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**A Case Study of
Lean Software Practices in an IT Application Support Department**

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Lean Software Practices in an IT Application Support Department**

by

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A Case Study of Lean Software Practices in an IT Application Support Department

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The University of Texas at Austin, 2011

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The concept of lean manufacturing was formed at Toyota by Taiichi Ohno, who originated the system of “Just-in-Time” production with the goals of delivering high value and cutting down waste. These concepts were partially adapted to software development in an Agile development context [1] where the goal is to deliver value to the customers more quickly by eliminating waste and improving quality. However, we are not aware of any published attempt to adapt lean principles to IT maintenance work.

The purpose of the case study reported here is to demonstrate that the principles of lean software development could be effectively applied to a specific IT application support department. It is an empirical study of lean practices in the maintenance department of a large organization. A comparison was made from the collected data from our release management tool before and after applying the lean principles to our IT group. Our analysis shows that the lean principles improved the developers’ focus on the given corrective or preventive task. Application quality also improved to a significant extent. More importantly, our customers did see more efficient support efforts that delivered good quality in a shorter time. All in all, the newly conceived support process

adapting lean principles to our situation did, in fact, deliver more highly valued software to our customers more quickly while cutting down waste. On the other hand, we also learned that there were some challenges that arose from a conflict between the new lean practices and our previous practices. The most significant of these conflicts was revealed in developer work load imbalances and customer confusion due to having to communicate with different IT support teams for different type of maintenance requests. A future adjustment of how the lean principles can be applied to IT maintenance may be necessary.

Table of Contents

List of Tables	ix
List of Figures	x
Lean Principles and Software Development.....	1
Introducing Lean Principles and Practice	7
Defining Lean IT Support.....	8
Re-organizing the Lean Support Team	9
Lean Objectives and How they were addressed	11
Deliver Customer Needs Fast	11
Eliminate Waste	12
Estimate Support Efforts.....	13
Build Quality In	14
Create Knowledge.....	15
Defining the Measures for Improvement.....	16
Waste Reduction	16
Customer Satisfaction	16
Employee Productivity.....	17
Software Quality	17
Time To Market.....	18
Data Collection And Analysis Methods	19
Results of Lean Practices Implementation.....	21
Customer Satisfaction Increased.....	21
Productivity Improved	23
Quality of Maintenance Effort Improved	25
Time To Market Improvement Unknown.....	27

Conclusion	28
Appendix.....	30
Acronym Table	30
Bibliography	31

List of Tables

Table 1:	Request Priority	12
Table 2:	Average Request Completing Days	23
Table 3:	System Failure Hours.....	24

List of Figures

Figure 1:	Organizational Context: Before Introducing Lean Principles	4
Figure 2:	IT Support Task Process	5
Figure 3:	Developer's Assignments	8
Figure 4:	Organizational Context: After Introducing Lean Principles	10
Figure 5:	System Availability.....	21
Figure 6:	Implemented Requests	22
Figure 7:	Average Request Completing Days	23
Figure 8:	Waste Reduction	24
Figure 9:	Average Hours of Implementing One Request.....	25
Figure 10:	Quality Improvement	26

Lean Principles and Software Development

In the late 1940s, Toyota, now the world's largest car manufacturing company, confronted typical problems: waste and low quality. They worked to eliminate seven forms of waste (overproduction, time on hand, transportation, processing, stock at hand, movement and defective products), developing a process now known as lean manufacturing. In Toyota's lean thinking, anything that does not create value for a customer is waste.

In the book "Lean Software Development: An Agile Toolkit" [1], the authors introduced their concept of applying lean principles to software development in an Agile context by giving seven fundamental areas for "lean" software development:

- Eliminate waste
- Build quality
- Create knowledge
- Defer commitment
- Deliver fast
- Respect people
- Achieve Optimization

There are few papers on case studies of lean software development. [3,4,5]. As software quality affects multiple sectors of the company, it is essential to a company to focus on widening its efforts rather than just being confined to the software developers [6]. A major implementation issue is that lean software development may require drastic changes in the way an organization is managed.

After an extensive search of the published literature, no articles were found that describe how to apply lean principles to an IT application support situation. That gap in the literature motivated this study of such a situation. This report is about an IT maintenance group and their three year journey into leanness. Their progress was tracked as a case study in the application of lean principles to IT application support.

Organizational Context: Before Lean

The IT organization of the studied company A comprised of two main departments, namely the IT Development Department, and the IT Support Department. There are application development teams named, for example, the Application A project team, Application B project team, etc. Every large development project is implemented by a development team, and after system deployment, the maintenance and support department takes ownership of the applications in order to perform the ongoing maintenance work.

The Support Group which is focused on supporting application systems was chosen for this case study reported in this paper. The same 100 developers were in this support group both before and after this case study. Before there were nine business applications focus support teams in this group. The groups' organization context before the case study is shown in Figure 1.

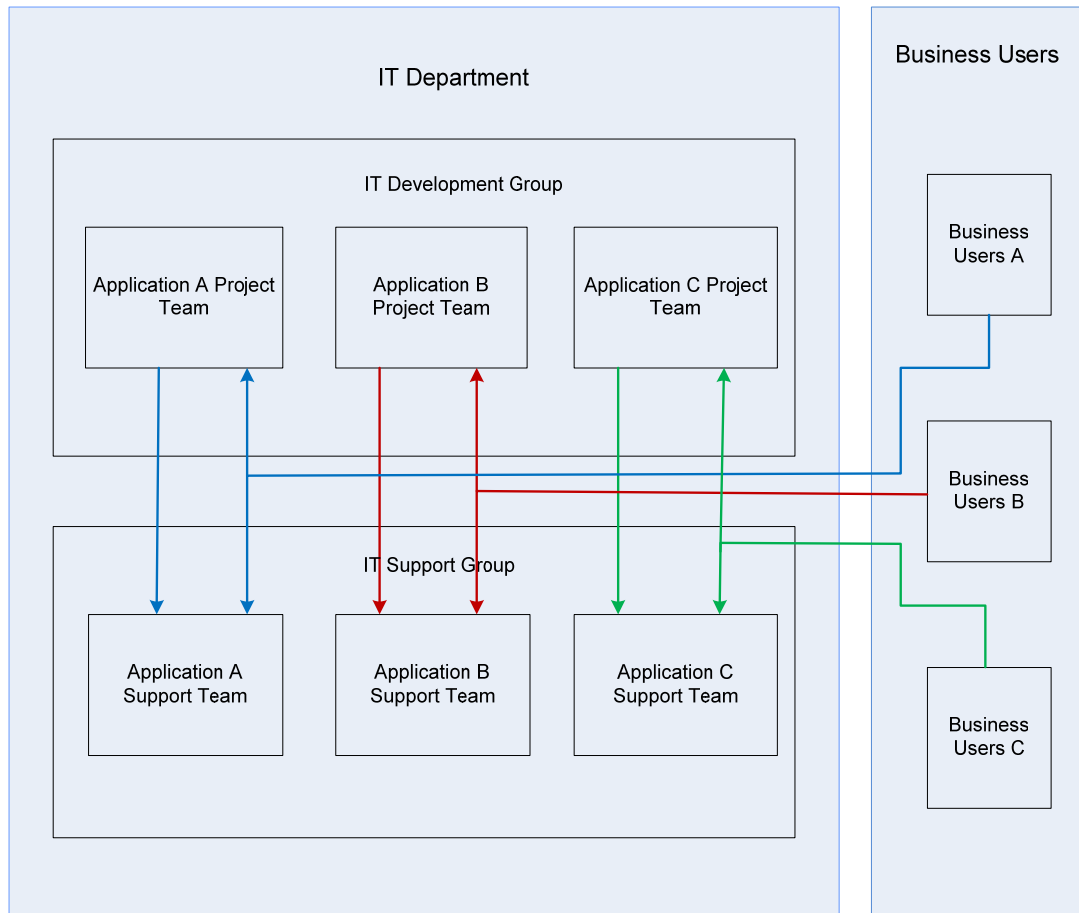


Figure 1: Organizational Context: Before Introducing Lean Principles

The Application A Support team supported business application A which had been implemented by the Application A project development team. The responsibilities of the staff in support team A were to fix application A production defects, implement application A small enhancements, and all maintenance work related to application A. The same application focus model applied to all the other support teams in the IT Support Group.

Software support is an important phase in the software development life cycle. The more effective the system support effort is, the higher the stability and availability of IT system capabilities provided to the customers will be. The

application support team is very important to the company to ensure the high quality and availability of support to customers [7]. Maintenance consists of four parts:

- Corrective maintenance, which deals with fixing bugs in the code
- Adaptive maintenance, which deals with adapting the software to new environments
- Perfective maintenance, which deals with updating the software according to changes in user requirements
- Preventive maintenance, which deals with updating documentation and making the software more maintainable

System support tasks are usually small and lifecycles are very short. Each support task that planned to be released to production had a change request (CR) in a release management tool. This release management tool was used to record all the related data right from the change request priority, baseline business requirements, to system analysis, design document and impact analysis document to start date, release date, test cases, testing sign off, related defects, system outage. Figure 2 shows the application support task process as it is tracked as a CR in the release management tool.

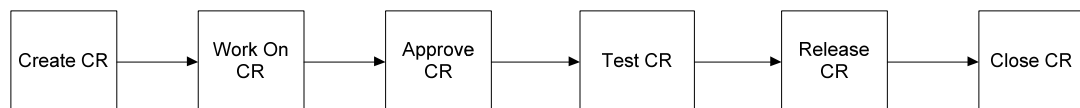


Figure 2: IT Support Task Process

The main value produced from IT support group to their business partners are always increased application availability, improved application quality, decreased high production defects, and in-timed implemented small change

requirements. Even though the support team believed that they were doing a good job, the disheartening comment from their business partner (representing the Application A users) was **“though there is a cost, there seems to be no value.”**

Introducing Lean Principles and Practice

In order to address that perceived problem, new practices based on lean principles were implemented in the IT support group in late 2009 with the goal of delivering more value to the customer in order to increase their level of satisfaction. There were two main areas of change in practices introduced into the IT maintenance department based on lean principles, namely creating a leaner organization and also creating a leaner support process. Both areas are described in the following paragraphs.

IT SUPPORT BEFORE LEAN

Before applying Lean practices in the IT support group before, each support team in support group was responsible for all system maintenance and support works related to all systems. The primary responsibilities of all developers were similar and shown as:

- Monitored systems and ensuring it's high availability
- Assigned task of upgrading and validating software or license of the systems
- Analyzed system defects of the system and applied corrections
- Worked on small change requirements from the business partner

An example as shown in Figure 3 is one developer in old support team's assignments in 2 weeks. It stated he had to stop his defect and small enhancement assignments to start a new assignment of fixing system failure. But only after the system failure had been solved he continued his defect assignment in the following week. Thus, there is a handoff of assignments resulting in identifying waste.

ID	Task Name	Start	Finish	Duration	Jan 2009													
					5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Defect assignment	1/1/2009	1/6/2009	4d	█													
2		1/12/2009	1/14/2009	3d														
3	Small Enhancement assignment	1/5/2009	1/7/2009	3d	█													
4		1/14/2009	1/16/2009	3d														
5	Application Failure	1/7/2009	1/9/2009	3d														
6	Software Upgrade	1/15/2009	1/16/2009	2d														

Figure 3: Developer’s Assignments

All remaining nine system support teams had similar responsibilities, but to support other different system applications. Every developer worked at a frantic pace, but the business users still complained about the availability -- that was still around 97-98 -- which is not the required goal. The end users complained that the system response time was too slow and there were still some defects in system for a long time. There were similar issues in every team. In spite of their best efforts, productivity remained low and business partners were not convinced of the teams’ value. Therefore, the company decided to implement the Lean IT Support team process in late 2009.

DEFINING LEAN IT SUPPORT

The core idea of leaner IT support teams is maximizing customer value by minimizing waste. A lean organization must understand customer values and focus its key processes continuously to meet or exceed customer expectations. This ensures provision of more value to customer, and with fewer resources. Leaner team solves the issue of low productivity and lower customer satisfaction using the current support group.

Lean principles in support group practices were the concept of “Task Focus.” By focusing the tasks, both managers and developers were grouped on the

basis of specific support tasks. Developers focused only on assigned single type of support task, rendered more effective assignments and improvement of productivity, thereby produced more value with which to satisfy the business partner and end users. For example, task of fixing system defects is one of the most important tasks in the support team to provide quality system to users. Given that, a Corrective team was formed that the developers' responsibility was only to fix system defects. The leaner organization was described in the following session.

RE-ORGANIZING THE LEAN SUPPORT TEAM

The organization chart shown in Figure 4 shows how the support teams were re-organized based on the specific type of support tasks that they performed. Support task types include, for instance, defect fixing, small enhancements, etc. In this new organization model, staffs on the Corrective team only work on fixing defects for all systems. Similarly, staffs on the Perfective team only work on small enhancement tasks for all systems.

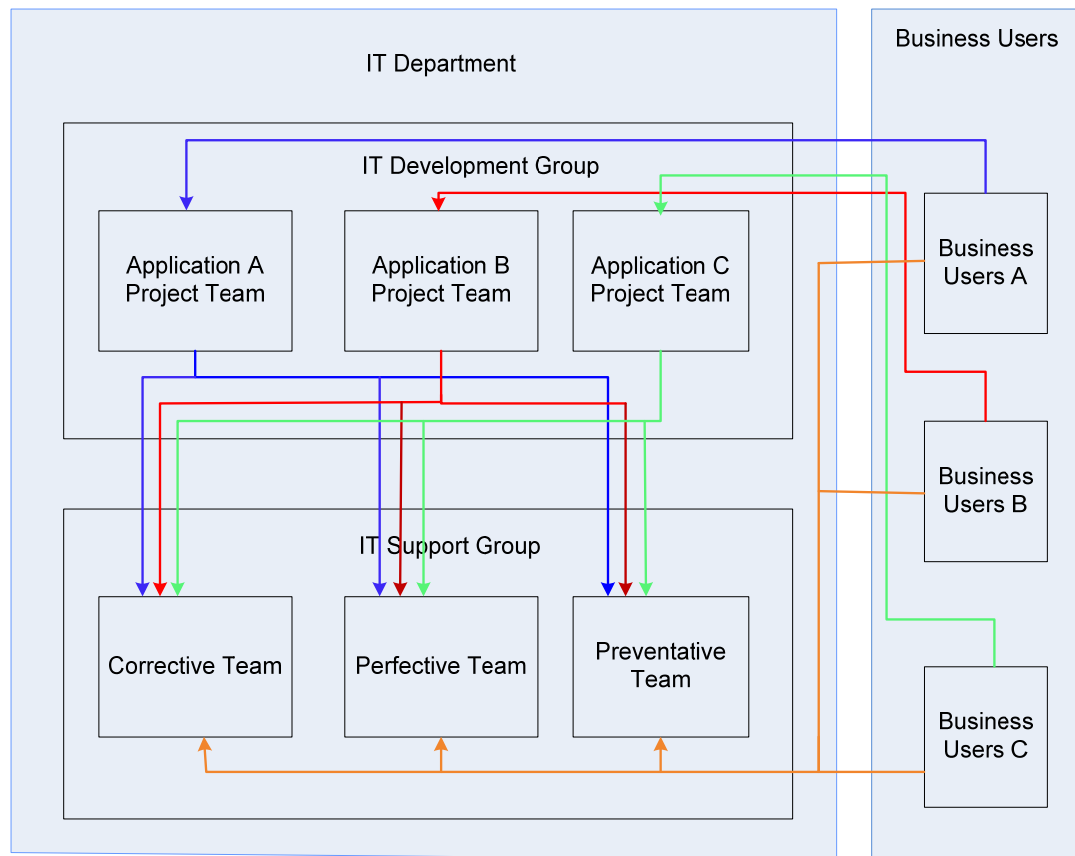


Figure 4: Organizational Context: After Introducing Lean Principles

- Preventative Team: This team worked on monitoring the deployed applications to fix System Failure (SF) for all system. A System Failure occurs when the system no long delivers a service to end users. The responsibility of this team was creating a System Failure in release management tool, fixing the root cause of the System Failure, and returning back the system to service.
- Adaptive Team: This team only worked on software upgrades and maintenance.

- Corrective Team: This team only worked on the system defects analysis and fixes. If system defects were reported, a defect Change Request was created and assigned to corrective this team.
- Perfective Team: This team included Java developers, VB developers, and mainframe developers. Their single task was adding small business change requirements to systems.

LEAN OBJECTIVES AND HOW THEY WERE ADDRESSED

Lean principles aim to eliminate waste, and multiple advanced processes were used in the studied support group. Key processes were defined and implemented as below description.

Deliver Customer Needs Fast

The change request priority list was created by business teams delineating all the business requests which were to be completed by IT support group. The change requests were ranked by an appropriate prioritization score. The score was given by business partner that based on business priority, users' impacts, system volume, etc.

Table 1 is an example of a defect priority list for Corrective team which is designed to assist manager to assign assignment to developers. Defect #2 has the highest score in the list so it will be the #1 assignment in Corrective manager's task lists.

Defect #	CR Priority score	Assignments list
1	85	3
2	95	1
3	50	4
4	90	2

Table 1: Request Priority Lists

Owned by the business stakeholder, the priority lists are the backlog for each type of support request. There was one priority list for each lean support team. For example, system defects priority list was for Corrective team, small change priority list is for Perfective team. One of the lean principles is just in time to deliver the customer's need only. Any extra functions are not needed by customer now are the waste that must be avoided.

Eliminate Waste

There are a number of other places to look for waste [2]. For example in:

- Partially Done Work
- Extra Features
- Relearning
- Handoffs
- Delays
- Task Switching
- Defects

In the old support team model, developers took a new assignment while their current assignment was not completed. Partially done, their work does not give any advantage to the user. Task switching can be very detrimental to a project. The

The amount of waste created when bouncing back and forth between tasks is generally very large [12]. While in the lean support team, developers only take the next assignment after finishing their current task. This practice avoids partially done work.

Extra processes do not add any value to the customer either. Processes that do not add any value for the specific application should be eliminated since they are considered waste [12]. Developers in Corrective team only worked on fixing one deployed system defect then deliver it to production, nothing else. There is system upgrade effort, and there is no waiting and no handoff between developers either. Customers are able to see the value in that system defects have been fixed more quickly.

Estimate Support Efforts

The lean fundamental approach is to make decisions based on known events and not forecasts [12]. The goal is to delay commitment as long as possible and to eliminate waste. Efficient effort estimation process was implemented and to have an insight at the beginning that allowed control of the effort in order to deliver a high quality service on schedule. There are currently several estimate tools available to industry. Most of the IT support tasks are small and require only one developer or and such small tasks are typically completed quickly. Therefore, Support tasks cannot use the traditional function points or object points to assist in the estimate. The support estimate template was created in each lean support team based on the request point.

There are 20 hours dedicated for one request point. Each team, therefore, had its own factor based on the request point. For example, the Corrective team had factor five for high defects, meaning one high level system defect had an estimate of $5 \times 20 = 100$ hours. Perfective tasks were a little more complex so there was factor twenty was used to estimate a Perfective CR. Developers knew the size of the effort they were working.

Specific ground rules existed for estimates practice. First, the support task estimate was created by the specific team who would work on it. Everyone in the team provided input on their respective subject and this was reflected in the new estimate. Second, it was clear that the estimate was ultimately not a commitment. The actual size of the effort may, in fact, be different. In addition, each estimate could be changed because it may be influenced by many factors.

Build Quality In

Numerous processes were established in IT support group to improve IT support quality after lean practices.

- *CR must be submitted as early as possible.* It ensured the support task had followed the existing release plan and there was enough time to check the code, and perform all the necessary assessments such as unit testing, integration testing, system testing, and QA testing.
- *Testing is, of course, was required for all support tasks.* The change in support team was small mostly -- which is similar to configuration file change(s), addition of additional lines of code, etc. However, very small changes may also have a large system impacts. Given

that, all the support efforts scheduled into a system must be executed system testing.

- *There was no newly introduced system defects just because the support efforts. A defect fix only needs a few lines of code change but a very small change may have very large system impacts. Any untested change will introduce potential production defects.*

Create Knowledge

Create knowledge is another of the seven Lean principles requiring extensive technical knowledge relating to the supporting system and is a fundamental requirement in support of quickly correcting. IT supporting best practices is realized from communication with the project team that actually designed and contracted the system. The best way to support system functionality is to learn from the project development team which designed and constructed the systems.

The transition to maintenance checklists template [11] must be created for each development. The checklists were used to allow support teams to check if enough supporting documents were included. At the same time, developer from the support team attended all the design reviews, code reviews and defects review meetings in order to clearly understand the project. The project knowledge has been transferred to support team by this practice.

In a lean IT support group, developers must work on the single type of support task for all the supporting systems. The developers in the Corrective team had to work on any system defects. There was a new challenge for developers to gain the technical knowledge for so many systems.

Defining the Measures for Improvement

In order to see the results of the new lean IT support group an applicable set of metrics were defined and used in the study team.

WASTE REDUCTION

Lean principles are supposed to significantly reduce the time taken to deliver new products while substantially reducing cost [12]. Waste is considered anything that interrupts the flow of value to customer. The following metrics for waste reduction were defined to measure how much waste has been cut:

- Reduction of Waste for CRs: This measures how many hours are reduced for completed CRs.
- Waste Reduction Rate (WRR): This measures the different hours of completing one CR compare to hours before lean IT support team.
$$WRR = (\text{hours of completing one CR before lean} - \text{hours of completing one CR after lean}) / \text{hours of completing one CR before lean IT support team}.$$

CUSTOMER SATISFACTION

Lean principles are supposed to increase customer satisfaction. The following metrics were defined for customer satisfaction:

- System Availability: This measures system failure and its associated consequences. This is typically defined as:
$$\text{availability} = \text{mean time to failure} / (\text{mean time to failure} + \text{mean time to repair}).$$
- Number of Change Requests implemented: This measures how many CR have been implemented or completed by a support team.

- CR completed day: This measures how soon the IT support team completes the CR. It is the days between the CR submission date to the CR implantation date.

EMPLOYEE PRODUCTIVITY

Employee productivity is the way to measure the degree to which a developer has delivered higher value with lower cost. It is defined as Output/Input. The output is the value delivered, consisting solely of the total benefit provided to the customers. The input is the resources consumed, which include time, cost, etc. In terms of software development, productivity can focus on total lines of code per day and total functions points per day. Because the efforts of application support are different than those of development, the way to measure the support team's productivity varies. Employee productivity metrics were defined for the support teams as follows:

- CR Executing Age: This measures the total hours that a developer spend on one CR.
- Number of CRs Completed: This is a measurement of how many CRs have been implemented or completed by a developer or a team.

SOFTWARE QUALITY

High quality software meets the business requirements with few operational defects. Every mature software company adheres to a quality control process in order to ensure the delivery of high quality software to their customers. Quality control plays an important role in the application support effort as well. It is not acceptable to bring a new issue to the production while fixing a current production

defect. For example, while performing a maintenance task like upgrading a database to a new version, no one wants to cause a system outage.

There are various metrics used to measure software quality. Based on well-known software quality models [8,9,10] we see that software quality can be broken down into following types of elements or quality factors: functionality, capability, usability, testability, portability, performance, reliability, reliability, maintainability, supportability, documentation, and availability.

In this case study the following quality metrics were defined for measuring quality production support tasks.

- Number of introduced defect: This is the count number of new defects that have been introduced into the system because of support tasks.
- Bad Fix Rate (BFR): It measure number of introduced defect compare to the total number of completed CRs by one team or one developer in a fixed time period. It was defined as:

$$\text{BFR} = \text{Number of introduced defect} / \text{Number of CRs Completed.}$$

TIME TO MARKET

Time to market is the day between the dates of a new marketing business requirement to the date of it in serving end users. It is a very important measurement for business department to identify new requirements and request IT's on-time implementation. Most companies are looking for the process to reduce the time-to-market period. Some extensive and large requirements, as well as the development project teams were formed to specifically focus on the implementation of extensive and large business requirements. Even so, for some small change

requirements there is still a need to have an IT support team work effort. IT plays a very important role in ensuring business meet their time-to-market goals by providing requested capability quickly and with appropriately high quality. The following two metrics were defined to measure it:

- Elapsed days: This is the days a new requirement to be implemented and in production. This measures how quickly a new business function has been put in place to serve customers.
- Request backlog age: This measures how long it takes for the IT support team to start to work on the change request.

DATA COLLECTION AND ANALYSIS METHODS

The support group was chosen for this case study. The evaluation was based on an analysis of data examples extracted from 3 of 4 support teams in this IT support group: the Corrective team, Preventative Team, and Perfective team. The reason these three teams were chosen was the availability of extensive data recorded by the release management tool that was related to their support assignments before and after Lean practices were established.

The base data before and after the lean practices were implemented were collected from IT release management tool and interviews with developers. Caveats - There are many uncontrolled factors that will affect result of this study. It is difficult having reliable statistical inferences based on data collected from IT support group. This Lean IT support group principles started in late 2009. There are 2 years data 2009 and 2010 collected from the selected IT support teams in this study. Some simple statistics methods were used for the data analysis to indicate some validity to the lean IT support group experimenting result.

There is an abundance of data that was pulled from this release management tool in 2009, which was before lean IT practices in the support team and for 2010, after lean IT support practices were established in the department. The data was sorted on the basis of release date, platform, application, developer, and manager. By performing data analysis on the collected data from the release management tool, the results of lean IT support group were derived.

A monthly developer work timesheet was used to obtain developers' work hours for each support assignment. These data can show developers' work hours based on each support task. For a Corrective and Perfective effort, there are CR lists on their time sheets, and developers post the hours for each CR for each week. The data is entered by developers themselves and the purpose is to record attendance, not carry out lean analysis. By interviewing developers in different teams, the hours for CRs were collected for this case study.

Results of Lean Practices Implementation

The following are the results of instituting Lean principles practices in the selected application support group.

CUSTOMER SATISFACTION INCREASED

High system availability is one of the major factors in achieving customer satisfaction. Developers in support group only worked on the tasks related to applications availability. When a system failure was caught in the production monitor dashboard, an investigation was started immediately by Preventative Team to analyze the root cause and then return the system to service back as soon as possible. Figure 5 shows the availability of the 4 systems in 2009 and 2010. Applications availability was increased in 3 of the 4. However, availability of the 4th system was not improved and the one of the reasons was a new vendor system's bad capability.

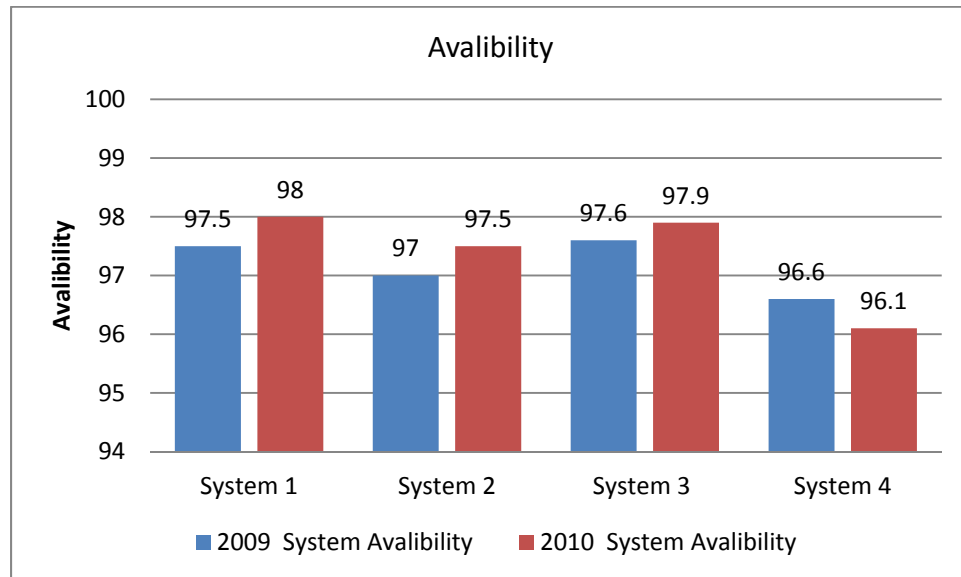


Figure 5: System Availability

More high priority business Change Requests were implemented by IT support group was another value to customer. Although there were only six developers in selected Corrective team, each developer worked on only defects fixing assignments. They focused on analyzing the root cause of the defects, designing the solution to fix it, coding, working with QA to test the fix, and releasing the defect fix to production system. The whole lifecycle of one defect fix was decreased from a month to two to three weeks after applying lean principles. The total numbers of implemented CRs were increased in both Corrective team and Perfective team in 2010 as shown in Figure 6.

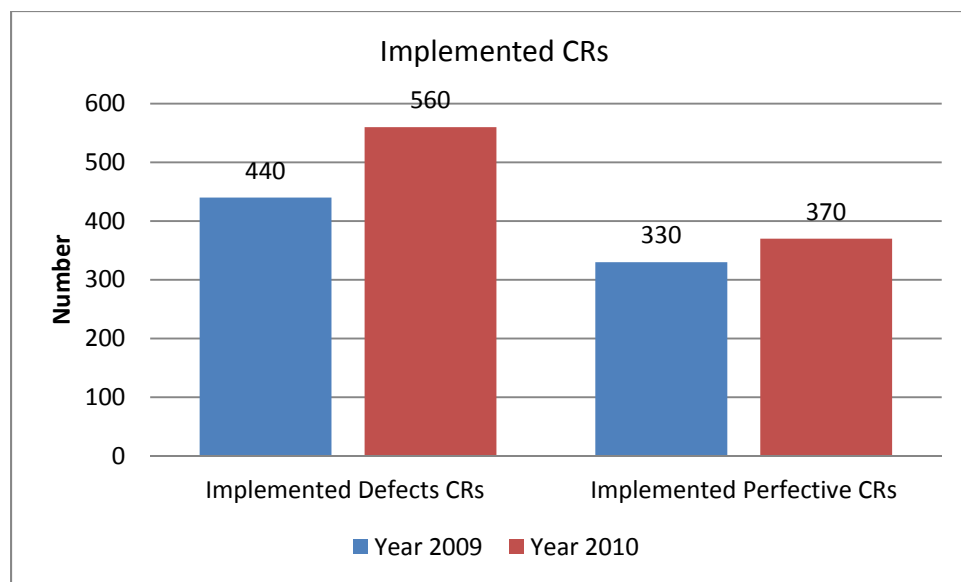


Figure 6: Implemented Requests

Change Requests were delivered faster was another return value to satisfy customer. This improvement was important for customer to see how efficient the IT support team worked. Request completed was the sum of CR Backlog Age and CR Executing Age was shown as Table 2. Both average time of completing a CR were

decreased as shown Figure 7. It was 28% decreased for Corrective team and 38% decreased for Perfective team from 2009 to 2010.

Average Days of Completing a CR	Year 2009 (Days)	Year 2010 (Days)
Defects CR Backlog Age	10	6
Defects CR Executing Age	43.7	34
Defects CR Completing Days	53.7	40
Perfective CR Backlog Age	15	7
Perfective CR Executing Age	73	48
Perfective CR Completing Days	88	55

Table 2: Average Request Completing Days

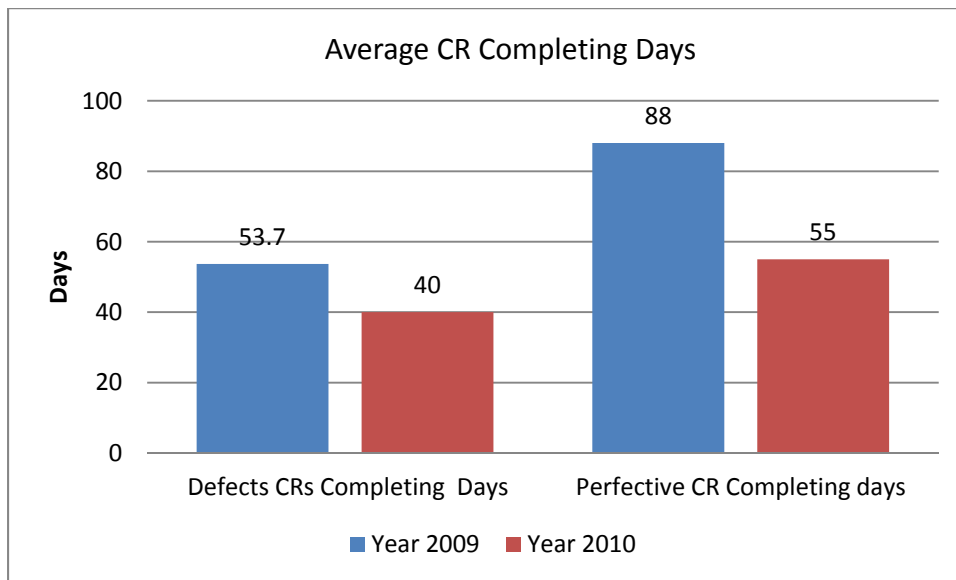


Figure 7: Average Request Completing Days

PRODUCTIVITY IMPROVED

This study demonstrated developer productivity was improved significantly after the Lean support group practices.

As the Preventative Team has completely transferred knowledge of all the system, they have support documents in place which state the fix solutions for all major failures. The hours of completing a System Failure (SF) was decreased considerably was shown as Table 3. The reduced hours were defined the cutting down waste from Preventative Team. There was 33% waste reduction obtained by fixing major issues that caused system failure for 1 of 4 systems in the last 2 years was shown as Figure 8.

System	2009 SF hours	2010 SF hours	Reduced SF Hours	SF WRR
System 1	5	4	1	20%
System 2	12	8	4	33%
System 3	10	8	2	20%
System 4	15	11.5	3.5	23%

Table 3: System Failure Hours

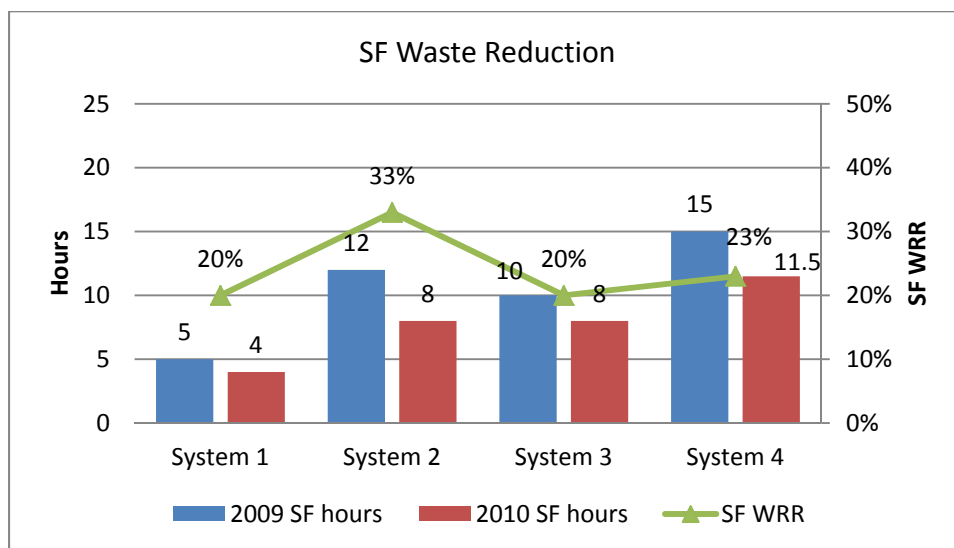


Figure 8: Waste Reduction

In the Corrective team, developers only worked on the systems' defects fix tasks. The hours of completing a defect CR was reduced as seen in Figure 9. In Perfective team, developers focused on the small business enhancement assignments only. Because of this focused approach, the implementation of a Perfective CR was extremely shorter. The average perfective CR completed hour was decreased from 146 hours in 2009 to 110 hours in 2010 as Figure 9. The reduced hours of completing CRs here was defined as cutting waste by Corrective team and Perfective team.

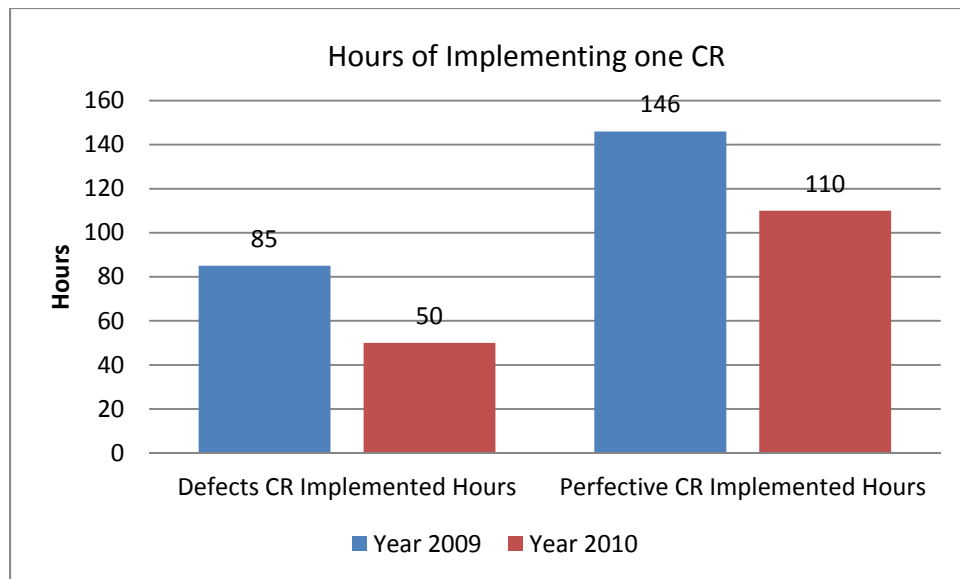


Figure 9: Average Hours of Implementing One Request

QUALITY OF MAINTENANCE EFFORT IMPROVED

Improved support quality is another result by analysis the collected data from release management tool. Developer in Corrective team had a better project plan, provided a good solution to fix system defects, and then worked with tester to perform all needed test cases testing. All these factors ensured a lower number of

new defects introduction into system. The total count number of Defects Introduced Rate (DIR) by Perfective team CRs were reduced from 25 in year 2009 to 7 in year 2010. The count number of DIR by Corrective team implemented CRs were reduced from 10 in year 2009 to 6 in year 2010 as shown in Figure 10. Reduced Bad Fix Rate (BFR) was another quality improvement that demonstrated higher quality effort of leaner IT support group. There was 3% CR BFR in 2009 for Perfective team but it was 7% in 2009 that was 57% decrease. The same good result for Corrective team, the BFR was reduced from 2% to 1%.

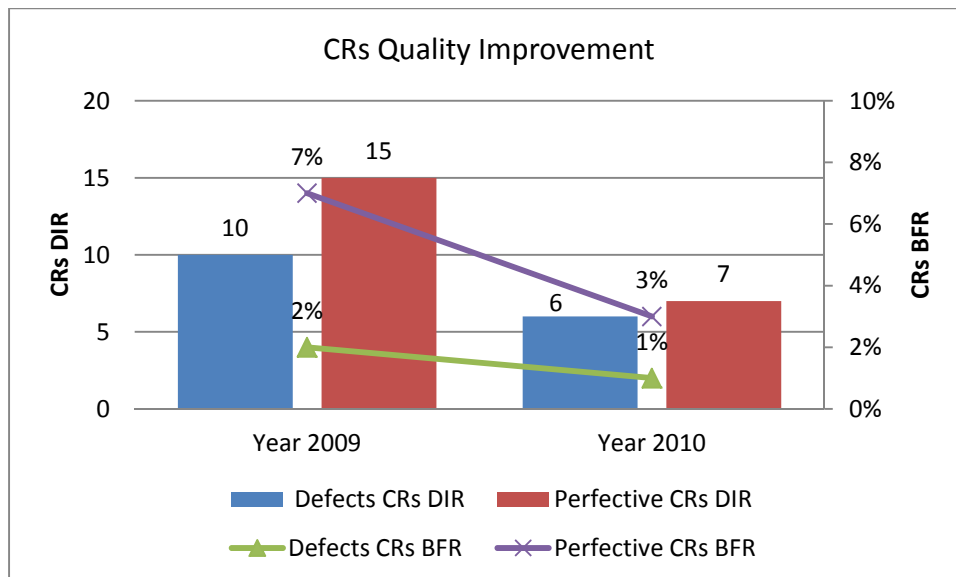


Figure 10: Quality Improvement

The other quality result from applying lean principles into the selected support group is the low number of system failure in their supported applications. There are multiple factors that impact one particular system’s failure like system architecture and design, vendor’s response, hardware’s capability, etc. But quality support work was one of the important factors that reduced system failure.

TIME TO MARKET IMPROVEMENT UNKNOWN

The company's Time-To-Market strategy involved marketing, business process, and IT implementation. The Time-To-Market impact of lean principles on the IT support group was hard to determine in this study. By adopting lean principles, developers in each team were able to focus on their particular support tasks that enabled them to implement CRs faster than before lean principles were in place. The backlog age for the Corrective team and for Perfective team were reduced after lean practices as shown in table 2. A short CR backlog age was important for customer to see how efficient the IT support team worked. A future study can be undertaken to find the impact area and evidence between Time-To-Market and IT Support group.

Conclusion

This paper described a case study of the effects of instituting lean software development practices in an IT application support group. Previous studies of lean applied to software focused on the development process, for example, design and construction. This paper has a different emphasis focusing on the maintenance process in a company IT department. The study metrics were defined to include customer satisfaction, waste reduction, productivity, availability, quality, and time-to-market. Actual data from the release management tool was captured and analyzed.

The results of analyzing the obtained data from before and after the introduction of lean practices demonstrated that these practices can be successfully applied to IT maintenance and support. There were two major lean practices implemented in the studied department. First, the department was reorganized to allow developers to focus on one single type of maintenance task, in contrast to the previous organization where each developer performed all maintenance tasks for a specific line of business applications. Secondly, changes to the maintenance process were made (e.g. priority list of CRs) in order to cut waste and still maintain fully knowledgeable developers to support the systems. The results were: increased customer satisfaction, improved developer productivity, and improved application quality. For example, Customer satisfaction was increased because the average number of days for completing a CR was decreased by 28% by the Corrective team and by 38% in the Perfective team. The developer's productivity was increased by cutting down waste by 24%. The application quality was improved as seen in the 57% decrease in the Bad Fix Rate (BFR) by the Corrective team.

There were some issues that arose in the implementation of our lean practices. One issue was developers' work load imbalances. At times, Corrective team developers had fewer assignments if there were not a large number of production defects in their backlog. At the same time, The developers in the Perfective team were not available to pick up higher priority perfective CRs. Building a resource rotation plan to adjust the assignments, workloads, and skills was required. The other issue was customer confusion. Prior to this study, business customers had only one contact for all their change requests, but now they have to communicate with each support group for the different maintenance tasks. For example, one Perfective request with a higher priority score may be taken off the priority list because it is a Corrective effort. But from a business perspective, with IT support viewed holistically, such a move might lead to confusion. Additionally, the impact of time-to-market was not evaluated because of the lack of data.

A limitation in the existing data was another issue that impacted this study. Most of the data was collected from the release management tool and employees' time sheets related to each CR. However, there was no data available for developers' skill sets, and technical experience. Yet, these are important factors for performing maintenance successfully.

It is hoped that this study will serve to inform future research and studies evaluating Lean principles applied to IT maintenance.

Appendix

ACRONYM TABLE

Term	Definition
CR	Change Request
SF	System Failure
DIR	Defect Introduced Rate
WRR	Waste Reduction Rate
BFR	Bad Fix Rate

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