure 7.7.

Installing Plugins/Upgrades

Preparation

- Checking internet connectivity
- Checking update center connectivity
- Success

Persona Plugin

 Success

ChuckNorris Plugin

 Success

 [Go back to the top page](#)

(you can start using the installed plugins right away)

 Restart Jenkins when installation is complete and no jobs are running

Figure 7.6: Plugin installation status screen.

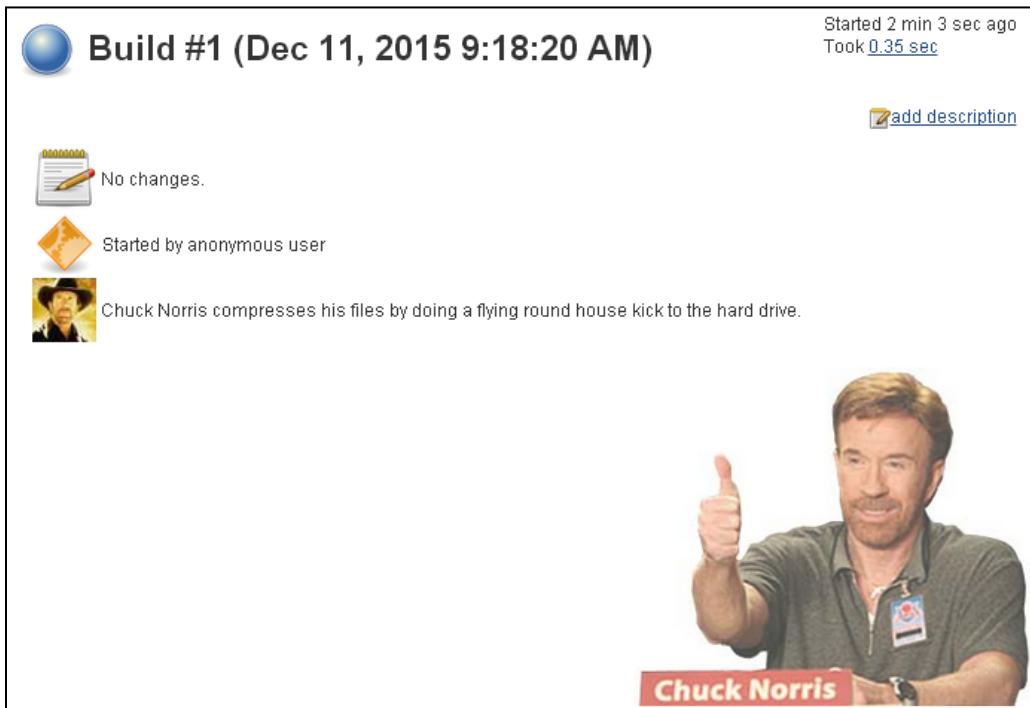


Figure 7.7: Chuck Norris Plugin.

If you happen to have a custom-made Jenkins plugin, which should be a .hpi file, then you can import it into Jenkins in the “Advanced” tab of Manage Plugins and then importing said file, as seen in figure 7.8.

Updates Available Installed **Advanced**

HTTP Proxy Configuration

Server primary-proxy [?](#)

Port 80 [?](#)

User name [?](#)

Password [?](#)

No Proxy Host [?](#)

[Advanced...](#)

Submit

Upload Plugin

You can upload a .hpi file to install a plugin from outside the central plugin repository.

File: Choose File No file chosen

Upload



Figure 7.8: Uploading a custom plugin.

Appendix C: Nolio Installation Instructions

1. Request two functional groups to be created, one labeled Dev and one labeled Ops. Functional groups are Barclays system groups for developers to coordinate with each other.
2. Request that the two groups be added to the “sandpit” Nolio instance. An instance can be considered a Nolio website dashboard. Barclays has two different instances: sandpit (for learning and familiarization purposes only) and production (for actual development of flow and deployments).
3. Download a zip file that contains Barclays’s Nolio extended version template from the tutorial page.
4. Go to the Nolio sandpit website dashboard and enter the ROC.
5. Import the zip file making sure to import all components.
6. Set your application as Barclays’s Nolio extended version platform test application.
7. Navigate to Designer -> Process Design -> Components.
8. Assign shared components from the imported components. For the tutorial, it stated to assign deploy copy & uncompress, windows service start & stop, and email utility components.
9. Map a server type, the tutorial stated App_Name1, for each shared component.
10. Navigate to Designer -> Process Design -> Processes.
11. In the process Deployment, select Notify_Deploy_Begin and click “Add Action/Flow” for the email utility component.
12. Select the f_send_release_begin_email flow from the dropdown list. Save and publish. Make sure to assign the process to the UAT environment.
13. Repeat steps 11 and 12 for the following as table 7.2.

Table 7.2: Process areas and flows

Process Area	Flow
Post-Deployment -> Notify_Deploy_End	f_send_release_end_email (from email utility shared component)
Deployment -> Stop_System	f_stop_component (from windows service start & stop shared component)
Deployment -> Start_System	f_start_component (from windows service start & stop shared component)
Deployment -> Deploy_Binaries	f_deploy_component (from deploy copy & uncompress shared component)

14. Navigate to Environment -> Agent Assignment.
15. Make sure that your Nolio agent is installed and running properly. For our team’s case, we installed the agent, which is a windows service running in the background, on one of our local work computers.
16. Select the appropriate server name (for our case it was the local computer hostname) and assign it to the server type App_Name1. Also set the environment as UAT.
17. Repeat step 16 for the server type util.Email.
18. Navigate to Artifact -> Artifact Management.
19. Select the artifact SC.Compressed and select Add Artifact Definition.

20. Be sure to set the file type of the definition as zip and ensure that the server type App_Name1 is selected for the definition.
21. Select the newly created Artifact Definition and then click Add Version.
22. Version can be any version. The artifact source should be the full path where the artifact source file should be (steps 18-20 did not work for our case, so we skipped these steps).
23. Navigate to Releases -> Template Categories. Click "New".
24. Create a new template category with any name.
25. Within the new template category, click "New" and create a new deployment template.
26. Within the new deployment template, click "Add Step". Add the steps as shown below:

Table 7.3: Processes and Categories

Process	Category
Notify_Deploy_Begin	Deployment
Stop_System	Deployment
Deploy_Binaries	Deployment
Start_System	Deployment
Notify_Deploy_End	Post Deployment

27. Drag and drop all deployment steps to the center tab called "Deployment Steps" or "Post Deployment". This is when you can also set dependencies.
28. Navigate to Environments -> Parameter Configuration -> Parameters tab.
29. Select the UAT environment. You will see a list of the shared components we selected. It is here that a user can set up the email addresses for emails to be sent to, the specified windows services to stop and start, and the artifact definition path.
30. Navigate to Releases -> Deployment Plans. Click "New".
31. In the newly created deployment project, click "New Deployment Plan".
32. Within the settings for a new deployment plan, you must supply a build number and have the plan use the template that we created.
33. Click on the newly created deployment plan to view details. There should be a "Deploy" button, which is the final step.
34. Click "Deploy" and you must supply some settings, for the tutorial's case you must select the UAT environment.
35. All done!

Appendix D: job_per_branch.groovy

```
/*
 * WPI DevOps MQP
 * Khazhismel Kumykov
 * <khazhismelkumykov.kumykov@barclayscapital.com>
 * job_per_branch.groovy
 *
 * Overview:
 * This script gets a list of branches from the given SVN repository, sorted
 * by
 * jobs
 * creating
 * existing in Jenkins with the *exact same* name as the branch.
 * The script will use the matching job for the newest branch as a template for
 * new jobs.
 *
 * The script will create new jobs for up to `BRANCHES_TO_KEEP` branches.
 * The script will disable jobs after `BRANCHES_TO_KEEP` branches.
 * The script will *delete* jobs after `BRANCHES_DELETE_AFTER` branches.
 *
 * Branch names *must be* unique between projects.
 *
 * Using:
 * - Must create and configure a base branch job for one of the branches in
 * SVN.
 * - The job must be configured such that copying and renaming the job are
 * only required configuration changes to allow the job to work for a new
 * branch.
 * (i.e., use $JOB_NAME for SVN branch selector, etc.)
 * - Must create a new Job for each SVN repository you wish to be managed.
 * - Add a required Credentials Parameter named "SVN_CREDS" with the default
 * set to the
 * 'username with password' credentials for your SVN repository.
 * - Check "Prepare environment for the run"
 *   - Check "Keep Jenkins Environment Variables"
 *   - Check "Keep Jenkins Build Variables"
 *   - Add Parameters as needed to "Properties Content" (Do not
 * surround in quotes) e.g.:
 *     BRANCHES_REGEX=^WPI_Copy_.*
 *     SVN_REPO=http://svn/repos/WPI/
 * - Set the Job to build periodically as appropriate.
 * - Add a "Execute system Groovy script" build step, select "Groovy script
 * file" and provide
 *   the path to this groovy script.
 * - Optionally, you may configure global properties in the global
 * configuration.
 *   - "Manage Jenkins" > "Configure System" > "Global Properties"
 *   - Check "Environment variables" and add key-value pairs as desired
 */
```

```

Required Plugins
    - Subversion Plugin (Comes with Jenkins)
    - Groovy Plugin (http://wiki.jenkins-ci.org/display/JENKINS/Groovy+plugin)
    - EnvInject Plugin (https://wiki.jenkins-ci.org/display/JENKINS/EnvInject+Plugin)
    - Credentials Plugin (https://wiki.jenkins-ci.org/display/JENKINS/Credentials+Plugin)

Params:
    BRANCHES_TO_KEEP - How many branches to keep active projects for.
    BRANCHES_DELETE_AFTER - How many branches to keep in Jenkins.
        If there are more jobs than this limit, extra jobs will be deleted.
    BRANCHES_REGEX - Regex for branches to look at.
        E.g. "^WPI_Copy_.*" - All branches starting with 'WPI_Copy_'
        E.g. "^[^_].*" - All branches not starting with '_'
    SVN_REPO - The __root__ of the repository.
        E.g. "http://svn/repos/WPI/"
    SVN_CREDS - Must be a username-password credentials ID for accessing the SVN Repo
*/
import hudson.model.*

import com.cloudbees.plugins.credentials.CredentialsProvider
import com.cloudbees.plugins.credentials.common.StandardUsernameCredentials

import org.tmatesoft.svn.core.io.SVNRepositoryFactory
import org.tmatesoft.svn.core.SVNURL
import org.tmatesoft.svn.core.auth.BasicAuthenticationManager

def log(l) {
    println "[SVN Branch Sync] $l"
}

def resolve(name) {
    bv = build.buildVariableResolver.resolve(name)
    if (bv != null) {
        return bv
    } else {
        return build.getEnvironment(listener).get(name)
    }
}

SVN_REPO=resolve("SVN_REPO")
SVN_CREDS=resolve("SVN_CREDS")
BRANCHES_REGEX=resolve("BRANCHES_REGEX")
BRANCHES_TO_KEEP=resolve("BRANCHES_TO_KEEP")
BRANCHES_DELETE_AFTER=resolve("BRANCHES_DELETE_AFTER")

log "Beginning SVN Branch Sync"

```

```

log "SVN_REPO: $SVN_REPO"
log "SVN_CREDS: $SVN_CREDS"
log "BRANCHES_REGEX: $BRANCHES_REGEX"
log "BRANCHES_TO_KEEP: $BRANCHES_TO_KEEP"
log "BRANCHES_DELETE_AFTER: $BRANCHES_DELETE_AFTER"
log ""

// Lookup the credentials by ID
cred = CredentialsProvider.lookupCredentials(StandardUsernameCredentials.class,
Hudson.instance).findResult({it.id == SVN_CREDS ? it : null})

if (cred == null) {
    throw new hudson.AbortException("Could not find credentials with ID: $SVN_CREDS")
}

// Depending on how they are specified, they may be Ints or Strings.
// Will throw if unable to parse.
if (!(BRANCHES_TO_KEEP instanceof Integer)) {
    BRANCHES_TO_KEEP = Integer.parseInt(BRANCHES_TO_KEEP)
}
if (!(BRANCHES_DELETE_AFTER instanceof Integer)) {
    BRANCHES_DELETE_AFTER = Integer.parseInt(BRANCHES_DELETE_AFTER)
}

// Throw if this is invalid
if (BRANCHES_DELETE_AFTER < BRANCHES_TO_KEEP) {
    throw new hudson.AbortException("BRANCHES_DELETE_AFTER should be greater than or equal to BRANCHES_TO_KEEP")
}

if (BRANCHES_TO_KEEP <= 0) {
    throw new hudson.AbortException("BRANCHES_TO_KEEP must be greater than 0")
}

items = Hudson.instance.items.groupBy{ it.name }

def repo = SVNRepositoryFactory.create(SVNURL.parseURIDecoded(SVN_REPO))

repo.setAuthenticationManager(new BasicAuthenticationManager(cred.username,
cred.password.getPlainText()))

def branches = new ArrayList()

repo.getDir("branches", repo.getLatestRevision(), true, branches)

branches.sort{a,b -> b.date <=> a.date}

branches = branches.findAll {
    log "Found Branch: $it.name - rev. $it.revision ($it.author) - $it.date"
    should_manage = (it.name =~ BRANCHES_REGEX).matches()
    if (!should_manage) {
        log "Ignoring Branch: $it.name"
    }
}

```

```

        }
        return should_manage
    }

log ""

// Find newest branch that exists
newestBranchWithJob = ""

for (branch in branches) {
    if (items.containsKey(branch.getName())) {
        newestBranchWithJob = branch
        log "Using ${branch.getName()} as template job."
        break;
    }
}

log ""

// Throw if we can't find a template job.
if (newestBranchWithJob == "") {
    throw new hudson.AbortException("Could not find branch job to copy!")
}

templateJob = items[newestBranchWithJob.name][0]

// Iterate over every branch that we aren't ignoring
branches.eachWithIndex({branch, idx ->
    jobExists = items.containsKey(branch.name)
    job = null
    if (jobExists) {
        job = items[branch.name][0]
    }

    if (idx >= BRANCHES_TO_KEEP) {
        // If job exists, we want to disable or delete it
        if (jobExists) {
            if (idx >= BRANCHES_DELETE_AFTER) {
                log "${branch.name} - Deleting job ${job.name}"
                job.delete()
            } else {
                if (job.disabled) {
                    log "${branch.name} - Doing nothing for job ${job.name} - it's disabled as it should be. It will be deleted soon."
                } else {
                    log "${branch.name} - Disabling job ${job.name} - it will be deleted soon"
                    job.disabled = true
                    job.save()
                }
            }
        } else {
            log "${branch.name} - Doing nothing - it should be deleted, and

```

```

is."
    }
} else {
    // If job doesn't exist, we want to create it.
    if (jobExists) {
        if (job.disabled) {
            log "${branch.name} - Enabling job ${job.name}"
            job.disabled = false
            job.save()
        } else {
            log "${branch.name} - Doing nothing for job ${job.name} - it exists as it should"
        }
    } else {
        log "${branch.name} - Creating new job ${branch.name} by copying ${templateJob.name}"
        newJob = Hudson.instance.copy(templateJob, branch.name)

        // This seems to be required to enable building
        newJob.disabled = false
        newJob.save()

        // Run a new build right after making the job.
        newJob.scheduleBuild(0, new Cause.UpstreamCause(build))
    }
}
}

// build.result = Result.UNSTABLE

log ""
log "SVN Branch Sync Complete"

```

Appendix E: Excel Reporting using SQL database

- 1) Within Excel, click the Data tab and then click “From Other Sources” -> “From SQL Server”, as seen in figure 7.9.

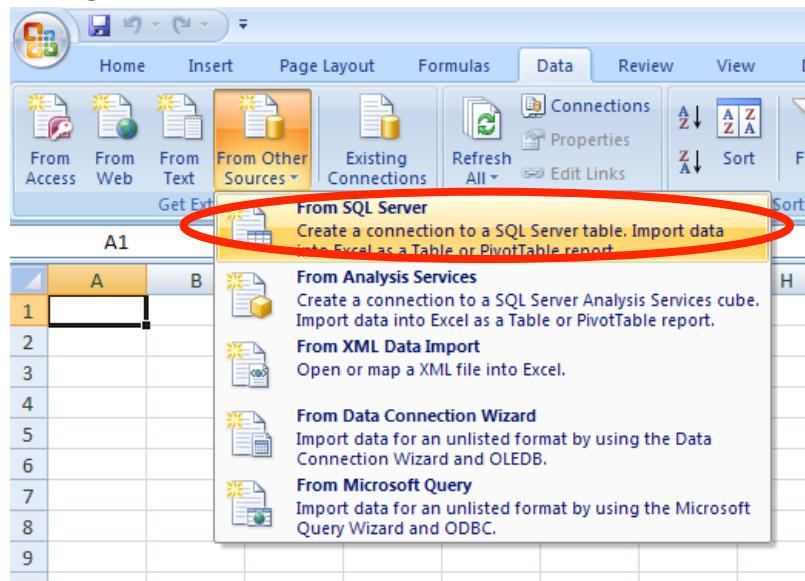


Figure 7.9: Import a SQL database data

- 2) In the Data Connection Wizard, fill out the SQL server name as well as username and password log on credentials, as seen in figure 7.10.



Figure 7.10: Data Connection Wizard

- 3) Next you need to select the appropriate database that our plugin extracted the data to. You also need to select the appropriate table from the list:

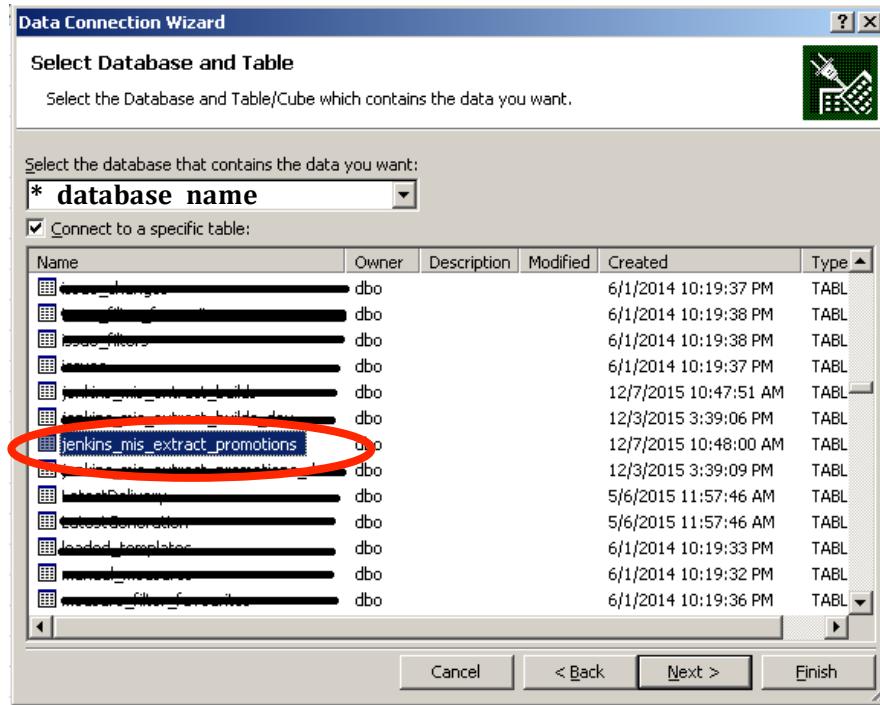


Figure 7.11: Select the appropriate database

- 4) At the next window, you're prompted to write a name and description for the Data Connection file that has this connection. When finished, click "Finish":

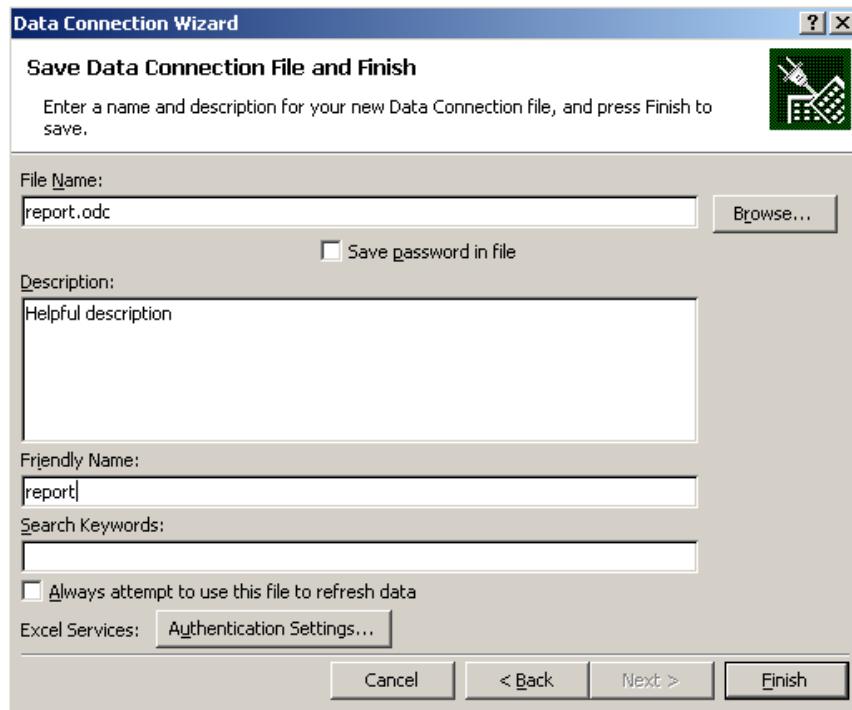


Figure 7.12: write a name and description for the file

- 5) The next window will prompt you on how you want to view the data. Make sure “Table” is selected and then click “Properties”, as seen in the left of figure 7.13. In the Connection Properties window, as seen in right of figure 7.13, you can edit the refresh settings in the “Usage” tab. Click the “Definition” tab; the important areas here are “Command Type” and “Command Text”. Make sure Command Type is set to “SQL”.

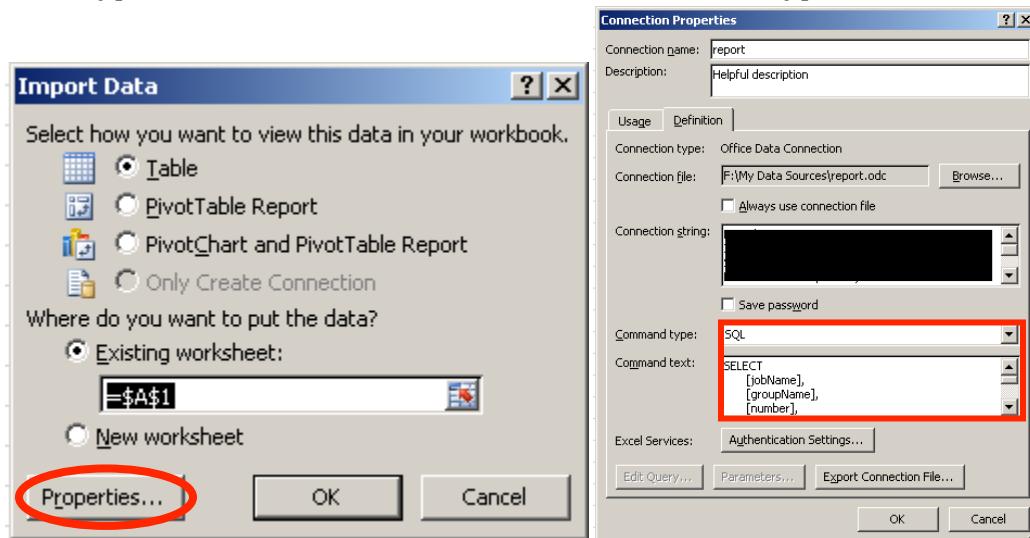


Figure 7.13: Import data (left) and properties window (right)

- 6) Paste in the following SQL command into the Command Text, as seen below , (please note the *YOUR_DATABASE_NAME* parts of the command should be replaced with the database name you selected from Step 3). Once complete, click OK and then OK in the “Import Data” window.

```

SELECT
    [jobName],
    [groupName],
    [number],
    [result],
    cast([time] as datetime) as [time],
    cast([finishTime] as datetime) as [finishTime],
    [promotionName],
    [promotionBuildNumber],
    [promotionBuildResult],
    cast([promotionBuildTime] as datetime) as [promotionBuildTime],
    cast([promotionFinishTime] as datetime) as [promotionFinishTime]
FROM [*YOUR_DATABASE_NAME*].[dbo].[jenkins_mis_extract_promotions] as prom
JOIN [*YOUR_DATABASE_NAME*].[dbo].[jenkins_mis_extract_builds] as build
ON (build.id = prom.buildId)
  
```

- 7) A “SQL Server Login” window should pop up prompting you for the log on username and password. The table should look like our example shown in figure 7.14:

A	B	C	D	E	F	G
promotionName	promotionBuildNumber	promotionBuildResult	promotionBuildTime	promotionFinishTime	jobName	groupName
UAT	6	SUCCESS	42320.7669	42320.7669	MyGreatProject	MyGreatProject
UAT	5	FAILURE	42320.76586	42320.76587	MyGreatProject	MyGreatProject
UAT	4	SUCCESS	42320.76416	42320.76417	MyGreatProject	MyGreatProject
UAT	3	SUCCESS	42320.75918	42320.75919	MyGreatProject	MyGreatProject
UAT	2	FAILURE	42320.75856	42320.75858	MyGreatProject	MyGreatProject
UAT	1	SUCCESS	42320.75734	42320.75734	MyGreatProject	MyGreatProject
QA	1	FAILURE	42321.68804	42321.68804	Promoted Builds Example	Promoted Builds Exa
0. QA	3	FAILURE	42332.75955	42332.75956	WPI_Copy_2.1.4	WPI_Copy_2.1.4
0. QA	2	SUCCESS	42332.75745	42332.75747	WPI_Copy_2.1.4	WPI_Copy_2.1.4
0. QA	1	SUCCESS	42332.7574	42332.75741	WPI_Copy_2.1.4	WPI_Copy_2.1.4
1. UAT	1	SUCCESS	42332.75787	42332.75789	WPI_Copy_2.1.4	WPI_Copy_2.1.4
2. PROD	1	SUCCESS	42332.75792	42332.75794	WPI_Copy_2.1.4	WPI_Copy_2.1.4
0. QA	1	SUCCESS	42331.78978	42331.7898	WPI_Copy_trunk	WPI_Copy_trunk
0. QA	1	SUCCESS	42328.79882	42328.79884	WPI_Demo_v1.0	WPI_Demo_v1.0
1. UAT	1	SUCCESS	42328.79892	42328.79895	WPI_Demo_v1.0	WPI_Demo_v1.0
0. QA	5	FAILURE	42345.70502	42345.70506	WPI_Eval_trunk	WPI_Eval_trunk
0. QA	4	FAILURE	42341.86659	42341.86662	WPI_Eval_trunk	WPI_Eval_trunk
0. QA	3	FAILURE	42341.86549	42341.86553	WPI_Eval_trunk	WPI_Eval_trunk
0. QA	2	FAILURE	42341.85456	42341.85463	WPI_Eval_trunk	WPI_Eval_trunk
0. QA	1	SUCCESS	42332.69698	42332.697	WPI_Eval_trunk	WPI_Eval_trunk
0. QA	8	SUCCESS	42328.61569	42328.61572	WPI_Eval_v1.0	WPI_Eval_v1.0
1. UAT	3	SUCCESS	42328.6167	42328.61671	WPI Eval v1.0	WPI Eval v1.0

Figure 7.14: Imported table

- 8) It is best to have all time related columns displayed as a date. Click any “time” column and then right-click and select “Format Cells,” as seen in figure 7.15. Select the appropriate date:

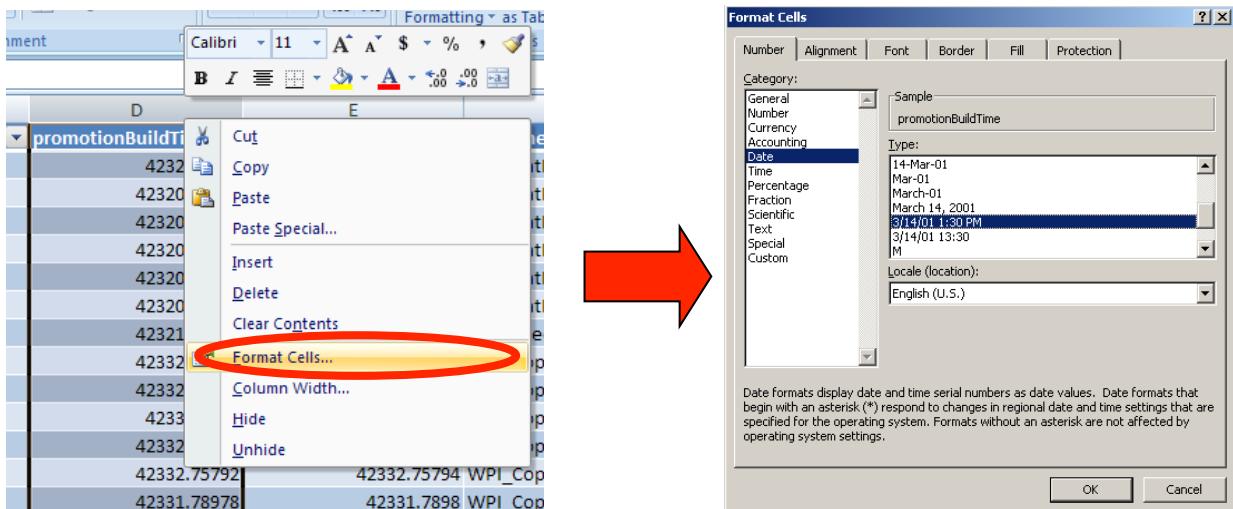


Figure 7.15: Format Cells

- 9) Next comes the pivot table creation process. Select a part of the table. In the “Table Tools, Design” tab, click “Summarize with PivotTable,” as seen in figure 7.16. Make sure the entire Table is selected, then click OK:

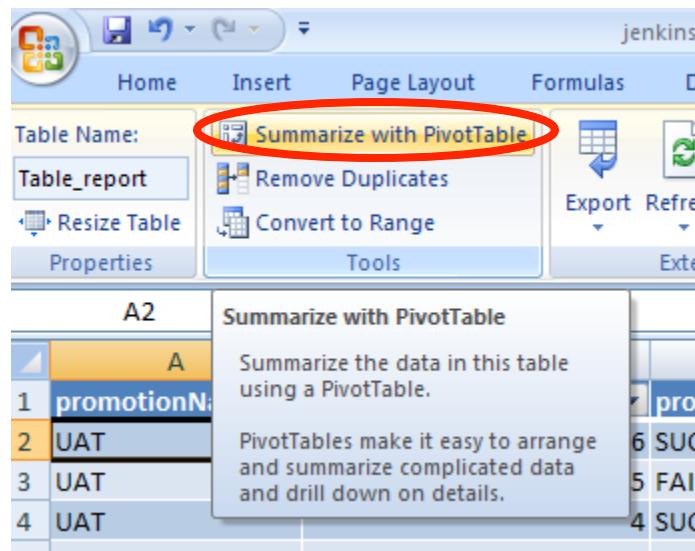


Figure 7.16: Summarize with PivotTable

10) You should now be on a new worksheet, with the following PivotTable Field List located on the right sidebar, like figure 7.17 shown:

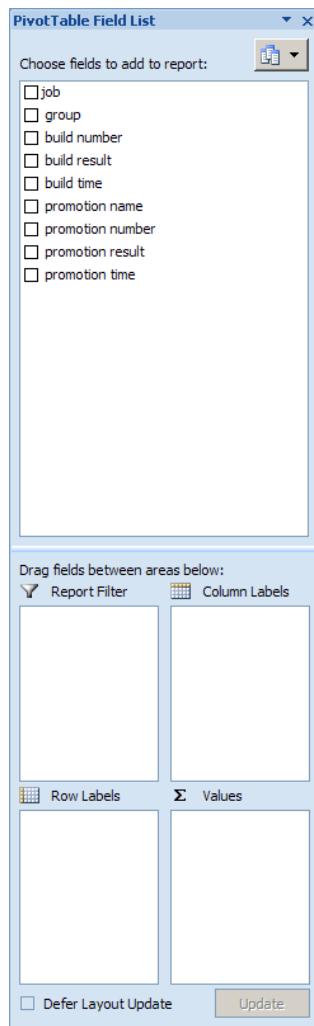


Figure 7.17: PivotTable Field List

11) Drag-and-drop the fields into the areas as shown below (dragging promotionBuildResult to Values should automatically set it as “Count”):

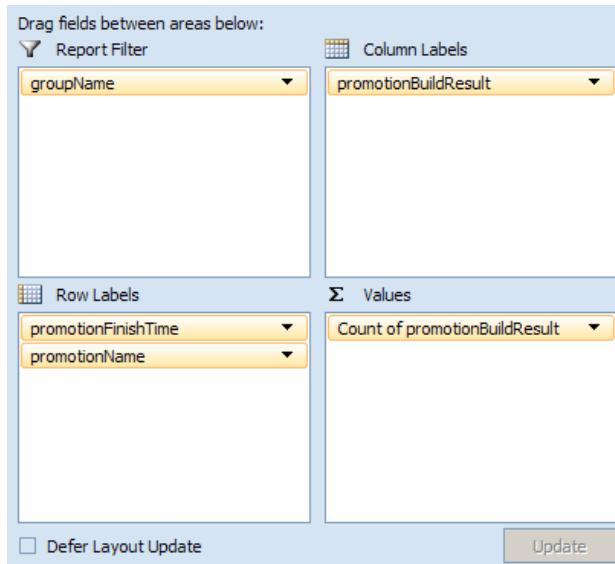


Figure 7.18: Customize row labels

12) Right-click any of the dates within the pivot table and click “Group”, as seen in the left of figure 7.19. Here you can select the start date and end date, as seen in the right of figure 7.19, as well as if you wish to view it by years, quarters, months, days, etc. For this tutorial, we will use months:

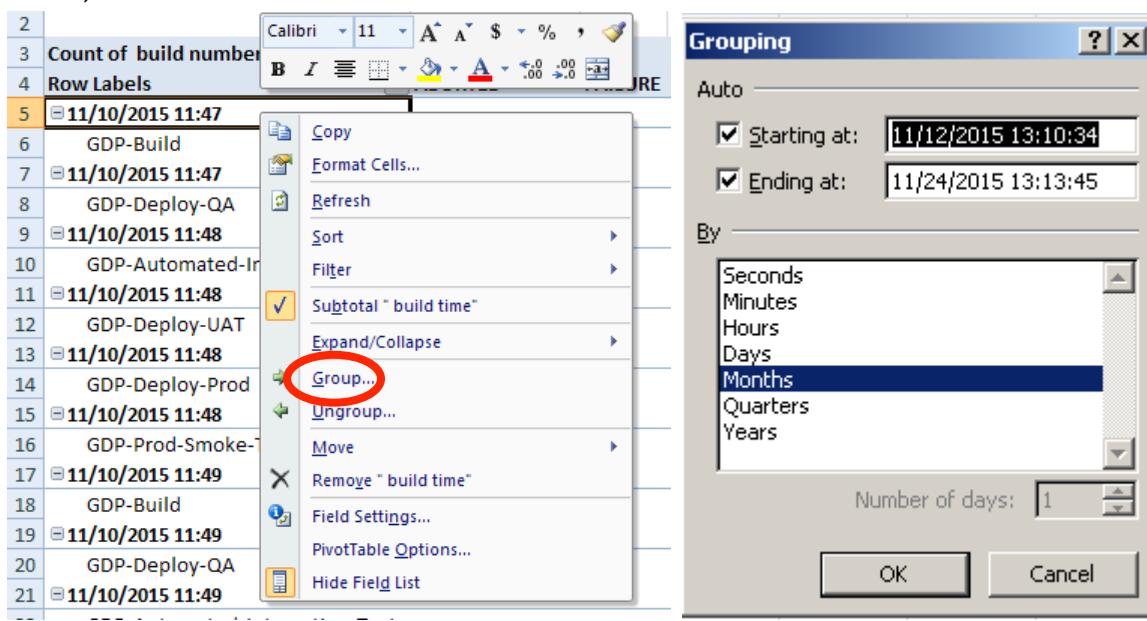


Figure 7.19: Group button (left) and grouping window (right)

13) Click anywhere in the pivot table. From the tabs at the very top, click “Options” under “PivotTable Tools.” Then click “PivotChart”, as seen in the left of figure 7.20. You can select any appropriate chart, as seen in the right of figure 7.20, but one suggestion is a “stacked column” chart. Now you have a pivot table and associated pivot chart! You can make any adjustments thanks to the versatility of pivot tables.

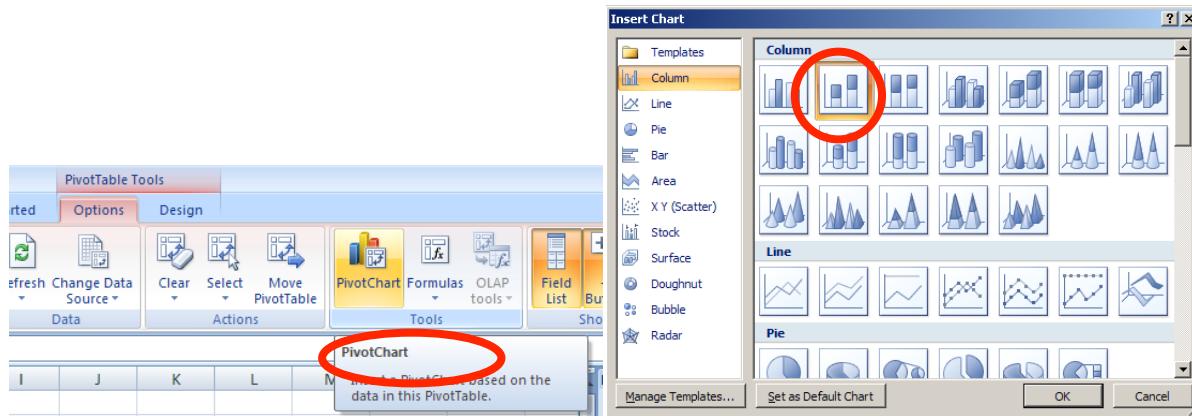


Figure 7.20: PivotChart button (left) and Chart style selection (right)

14) Figure 7.21 is the pivot chart for our example data set:

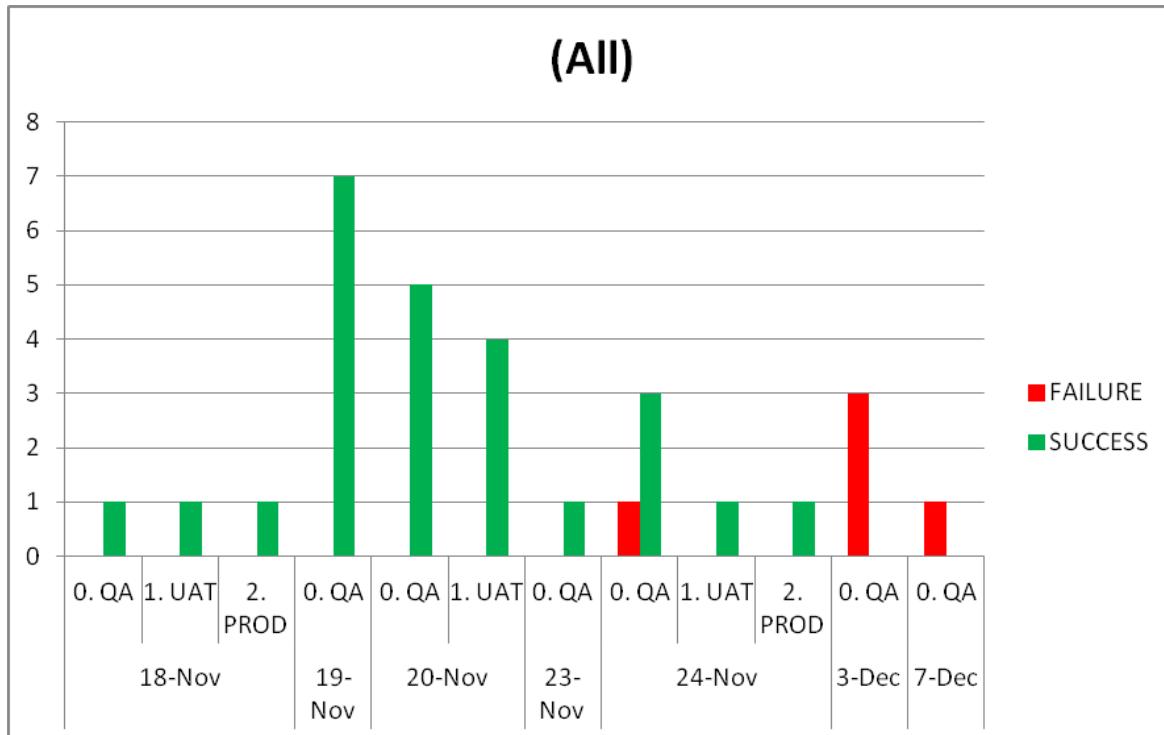


Figure 7.21: Sample pivot chart

If you would like to have only environments on the X-axis and the column bars being project names, then follow these steps:

15) Make sure the drag-and-drop fields are set up as shown in figure 7.22:

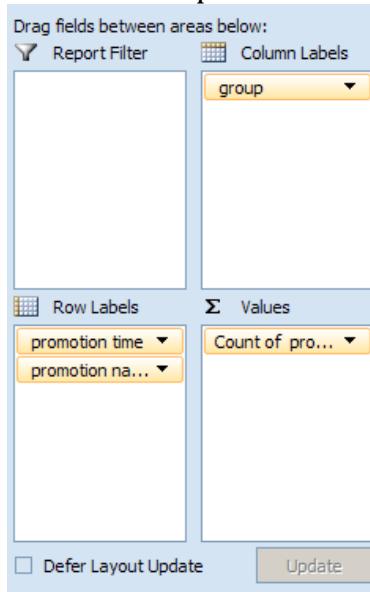


Figure 7.22: Customize columns and rows

16) Create a pivot chart from the new pivot table. Once again we recommend “stacked columns.” Now you have a pivot chart showing all environments for each month that has columns filled with total promotions per project. You can adjust the design as you see fit. Our example chart is shown in figure 7.23:

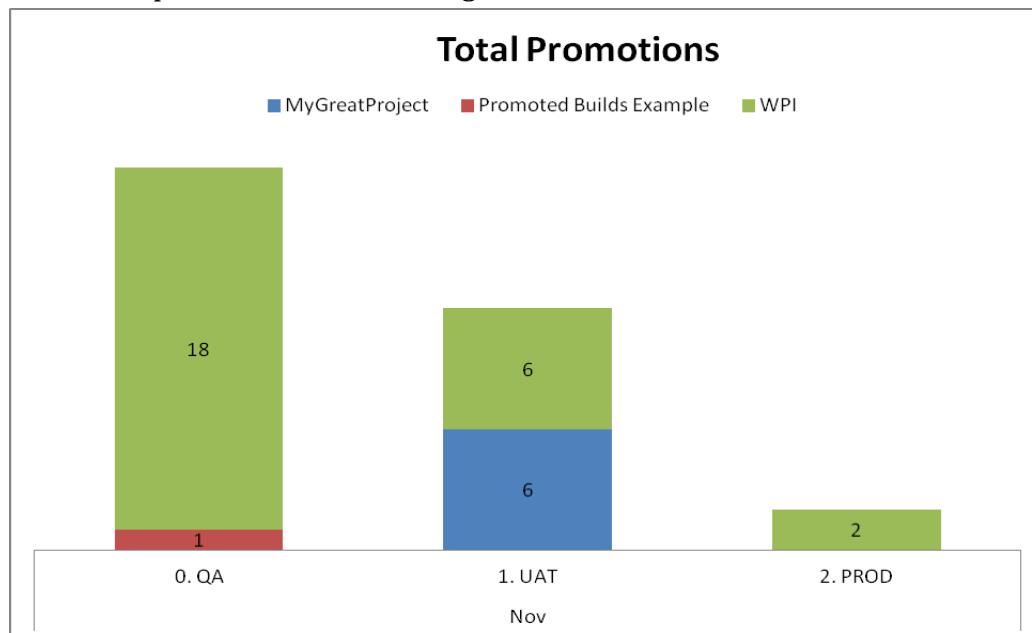


Figure 7.23: Sample chart

Appendix F: Excel Reports using CSV data

- 1) As seen in figure 7.24, from the first cell, in the above case it's G1, highlight all data until the last cell (you can accomplish this quickly by doing **ctrl+shift+right arrow key**, and then **ctrl+shift+down arrow key**).

	F	G	H	I	J	K	L	M	N	O		
1		job	group		build number	build result	build time	promotion name	promotion number	promotion result	promotion time	
2		MyGreatProject	MyGreatProject		5	SUCCESS	11/12/2015 13:21	1. UAT		6	SUCCESS	11/12/2015 13:
3		MyGreatProject	MyGreatProject		5	SUCCESS	11/12/2015 13:21	1. UAT		5	FAILURE	11/12/2015 13:
4		MyGreatProject	MyGreatProject		4	SUCCESS	11/12/2015 13:20	1. UAT		4	SUCCESS	11/12/2015 13:
5		MyGreatProject	MyGreatProject		2	SUCCESS	11/12/2015 13:12	1. UAT		3	SUCCESS	11/12/2015 13:
6		MyGreatProject	MyGreatProject		2	SUCCESS	11/12/2015 13:12	1. UAT		2	FAILURE	11/12/2015 13:
7		MyGreatProject	MyGreatProject		1	SUCCESS	11/12/2015 13:10	1. UAT		1	SUCCESS	11/12/2015 13:
8		Promoted Builds Example	Promoted Builds Example		1	SUCCESS	11/13/2015 11:28	0. QA		1	FAILURE	11/13/2015 11:
9		WPI_Copy_2.1.4	WPI		1	SUCCESS	11/23/2015 14:07	0. QA		3	FAILURE	11/24/2015 13:
10		WPI_Copy_2.1.4	WPI		1	SUCCESS	11/23/2015 14:07	0. QA		2	SUCCESS	11/24/2015 13:
11		WPI_Copy_2.1.4	WPI		1	SUCCESS	11/23/2015 14:07	0. QA		1	SUCCESS	11/24/2015 13:
12		WPI_Copy_2.1.4	WPI		1	SUCCESS	11/23/2015 14:07	1. UAT		1	SUCCESS	11/24/2015 13:

Figure 7.24: raw .CSV data set in Excel

- 2) In the left of figure 7.25, in the Insert tab, click PivotTable. Use the default selected table or range. In the right of figure 7.25, you may choose where you would like the PivotTable report to be placed; it will be placed in a new worksheet by default.

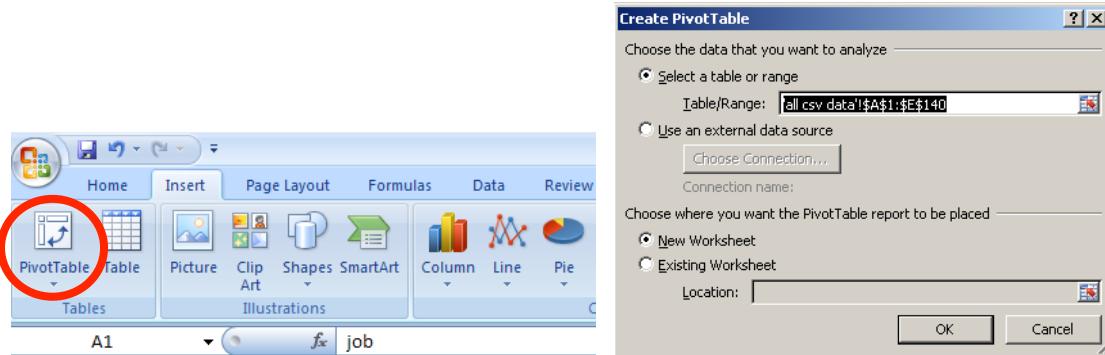


Figure 7.25: Insert PivotTable button (left) and create PivotTable window (right)

- 3) The following steps are similar to the instruction of reporting using SQL database.

Appendix G: Features of our pivot table configuration

Group report filter

By default, all applications and their respective information from the original data are displayed. Using group report filtering, you can specify either one or more applications to be viewable. Clicking the dropdown arrow next to (All) shows the other applications. See figure 7.26:

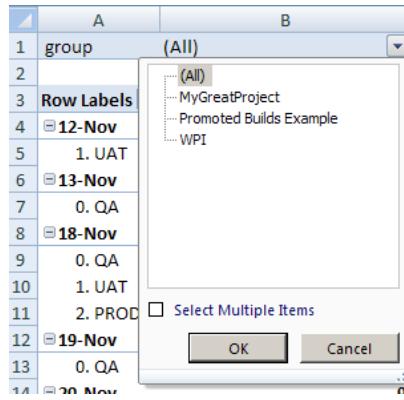


Figure 7.26: Group report filter.

Promotion result column label

Each value column represents a promotion result: SUCCESS, FAILURE, and UNSTABLE. You can change the ordering via sorting, or filter out to see only desired promotion results. Clicking the dropdown arrow next to Column Labels shows all promotion results. See figure 7.27:

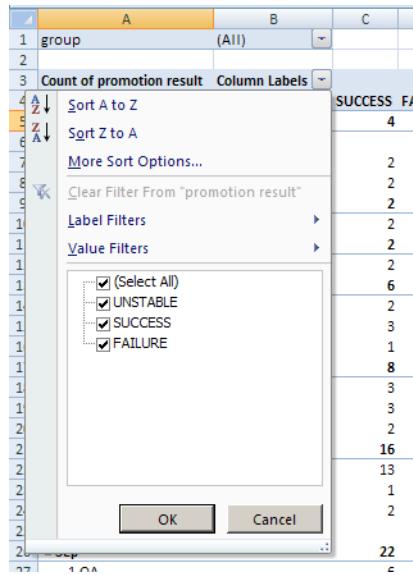


Figure 7.27: Promotion result column label.

Promotion time row label

Our pivot table configuration has it set up on a monthly basis. It's possible to change the promotion time grouping to daily, quarterly, annually, or a "X number of days" variation. You can also specify the end and start date range. Right click a month, select "Group" and change the date settings. See figure 7.28:

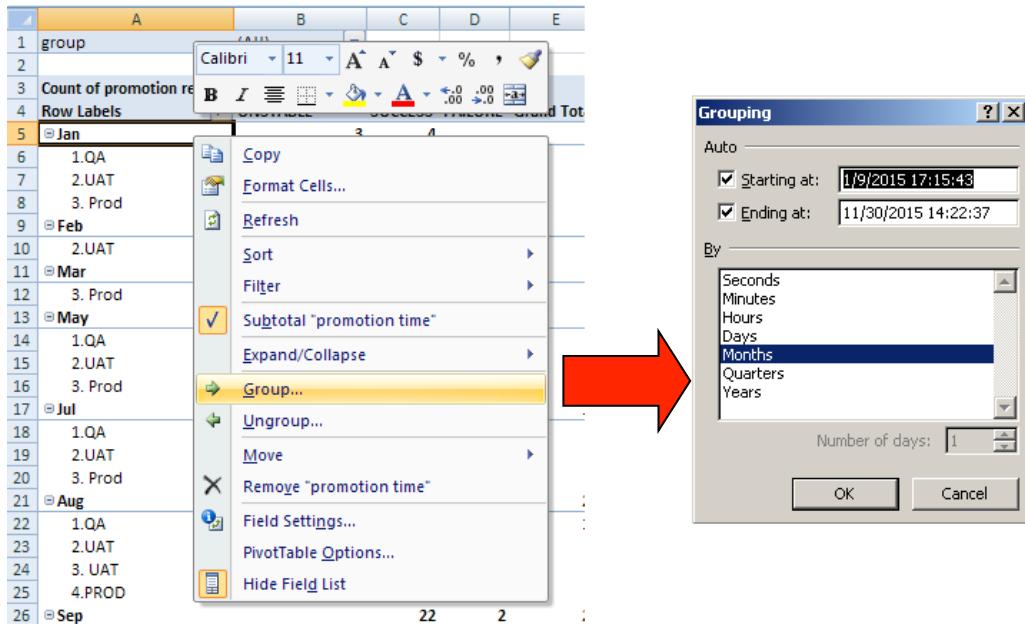


Figure 7.28: Promotion time row label.

Promotion name row label

By default, applications on Prime Financing's Jenkins have QA, UAT, and PROD promotion environments. It's possible to set up a custom promotion environment, such as DEV, in the onboarding process. One can set only certain promotion environments to be viewable in the pivot table. Click a promotion name and then click the dropdown arrow next to Row Labels to see all promotion environments. See figure 7.29:

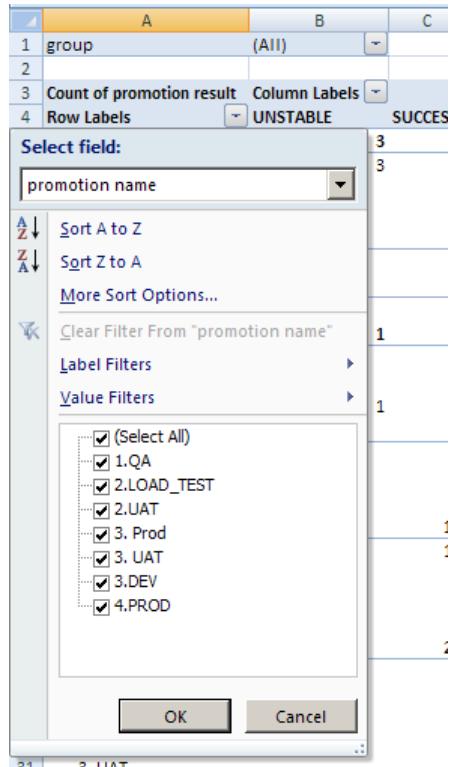


Figure 7.29: Promotion name row label.

The final pivot table/pivot chart as well as the SQL Database connection configuration can serve as a template for new reports for Prime Financing to create in the future. For example, say you're a manager for a group of application teams and you currently have promotion data for every month except December this year. Towards the end of December, if you manually tell Jenkins to extract the new data into the ongoing SQL database (or set Jenkins up to extract on a regular basis), then when you refresh the pivot table it will have the new December promotion information. One can adjust the refresh settings for the database table retrieval as well as pivot chart refresh. This helps in further removing manual steps for reporting. Additionally, when considering the promotion trend or even a forecast of the promotion count, one can easily use a trendline on top of the pivot chart, as seen in figure 7.30. The figure has a linear trendline that also forecasts two periods ahead. For our pivot chart configuration, the trendline can only be viewed for a specific promotion result.

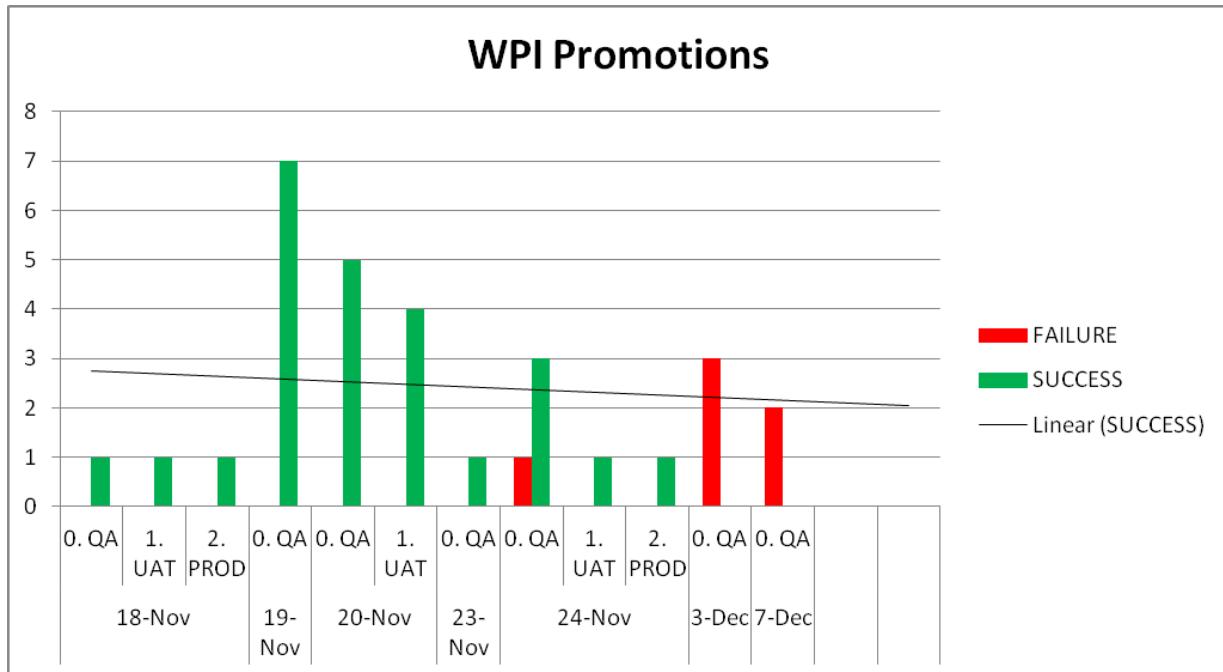


Figure 7.30: Pivot chart with trend line.

Appendix H: Dashboard View Plugin

Here are instructions on how to use the Dashboard View Plugin (Hayes & Ambu, 2015):

- On the Jenkins main page, click the “+” tab to start a new view wizard.
- Give it a name, and be sure to select “Dashboard” from the list of possible views as shown in figure 7.31

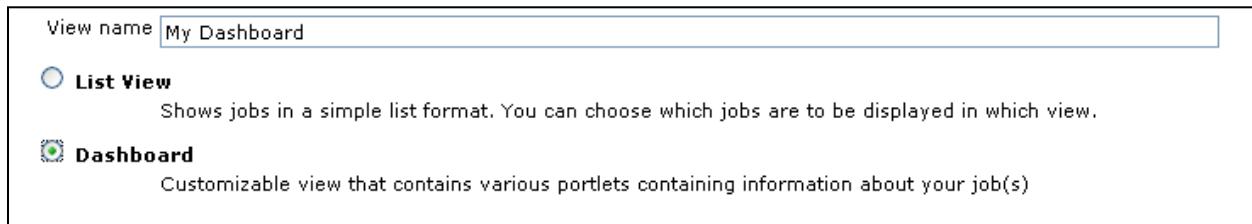


Figure 7.31: Add a new view when using Dashboard View Plugin

- For the new view configuration, besides selecting the appropriate jobs, the main area to focus on is the “Dashboard Portlets” area. You can add a dashboard portlet to the top, left column, right column, and bottom of the view. The view layout is as follows:

Top portlet 1	
Left portlet 1	Right portlet 1
Left portlet 2	Right portlet 2
Bottom portlet 1	

Default Available Portlets

There are several default available portlets within this plugin, and we introduce these portlets in this section.

Standard Jenkins jobs list

In Figure 7.32, this is the default Jenkins job list as seen in a normal Jenkins view.

All	Listy	New dash	+
Jenkins jobs list			
S	W	Name ↓	Last Success
		freestyle1	25 min - #2
		freestyle2	14 min - #2
Icon: S M L		Legend RSS for all RSS for failures RSS for just latest builds	

Figure 7.32: Jenkins jobs list under dashboard view

Job statistics

In figure 7.33, this portlet shows statistics based on jobs' health.

Job statistics		
Job health	Description	Number of jobs
	No recent builds failed	0
	20-40% of recent builds failed	0
	40-60% of recent builds failed	2
	60-80% of recent builds failed	0
	All recent builds failed	0
	Unknown status	0
Total jobs	All jobs	2

Figure 7.33: Job statistics under dashboard view

Build statistics

In figure 7.34, this shows statistics based on build status.

Build statistics			
Status of the build	Description	Number of builds	Percentage of total builds
Failed	Failed	2	50.0
Unstable	Unstable	0	
Success	Success	2	50.0
Pending	Pending	0	
Disabled	Disabled	0	
Aborted	Aborted	0	
Not built	Not built	0	
Total builds	All builds	4	

Figure 7.34: Build statistics under Dashboard View

Jobs grid

In figure 7.35, this jobs grid portlet displays a multi-column table a job's with current status, weather, clickable link to the job, and build button.

Jobs Grid			
  freestyle1	  freestyle2		

Figure 7.35: Jobs grid under Dashboard View

Unstable jobs

In figure 7.36, this shows the status, health, and a clickable link to an unstable job.

Unstable Jobs		
  freestyle2		

Figure 7.36: Unstable jobs under Dashboard View

Test statistics grid

Figure 7.37 shows detailed test data for the configured jobs.

Test Statistics		Success	Failed	Skipped	Total		
Job	#	%	#	%	#	%	#
4th job	0	0%	0	0%	0	0%	0
bar	1	50%	1	50%	0	0%	2
eit-insight-failing-jojo-1.x	0	0%	0	0%	0	0%	0
foo	0	0%	0	0%	0	0%	0
new-job	0	0%	0	0%	0	0%	0
stable	0	0%	0	0%	0	0%	0
Total	1	50%	1	50%	0	0%	2

Figure 7.37: Test statistics under Dashboard View

Test statistics chart

Figure 7.38 shows a pie chart of the configured jobs, including passing, failing, and skipped jobs, with total number and percentages.

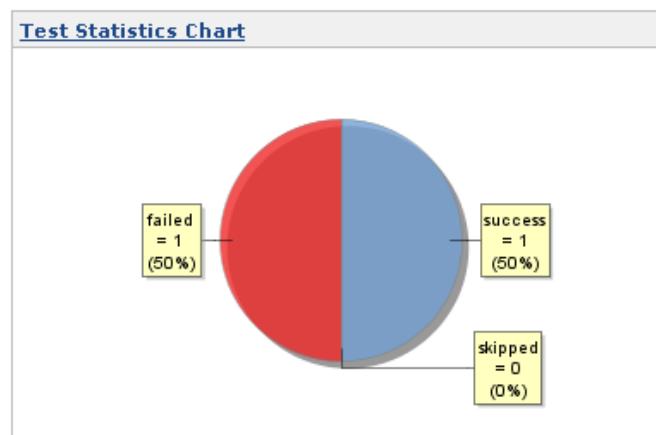


Figure 7.38: Test statistics chart under Dashboard View

Test trend chart

This is a chart, as seen in figure 7.39, which shows all tests over time in aggregate. For everyday, since the first job was built in the Dashboard View, the trend chart shows the total

number of passing, skipped, and failing tests in aggregate across the build. It assumes that if a build did not occur on a given day, the previous version of build results will be used.

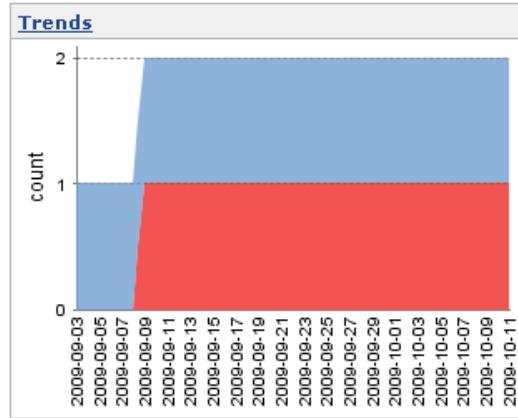


Figure 7.39: Test trend chart under Dashboard View

The plugin also has an Iframe Portlet, Image Portlet, and Slaves Statistics portlet available.

Below, figure 7.40, is an example of a full Dashboard view with default portlets:

The screenshot shows a Jenkins dashboard with several portlets:

- Jenkins jobs list**: Shows two jobs: freestyle1 and freestyle2. freestyle1 last success was 43 min - #2, last failure was 44 min - #1, and last duration was 0.21 sec. freestyle2 last success was 32 min - #2, last failure was 9 min 41 sec - #3, and last duration was 0.25 sec.
- Jobs Grid**: Displays icons for freestyle1 and freestyle2.
- Latest builds**: Lists the latest builds for each job, showing the build number and timestamp.
- Job statistics**: Shows job health, description, and number of jobs. Status: No recent builds failed (0), 20-40% of recent builds failed (0), 40-60% of recent builds failed (1), 60-80% of recent builds failed (1), All recent builds failed (0), Unknown status (0). Total jobs: All jobs (2).
- Build statistics**: Shows the status of the build, description, number of builds, and percentage of total builds. Status: Failed (3, 60.0%), Unstable (0), Success (2, 40.0%), Pending (0), Disabled (0), Aborted (0), Not built (0). Total builds: All builds (5).
- Test Trend Chart**: A chart showing test trends, which is currently empty with the message "No data available".
- Unstable Jobs**: Shows a single unstable job: freestyle2.

Figure 7.40: Dashboard View with default portlets

Additional Extend Portlets

Besides these default available portlets within the Dashboard View Plugin, new portlets can be contributed via other publicly available plugins or your own custom plugin.

Project Statistics plugin

In figure 7.41, this portlet is called “Number of builds” that shows each job’s successful, unstable, or failed builds (Ambu, 2015).

Project: Number of builds			
Job	Success	Unstable	Fail
freestyle1	4 (80%)	0 (0%)	1 (20%)
freestyle2	2 (50%)	0 (0%)	2 (50%)

Figure 7.41: Number of builds plugin

Project Build Times

The portlet, shown in figure 7.42, is called “RM Build Times Chart” which shows cumulative and separate build times (Rhine, 2014).

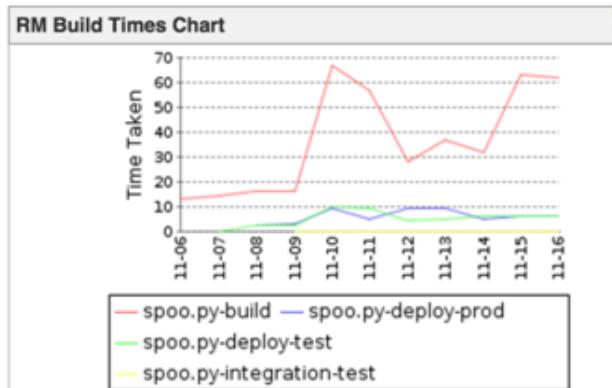


Figure 7.42: RM Build Times Chart

Latest Builds with Badges

As figure 7.43 shown, it is a new supportive plugin of Dashboard View called Latest Builds with Badges, which was created by our team. This plugin serves the same purpose as the default Latest Builds portlet, but with an additional column that shows the available badges associated with a job’s build, such as promotions, configuration changes and so on.

Latest Builds with Badges		
Job	Build	Time
freestyle1	#13	Nov 19, 2015 10:12:11 AM
freestyle2	#5	Nov 19, 2015 10:11:15 AM
freestyle1	#12	Nov 19, 2015 10:10:37 AM
freestyle1	#11	Nov 19, 2015 10:08:42 AM
freestyle1	#10	Nov 19, 2015 9:49:27 AM
freestyle1	#9	Nov 19, 2015 9:48:33 AM
freestyle1	#8	Nov 19, 2015 9:41:29 AM
freestyle1	#7	Nov 18, 2015 3:08:43 PM
freestyle1	nameeeee	Nov 17, 2015 12:05:47 PM
freestyle1	#5	Nov 16, 2015 2:24:29 PM

Badges

Figure 7.43: Latest Builds with Badges

Extensible nature of Dashboard View plugin

The Dashboard View plugin's architecture allows for extensions/custom portlets from any additional plugin. As retrieved from the plugin's wiki page, these general steps should be followed:

- Extend the DashboardPortlet class and provide a descriptor that extends the Descriptor<DashboardPortlet>.
- Create a jelly view called portlet.jelly.

For portlets that wish to use custom parameters such as a default number of builds to show, one can do that as follows:

- Create a jelly file called config.jelly to be used when the portlet is configured.
- Modify constructor (with @DataBoundConstructor) to receive the new parameters.

Trial and error can help with the creation process, as well as simply looking at the source code for Dashboard View or any extension plugins such as the previously mentioned ones.

Examples of sample code for an extension plugin are shown in figure 7.44 and figure 7.45.

```

import hudson.plugins.view.dashboard.DashboardPortlet;

class MyPortlet extends DashboardPortlet {

    @DataBoundConstructor
    public MyPortlet(String name) {
        super(name);
    }

    // do whatever you want

    @Extension
    public static class DescriptorImpl extends Descriptor<DashboardPortlet> {
        @Override
        public String getDisplayName() {
            return "MyPortlet";
        }
    }
}

```

Figure 7.44: sample code of MyPortlet.java (Hayes & Ambu, 2015)

```

<j:jelly xmlns:j="jelly:core" xmlns:st="jelly:stapler" xmlns:d="jelly:define" xmlns:dp="/hudson/plugins/view/dashboard" xmlns:l="/lib/layout" xmlns:t="/lib/hudson" xmlns:f="/lib/form">

<dp:decorate portlet="${it}"> <!-- This is to say that this is a dashboard view portlet -->
<tr><td> <!-- This is needed because everything is formatted as a table - ugly, I know -->

<!-- you can include a separate file with the logic to display your data or you can write here directly -->
<div align="center">
    <st:include page="myportlet.jelly"/>
</div>

</td></tr>
</dp:decorate>
</j:jelly>

```

Figure 7.45: sample code of portlet.jelly (Hayes & Ambu, 2015)

Appendix I: Extension of High Speed Equities Trading Research Study

1. Introduction

In January 2015, Hans R. Stoll published a study in the *Asia-Pacific Journal of Financial Studies* examining High Speed Equities Trading, A.K.A. High Frequency Trading (HFT), and its effect on the general market during the years 1993 to 2012 (Stoll, 2015). This appendix seeks to examine Stoll's study and attempt to replicate and extend a number of his findings using publicly and freely available data. In particular we aim to expand his observations through the most recent few years to determine if the conclusions that he had drawn remain relevant and accurate in the context of this new information. While Stoll used data from both the New York Stock Exchange (NYSE) and Nasdaq/OMX to support his claims of the effect that HFT has on the market, our team focuses only on collecting and analyzing data from the NYSE which would both limit the scope of our research and allow more focus on extending the existing conclusions to the current day. Our conclusions are drawn from this research and seek to bolster the conclusions Stoll formed as well as introduce our own analysis of the data to determine the implications of HFT on the greater market.

2. Background

With the rise of computing technology, and the introduction of this technology into the financial sector, a family of algorithmic trading strategies known broadly as High-Frequency Trading (HFT) emerged. This set of strategies takes advantage of electronic trading tools that have replaced human brokers, as well as low-latency technology and high-speed connections to perform trades precisely and efficiently. These tools allow traders to implement new techniques such as algorithmically trading short-term positions quickly and in high volumes to make a profit on the minute margins of change in equity prices. They also, however, allow techniques such as "quote

“stuffing” which attempts to deny information to other traders by overwhelming the trade queue with quotes that are then rescinded at the last minute. These strategies, and other derived strategies, however, have been criticized as contributing factors to so-called “flash crashes” that have cost investors trillions of dollars.

One of the more well known flash crashes was the crash of May 6, 2010. In less than an hour, securities such as the Dow Jones, Nasdaq Composite, and S&P 500 all collapsed and rebounded very quickly; the Dow Jones in particular dropped more than 600 points before rebounding. Nobody expected or could predict the 2010 flash crash. One of the most discussed potential reasons for the flash crash is HFT, since one can execute a technique in HFT where the computer program would set up a large trade to be placed, but then cancel it at the very last second. This technique known as quote stuffing, as previously defined, allows traders to artificially manipulate the market. It can also disrupt the market and cause extreme anomalies as seen in the 2010 flash crash.

3. Data

To investigate the effect of HFT on the market, and to replicate as well as extend Stoll’s research paper, our team analyzed data from the New York Stock Exchange (NYSE), both for the full exchange and individual equities. Due to time constraints as well as the resources available to us, we chose to only extend the study’s analysis for the NYSE rather than also including analysis on the Nasdaq as seen in Stoll’s paper. In order to reproduce the results from the study, the team examined 300 total NYSE stocks with data available from 1993 until present; we grouped 100 stocks from each of three market capitalization groups: large, mid, and small cap. Market capitalization is calculated by multiplying a company’s shares outstanding by the current market price of one share (Market Cap, 2016). This data was pulled and analyzed from Yahoo Finance using python scripts to access their API. We then used the available data for these stocks to calculate several relevant measures to determine the potential impact of HFT on the NYSE during this time. The result of the team’s investigation follows.

4. Trade size and trade frequency

The first measurement the team attempted to replicate from the study was the change in average trade size of transactions on the NYSE during the period in question. Since the requisite data to calculate this measure for individual stocks was not freely available, the team compromised to compare Stoll's study's findings to our examination of trade size changes across the entire exchange of the NYSE. We used the data available on the NYSE's website (NYSE, 2016) to find the daily values for the amount of available shares in the exchange and the amount of trades on the given day. We had to concatenate the 1993-2000 data with the recent 2000-present data in order to consider all values. The average trade size on a given day was calculated by taking of the total amount of shares available and dividing by the amount of trades done. The average trade size in shares is plotted for comparison and analysis in Figure 1.

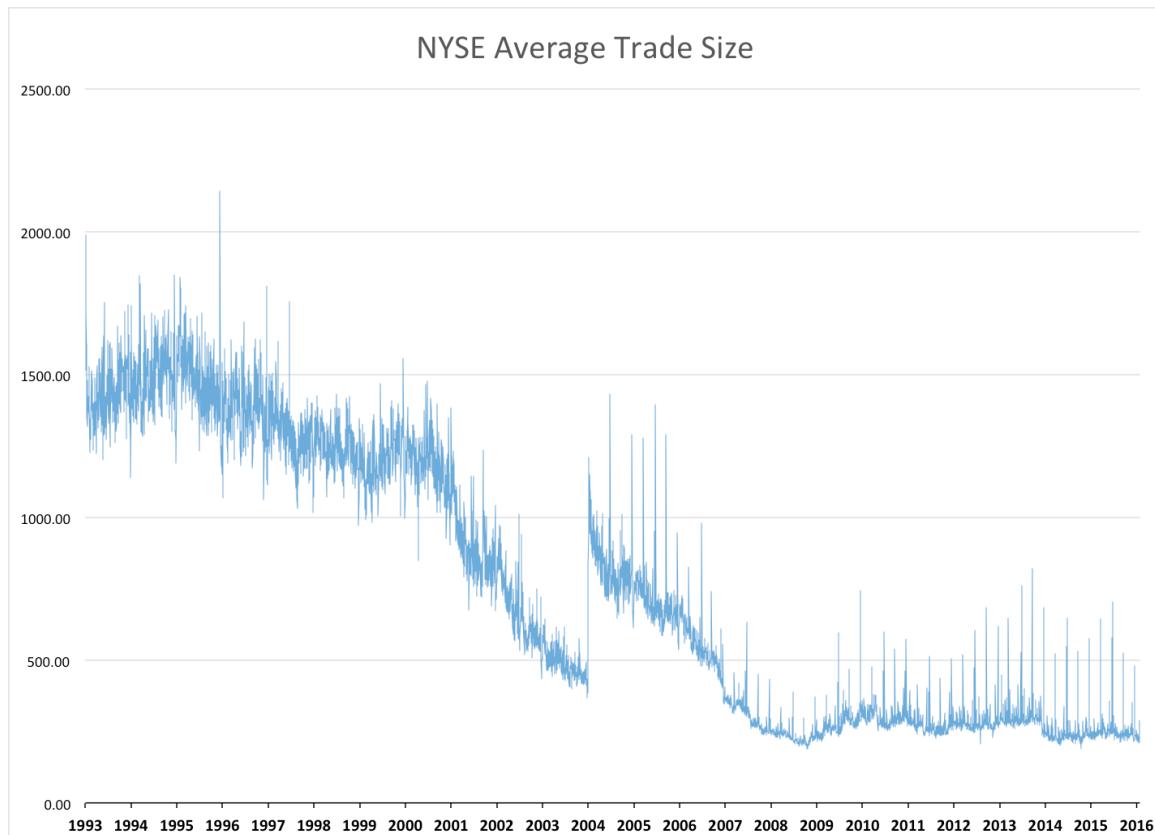


Figure 1: Average trade size across the NYSE for years 1993-2015

It's worth noting the spike anomaly in our graph at around the beginning of 2004. This is due to an inconsistency in the data that is provided by the NYSE through the Consolidated Tape Association (CTA) which provides "supplemental" trade data for trades prior to January 2004, but not for trade data after this date. This inconsistency manifests itself as a sharp jump in the calculated Average Trade Size at that time due to a decrease in the reported number of trades performed.

When looking at the overall trend of the NYSE's average trade size across time, Stoll's research paper found a steady decrease in recent years in average trade size. This correlates with an increase in the use of algorithms to perform trades quickly as well as a decline in the auxiliary costs in performing trades that would allow for traders to perform a higher number of smaller volume trades. Fortunately, ignoring the spike in the beginning of 2004, our data fits this trend as well, demonstrating that the effect is consistent even across the exchange as a whole and in the recent years of 2012-2015.

5. Effect of high frequency trading on market quality

5.1 Bid-Ask spread

One of the suggested effects of the introduction of high speed trading was a decrease in the bid-ask spread on average. The Stoll paper suggests a trend downwards with a sharp decline in 2001 that they attribute to a switch from fractional to decimal stocks, and a general downward trend thereafter.

In order to calculate bid-ask spread we used an estimator as described in Corwin and Shultz's research paper using daily high and low prices (Corwin et al., 2012). As seen in Figure 2, we do not see a similar dramatic drop in 2001 that was attributed to a change from fractional to decimal pricing, which may be a result of the estimator assuming that bid-ask spread is continuous rather than discrete. We do however see, from 2003 to 2007 bid-ask spread is mostly constant, and after 2010 it is as well, which suggests that even with the introduction and adoption of high speed

trading, we do not see a significant drop in the average bid-ask spread in the market. This matches Stoll's observation that "there is no indication that spreads increased after 2005 as HF trading became more common," (Stoll, 2015, p.777). We do see a slight downward trend for bid-ask spread for the high-cap group continuing after 2013, which may suggest an effect, however note that the decrease is seen after average trade size has stabilized.

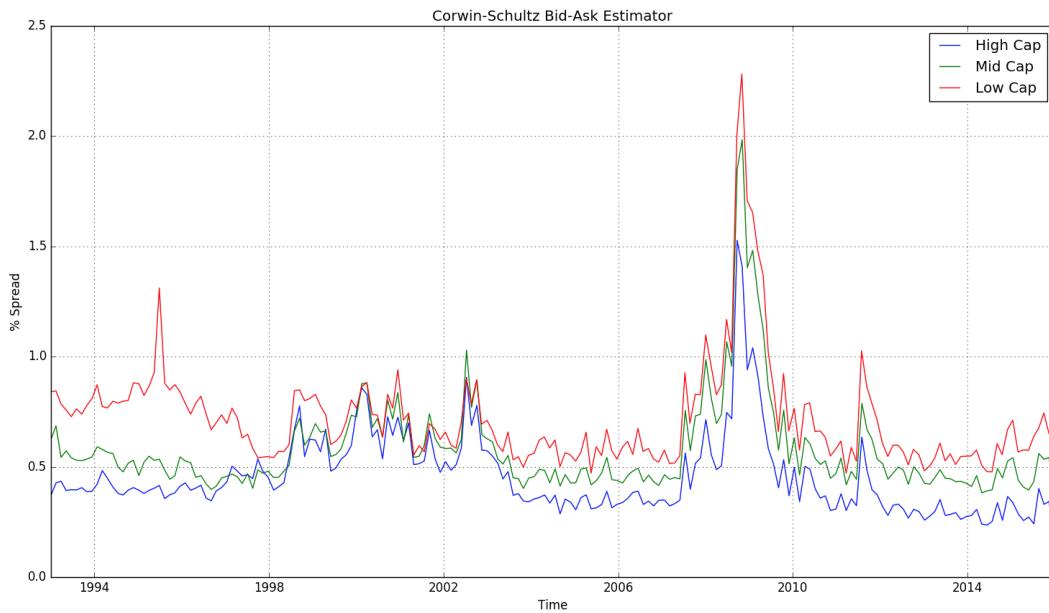


Figure 2: Percentage spread of Corwin-Schultz bid-ask estimator.

5.2 Volatility

In a similar vein to Stoll's paper, we wanted to see if the effect of HFT has any effect on volatility in the market, especially when looking at recent years. Generally speaking, one would guess an increase in volatility because of the large and rapid amount of trades occurring during HFT. One of the methods of calculating volatility that Stoll used was to compute the intra-day variance of trade-to-trade prices and then average them for the designated month. Unfortunately our team did not have access to intra-day data for our chosen stocks. We decided to use the second method from Stoll's paper which involves calculating variance of daily stock returns.

For each of the market cap stock groups, we retrieved the daily close prices and calculated the average of all the stocks for a designated day. We then calculated the 365-day variance of our average daily close prices and plotted our results across time as seen in Figure 3.

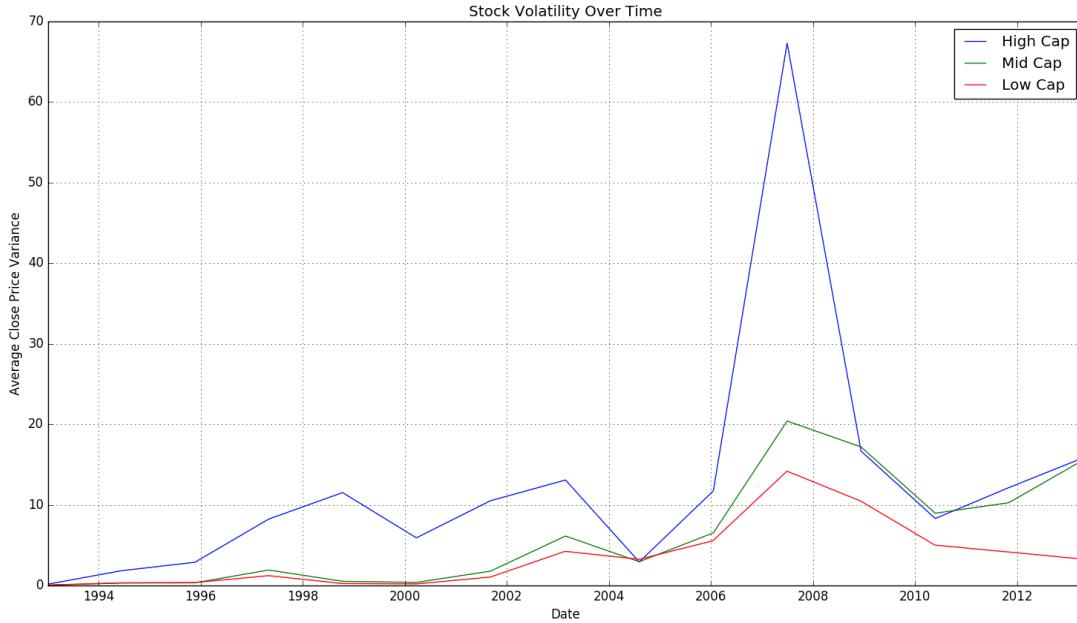


Figure 3: Variance of daily NYSE stock returns.

When comparing our figure to Stoll's daily variance volatility graph, our figure follows the same general trend. From just looking at the high cap stocks, the dot-com bubble and the 2007-2008 financial crisis are very pronounced. The stock volatility generally hovers around the average close price variance of 10, with the exception of anomalies. Our volatility analysis suggests that HFT can be correlated with the gradual increase in volatility over the recent years.

6. Conclusion and comments

Although the introduction of electronic trading began around 1999 after electronic exchanges were authorized by the Securities and Exchanges Commission in 1998 (SEC), it is important to remember that the introduction and usage of HFT started becoming more prevalent around 2005. Taking this into consideration and when looking at the average trade size trend, the average trade size has decreased as expected. This downward trend coincides with the introduction

and continued adoption of HFT. We also can observe that the average trade size reaches a level of saturation after the 2007-2008 financial crisis. One might infer that for the average trade size to reach this steady level, the proportion of traders who use HFT has plateaued, leading to a stability in this measure.

When looking at our results for bid-ask spread, although our analysis used a bid-ask estimation formula, it is clear that bid-ask spread has stayed steady since the introduction of HFT around 2005 - ignoring the 2007-2008 crisis anomaly. Even in the years of increased HFT adoption in the later years, bid-ask spread does not seem to correspond with the adoption of HFT.

In regards to HFT's effect on volatility on the NYSE, it can be inferred from our volatility analysis that HFT could be a factor in the gradual increase in volatility on the overall market. After 2005, even when ignoring the spike of the financial crisis, volatility has steadily increased across the recent years. This can be correlated with the increase in trade activity thanks to the rapid nature of HFT.

We can therefore conclude that there is no evidence that the introduction of HFT has a meaningful, negative impact on the market, at least in the case of the NYSE and based on the measurements we have examined. Our result is consistent with the result of Stoll's paper where he also concludes that HFT failed to have a negative effect on the market.

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