การจัดสรรพนักงานในกระบวนการจัดซื้อด้วยวิธีจำลองสถานการณ์และการวิเคราะห์การล้อมกรอบข้อมูล

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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาวิศวกรรมอุตสาหการ ภาควิชาวิศวกรรมอุตสาหการ
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2559

Operator Allocation in Procurement Process Using Computer Simulation and Data En
velopment Analysis

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Industrial Engineering
Department of Industrial Engineering
Faculty of Engineering
Chulalongkorn University
Academic Year 2016

Thesis Title	Operator Allocation in Procurement Process Using Computer Simulation and Data Envelopment Analysis
By	Mr. Vason Techamaitrechit
Field of Study	Industrial Engineering
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วสันต์ เตชะไมตรีจิตต์ : การจัดสรรพนักงานในกระบวนการจัดซื้อด้วยวิธีจำลองสถานการณ์และการวิเคราะห์การล้อมกรอบข้อมูล (Operator Allocation in Procurement Process Using Computer Simulation and Data Envelopment Analysis) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร. สีรง ปรีชานนท์, 75 หน้า.

เนื่องด้วยธุรกิจธนาคารพาณิชย์ในประเทศไทย กำลังอยู่ในภาวะการแข่งขันที่สูงมาก หน่วยงานจัดซื้อซึ่งเป็นหน่วยงานสนับสนุนจึงมีบทบาทสำคัญในการจัดหาทรัพยากร เพื่อเพิ่มความสามารถในการแข่งขันและความพึงพอใจของลูกค้า โดยหน่วยงานจัดซื้อของธนาคารพาณิชย์แห่งหนึ่งในประเทศไทยที่กำลังประสบปัญหาในการจัดสรรพนักงานเพื่อให้เกิดประสิทธิภาพสูงสุดในองค์ ได้ถูกเลือกเพื่อนำมาเป็นกรณีศึกษาในงานวิจัยนี้

ในธนาคารแห่งนี้หน่วยงานจัดซื้อแบ่งออกเป็นสามกลุ่มเพื่อทำการจัดซื้อสินค้าที่รูปแบบแตกต่างกันได้แก่ กลุ่มก่อสร้าง กลุ่มจัดจ้าง และกลุ่มทั่วไป ซึ่งขณะนี้หน่วยงานกำลังประสบปัญหาอัตรางานล่าช้าที่เพิ่มสูงขึ้น เนื่องจาก ความผันผวนของความต้องการจัดซื้อจัดจ้าง การจัดสรรพนักงานรายไตรมาสได้ถูกจัดทำขึ้นเพื่อบรรเทาผลกระทบของความผันผวนและลดอัตรางานล่าช้าของหน่วยงานลง การสร้างแบบจำลองสถานการณ์ด้วยโปรแกรม ARENA ได้ถูกนำมาใช้เพื่อประเมินแผนการจัดสรรพนักงาน โดยผลลัพธ์จากแบบจำลองจะถูกเก็บและนำไปใช้ประเมินแผนการจัดสรรพนักงานด้วยการวิเคราะการล้อมกรอบข้อมูล โดยแบบจำลอง BCC และ MCDEA ได้ถูกนำมาใช้ เพื่อประเมินทางเลือกที่มีประสิทธิภาพสูงสุด โดยผลจากแบบจำลองพบว่าการจัดสรรพนักงานที่เหมาะสมสามารถช่วยปรับภาระงานของพนักงานให้มีความสมดุลกันระหว่างแผนก ซึ่งส่งผลให้ช่วยลดเวลาในการทำงาน และปริมาณงานล่าช้าลงได้ โดนแบบการจัดสรรพนักงานทั้งหมดถูกประเมินด้วยการวิเคราะห์การล้อมกรอบข้อมูล โดยแบบจำลอง BCC ที่มีความสามารถในการคัดแยกต่ำกว่าไม่สามารถจำแนกประสิทธิภาพของแผนจัดสรรพนักงานได้ โดยประเมินว่า 6 จาก 10 แผนการจัดสรรพนักงานมีประสิทธิภาพ ในขณะที่แบบจำลอง MCDEAที่มีความสามารถในการคัดแยกสูงกว่าประเมินให้เพียง 1 แผนจัดสรรพนักงานเท่านั้นเป็นแผนการจัดสรรที่มีประสิทธภาพ โดยท้ายที่สุดแล้ว แผนการจัดสรรพนักงานที่มีประสิทธิภาพนี้สามารถช่วยลดปริมาณงานล่าช้าในหน่วยงานจัดซื้อได้ถึง 6% โดยต้องเพิ่มพนักงาน

ภาควิชา วิศวกรรมอุตสาหการ	ลายมือชื่อนิสิต ....
สาขาวิชา วิศวกรรมอุตสาหการ	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....
ปีการศึกษา 2559	

5871308121 : MAJOR INDUSTRIAL ENGINEERING
KEYWORDS: OPERATOR ALLOCATION / COMPUTER SIMULATION MODELING / DATA ENVELOPMENT ANALYSIS / PROCUREMENT

VASON TECHAMAITRECHIT: Operator Allocation in Procurement Process Using Computer Simulation and Data Envelopment Analysis. ADVISOR: ASST. PROF. SEERONK PRICHANONT, Ph.D., 75 pp.

Thailand's commercial banks have been in fierce competition for quite some years. Procurement is an important department where strategic decisions are made. With various procurement types and demand fluctuation over the year, the bank could find it difficult to allocate operators to efficiently handle the tasks at hand. In this research, a procurement department of an existing Thai bank is used as a case study.

In this particular bank, procurement department is divided into three teams which handle different types of procurement: Building, Outsourcing and General procurement. Currently, they are facing with a high rate of overall delayed work caused by a seasonal pattern of demand. Quarterly dynamic operator allocation alternatives are proposed in order to mitigate the effects of demand fluctuation and reduce the delayed work rate. The ARENA computer simulation is applied to help to assess alternatives. Parameters from the simulation model are collected and used for evaluating the alternative in Data Envelopment Analysis (DEA). Two DEA models which are BCC and MCDEA are used to determine the best allocation plan among alternatives. From simulation result, with proper operator allocation, the department can balance the operator utilization among teams which leads to lower cycle time and also the number of delayed work. Then these allocation plans are evaluated with DEA model. MCDEA shows superior discriminating power over BCC model by awarding only one scenario while BCC award to 6 out 10 scenarios to be an efficient alternative. Finally, with the best efficient allocation plan, the procurement department can reduce the number of delayed works by 6% without adding additional operator.

Department:	Industrial Engineering	Student's Signature	....
Field of Study:	Industrial Engineering	Advisor's Signature	....
Academic Year:	2016		

ACKNOWLEDGEMENTS

First, I would like to express my warm thank to my thesis advisor Asst. Prof. Seeronk Prichanont, Ph.D. of the Faculty of Engineering at Chulalongkorn University for his support and invaluable guidance. He also helped to coordinate with a management of Bank A to allow me to conduct research in their organization. This research cannot be finished or even created at the first place without his kindness, invaluable time and support.

Second, I would like to express my gratitude to a management of Bank A for providing an opportunity to conduct a research in a practical situation in your Bank. It is an honour for me to have an opportunity to be a part of one of the leading organization in Thailand. Moreover, I would like to thank procurement department manager and her staffs for all of their support and facility during my time at their department.

I would also like to thank Assoc. Prof. Wipawee Tharmmaphornphilas, Ph.D., and Pisit Jarumaneeroj, Ph.D. for being the committee of my thesis. Your recommendation in my thesis is invaluable and helps to shape my thesis to be more concrete and concise. I cannot get through the finish of this research without their advice.

Additionally, I would like to thank my friends for their empathy, encouragement and support in many ways. I would like to thank committee in Sasin Graduate Institute of Business Administration, and Industrial Engineering Department at Chulalongkorn University for providing scholarship and accepting me to be in the first class of SCE program. These magnificent years of study could not have happened without their consideration.

Finally, I must express my very profound gratitude to my parents and my family for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them.

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1. Introduction

Nowadays, there are rapid changes of business world in many aspects e.g. technologies, customer requirement, production cost, etc. which companies cannot avoid facing these challenges. Instead, they need to adapt themselves in order to cope with these problems. Process improvement concept has been initiated in many companies for research their existing process and develop to higher level of performance. This concept is originally and mainly applied in manufacturing field but many service industries have already adopted this idea recently including banking industry.

In Thailand, there are 14 commercial banks - *public company that authorized to accept deposits money subject to withdrawal on demand which distribute their funds from depositors and loan out to household and business sector (Thailand, 2014b)-* in total including government banks and private banks(Thailand, 2014a). Recently stability of commercial bank in Thailand is in good condition despite global economic downturn in past few years (Thailand, 2016) but it is not easy for banks to get through this kind of situation.

According to Figure 1, global economic recession presented by declining of world GDP growth since 2010 combining with internal political instability obstructed many industries in Thailand to recover from the crisis as shown in limited and non-continuous growth in GDP since 2008

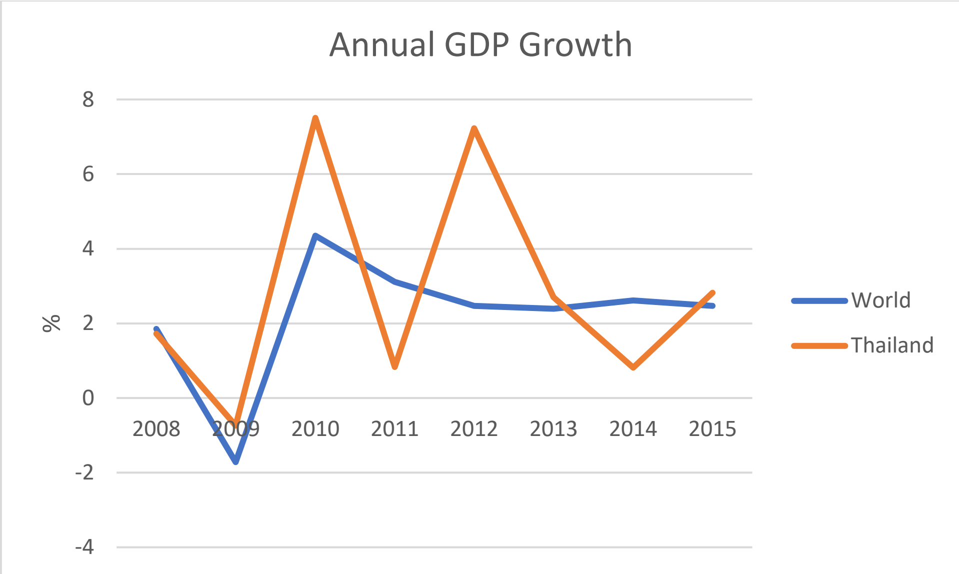


Figure 1 World versus Thailand Annual GDP Growth (Bank, 2016)

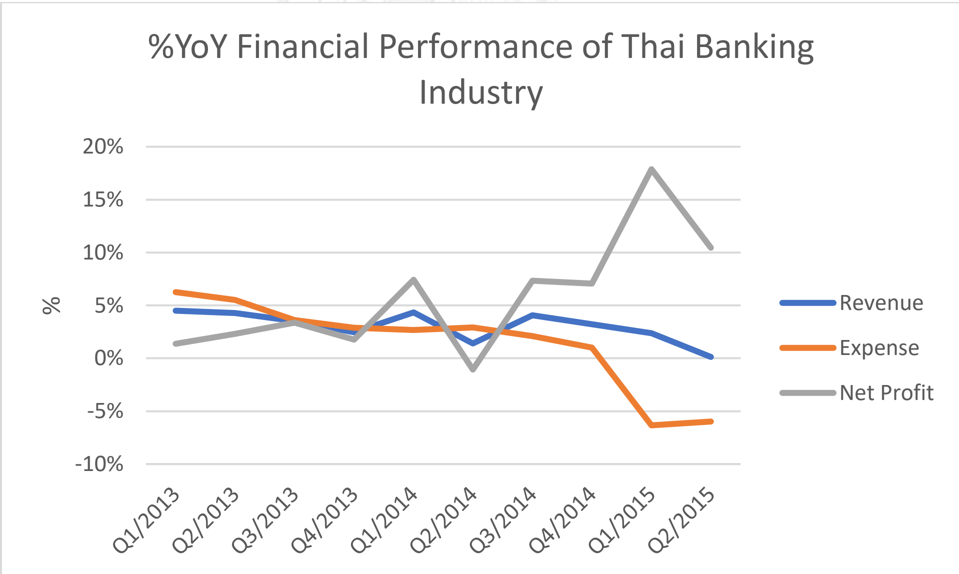


Figure 2 %YoY Financial Performance of Thai Banking Industry (Thailand, 2016)

The historical data since 2013 to 2015 in Figure 2 reveals status of Thai banking business which may not be in an attractive situation. The revenue growth is quite constant during 2013-2014 and become even lower in 2015 as a consequence of economic crisis and political issue as mentioned. Banks have been forced to improve their business in more efficient manner since growing only revenue is not a good option since revenue cannot be driving factor for sustainable growth represented by its trend.

Improvement of service level in order to support demand of customer and response actively to provide more customer satisfaction has already been widely executed in many aspects e.g. launching of new financial products, implementation of internet and mobile banking along with other premium services for their customer. Furthermore, for approaching to more customer and improve competitiveness in the market, banks have open new branches continuously as shown in Figure 3. 64 new branches have been opened since 2014 despite the economic downturn and limited revenue growth which indicates intensity of competition in this business.

The competition in this business will be much intensified by AEC which welcome more competitors in this business from this region then customer has more opportunity to select the best service from not only banks in Thailand but allows to move freely around ASEAN.

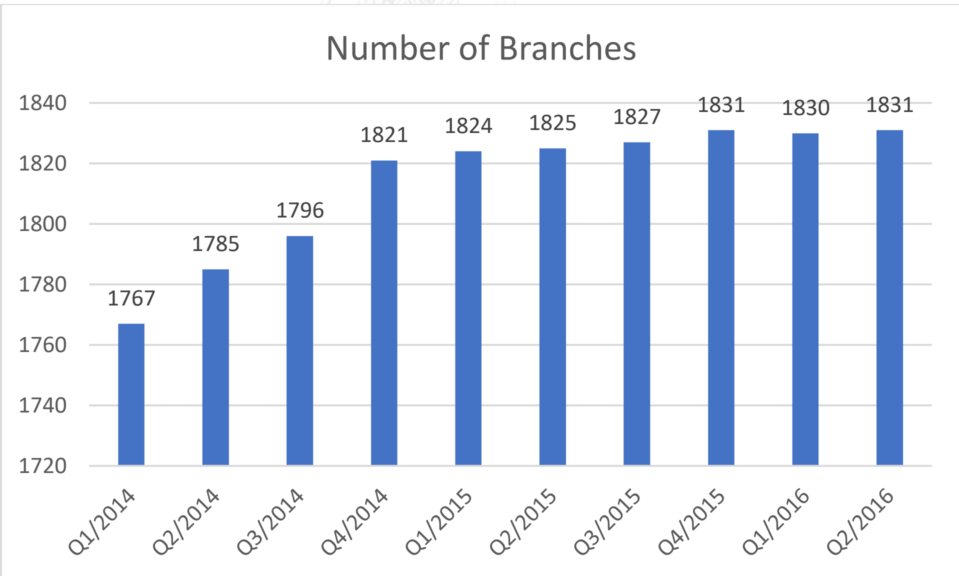


Figure 3 Number of bank branches in Thailand (Thailand, 2016)

In order to improve competitiveness in market and support business direction for coping with incoming challenge, banks need to focus not only on sales and marketing side but also need to improve customer satisfaction. Active and responsive reaction to customer demand is a key success factor for service business like banking.

To achieve higher service level as expected, synergy within organization is an important factor that helps the firm to achieve their goal firmly. In general, organization can be broadly classified as Main operation unit and Supportive function (GAIKWAD and KULKARNI, 2014). Main operation is an activity that directly produce product and service and also generate income to organization which can be banking services, loan, etc. in this case. While supportive function refers to a department that is responsible for activities those may not directly generate income or product but support main operation to be accomplished such as supply chain, human resource management, etc. Synchronizing between main operation and supportive function can lead to flawless end-to-end service system

In order to understand more regarding efficiency improvement in an organization, Bank A is selected to be case study. Bank A is one of leading commercial banks in Thailand. They provide a full range of financial services, including corporate and personal lending, retail and wholesale banking, foreign currency operations, international trade financing, cash management, custodial services, credit and charge card services and investment banking services, through its head office and its extensive branch network.

Target to be the best bank in Thailand is challenging the organization to improve their efficiency and performance then process improvement policy of every function is implemented. As mentioned above, supportive functions are also considered in this improvement policy since they also play important part in helping main operation to get customer satisfaction. Procurement is one of supportive function that is responsible for sourcing and procuring product and service according to requirement of internal customer in an organization.

Procurement process is part of most of operation in an organization since many activities require material or component which cannot be generated internally then must be purchased from external party. Therefore, efficiency of procurement greatly affects to responsiveness and cost of business. In many organization, procurement is considered as strategic function that plays major role in improving profitability then it is reasonable to focus on improvement of this department.

According to its nature of human-based activities, procurement needs many staff to accomplish many tasks in this department since it deals with many conversation-based activities such as vendor contacting, sourcing, negotiation and also deal settling. In addition, procurement process can be considered as production process which has purchase requirement as a raw material to produce purchase order then procurement can be considered as one of labor-intensive manufacturing system. Since it is labor-intensive, any changes in manpower of process can significantly effects to the performance of the process especially in throughput and cost. Unfortunately, most of management do not have proper tool to make decision on allocation. The allocation normally was made by experience or trial and error method which may not be fully utilize or over utilize their resources.(Rani, Ismail et al., 2014)

Many researches have already been done regarding operator allocation in many aspects. Methods, parameters and performance criteria were wisely selected to determining the optimal allocation in different circumstance. Most of studies have been done in manufacturing sector which typically select average waiting time, average cycle time, number of operators, operator utilization and throughput for optimizing the allocation.

In this study, situation of procurement process of Bank A is selected to be a case from actual business unit. The allocation has to be decided for optimizing between delayed work which refers to procurement transactions those take time over target of service level agreement (SLA) and other parameters to ensure efficiency of the decision.

2. Procurement Process

Procurement department of this bank is responsible for process of purchasing or hiring in order to obtain material, asset, IT equipment and electronic that requires set-up, testing, and also purchasing marketing service including construction and building construction. All of purchasing or sourcing of product and service need to be done or involved by central procurement department. This department has been divided into 2 sections. Since IT related item requires specialty in technical spec and specific knowledge for purchasing, bank has decided to separate procurement of IT equipment as "IT procurement section" and the remaining procurement transactions are handled by "Non-IT procurement section" which this study will focus on this section.

In Non-IT procurement section, which is the major procurement section for the bank, operators are called as "buyer" who responsible for execute procurement process according to procurement policy. They have been divided into 3 teams based on type of item to be purchased as shown in Figure 4

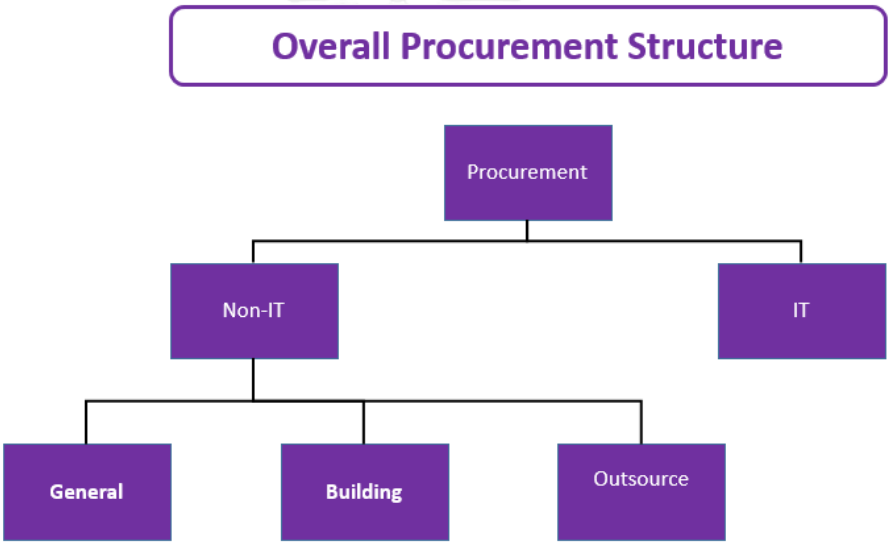


Figure 4 Overall Procurement Structure

- "Building team" is responsible for purchasing products and services those related to construction, renovation, decoration of building or parts of building including construction of new branches, office supplies, furniture, etc.
- "Outsource team" is responsible for sourcing of outside supplier to handle jobs which bank wants to outsource to subcontractor such as data entry staff, facilities management staff, transportation and logistics, etc.

- “General team” is basically responsible for the remain items from 2 above mentioned team. Mainly general team handle purchasing of premium gift or gift voucher for customer, uniform for bank staff, etc.

The procurement process begins with creation of user purchase request (UPR) from user which refers to person or department that want to use purchased product/service. UPR can be created digitally in in-house developed system and will be sent to related procurement team automatically. Then buyers of each teams have to response those UPR whether to receive or reject (mistakenly created, incomplete or incorrect UPR) within 1 working day. After UPR is received, buyer will process that UPR into further step based on its budget range which presented in Figure 9 below.

Basically, procurement process can be simply described as a process of buyer to convert UPR into Purchase Approval(PA). In order comply with transparency policy of bank, the difference of process between each ranges of budget are sourcing process and document that need to be attached with PA. The sourcing process can be separated by budget range as per Figure 5.

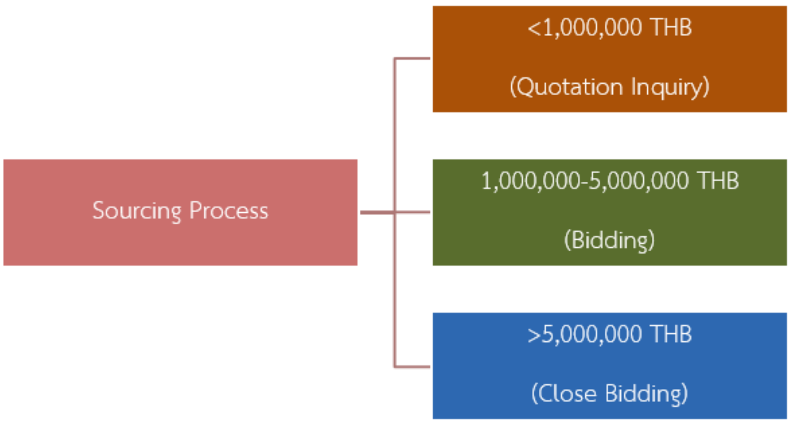


Figure 5 Sourcing process of procurement

For PA budgeted below 1,000,000 Baht, sourcing process can be easily done with send inquiry to at least 3 vendors for their quotation. Buyer will make negotiation once all quotations are received then issue PA to their manager for approval. The quotation inquiry process flow is presented in Figure 6.

Quotation Inquiry

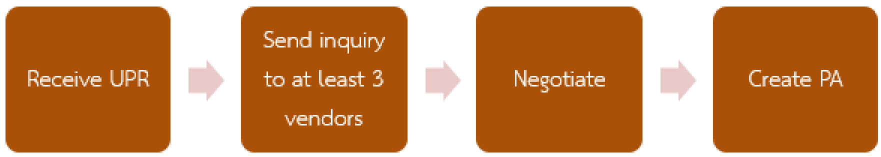


Figure 6 Quotation Inquiry Process

Secondly, PA with 1,000,000 to 5,000,000 Baht, Scope of Work (SOW) or Term of Reference (TOR) must be created according to the regulation then sent to at least 3 vendors along with the requisition. While all quotations are not received, buyer has to arrange meeting to assign “procurement working group” which consists of buyer, user and specialist if required to supervise this project and also evaluate and score each vendor in many dimensions e.g. company profile, technical and past performance comparison, etc. Meeting between vendors and buyer will be arranged after all quotations are submitted for clarifying SOW/TOR and also make appointment for further site visit and/or product demonstration if required. Once all quotations are submitted, meeting among working group will be arranged for announcing quotations and also input more data into scoring comparison. In general, bank will choose to award contract or select vendor into their final shortlist with the best Price Performance Ratio (PPR) which

PPR = Performance from comparison table / Unit price

Negotiation will take place after all technical comparison is done and potential candidate shortlist is settled. Candidates will be invited to office individually for official negotiation. PA will be issued after negotiation is finished and vendor is selected. The bidding flow is shown in Figure 7 below.

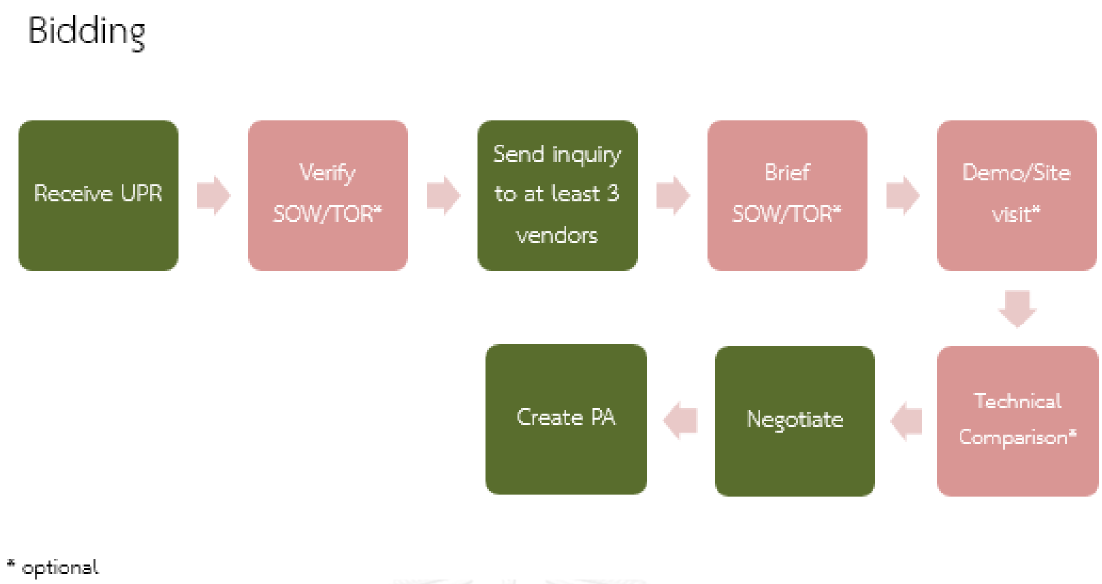


Figure 7 Bidding Process

Finally, PA with value more than 5,000,000 Baht, the process is almost similar to PA with 1 million to 5 million Baht but instead of supervision from procurement working group this type of PA is supervised by "procurement committee" which consists of same concerned parties with working group but higher authority. In addition, inquiry of bank must be announced on website for 3 days to make requirement public and open opportunity from wide range of vendors. Then each vendor has to make their bid on "Sealed Bidding" system which all quotations must be submitted in a sealed envelope along with money deposit and all envelopes will be opened on specific date. Another difference is presentation of PPR scoring. After completion of negotiation, scoring and support document must be presented to committee and management level before issue PA in order to ensure transparency of procurement. Process flow of close bidding is presented in the following Figure 8.

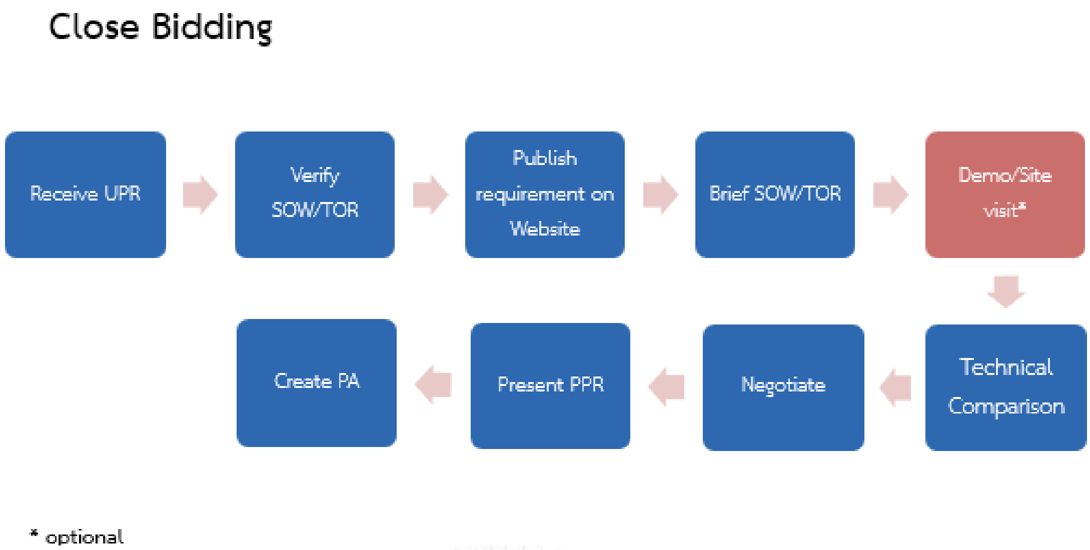


Figure 8 Close Bidding Process

Once PA is issued, it has to be initially approved by manager of their team before send it to procurement department manager or vice president (if value is above 20 million Baht) for final approval before send it to support team for issuing Purchase Order (PO) and submitted to awarded vendor which is the end of procurement process.

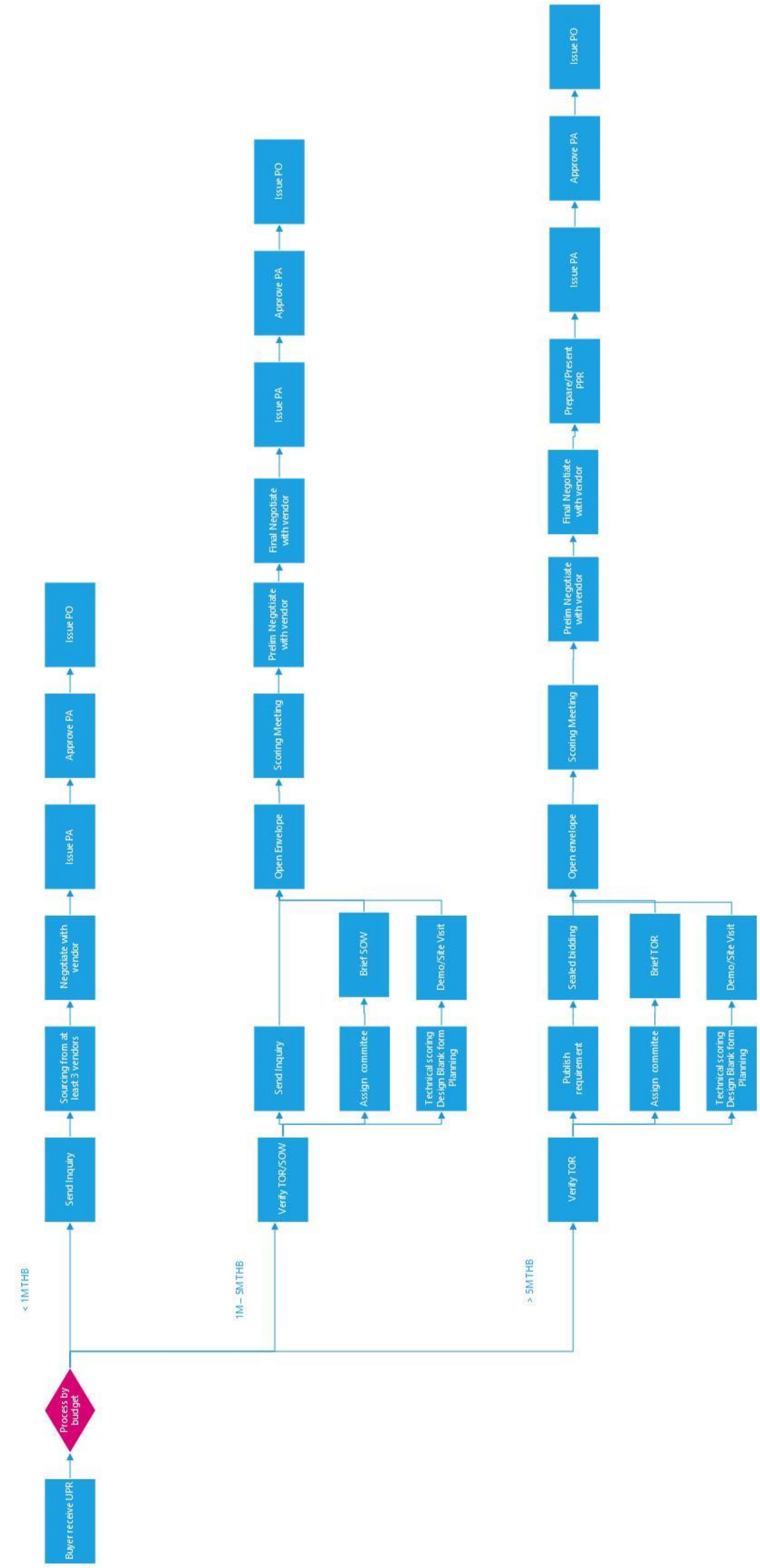


Figure 9 Overall Procurement Process Flow

3. Current Situation

According to historical data of 2012 to 2015 in Figure 10, procurement department has to handle more than 2,000 PAs each year and demand of users tends to grow up continuously.

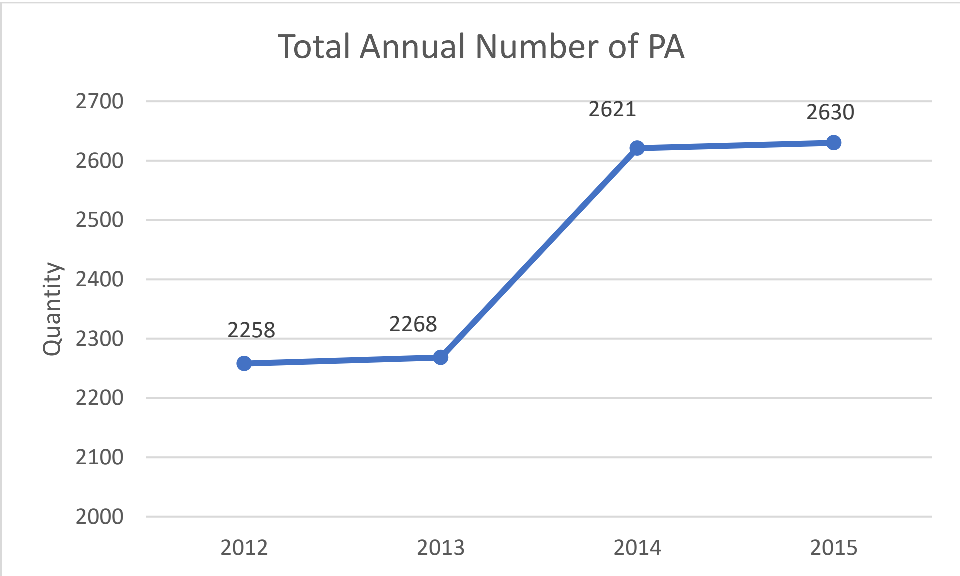


Figure 10 Total Annual Number of PAs from 2012 to 2015

On average, 2444 annual PAs are distributed mainly to Building, General and Outsource team respectively as shown in Figure 11. Continuous growing demand of users caused by bank policy which focus on continuous improvement in order to enhance competitiveness and service level in this challenging market. Most of activities are assigned to building team for expansion of branches and also develop environment in branches for improving customer satisfaction and well-being of employees.

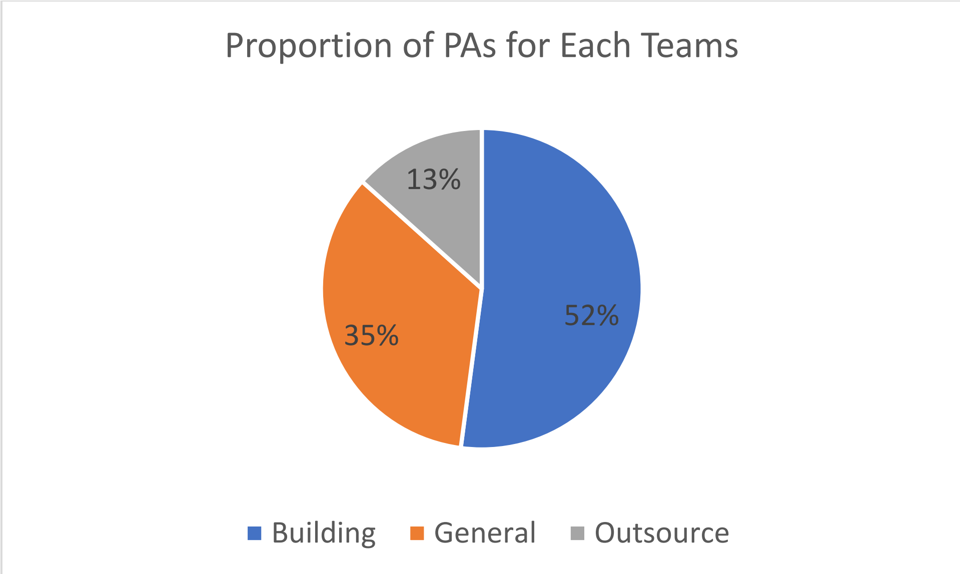
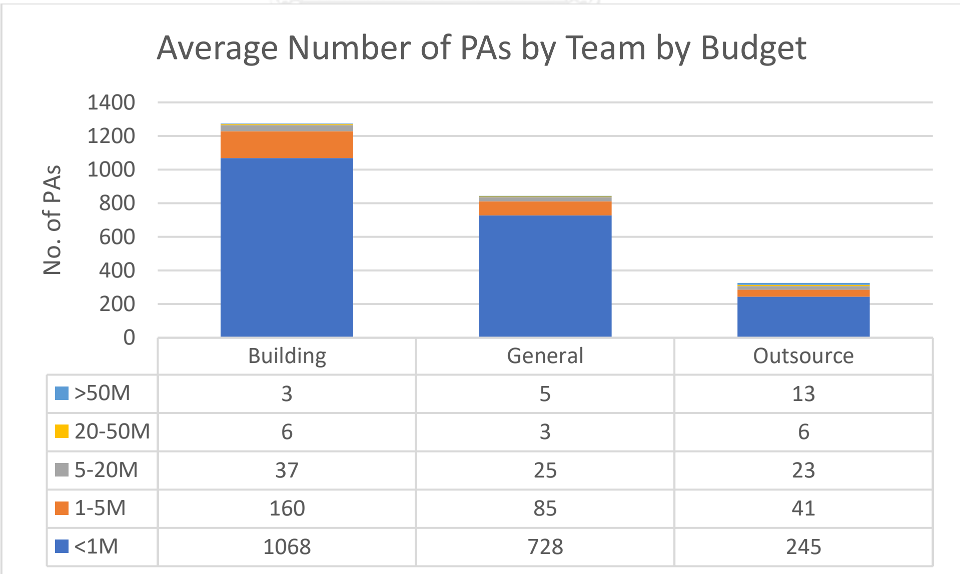


Figure 11 Proportion of PAs for Each Teams

Within each team, PAs with value below 1 million Baht is majority with more than 75% of proportion then the proportion is smaller once budget gets higher as shown in Figure 12.



	Building	General	Outsource
>50M	3	5	13
20-50M	6	3	6
5-20M	37	25	23
1-5M	160	85	41
<1M	1068	728	245

Figure 12 Average Number of PAs by Team by Budget

Figure 11 and Figure 12 show imbalance work quantity and also workload among teams. Unfortunately, this imbalance cannot be managed from demand side since they are requirements from users which depends on strategies of those unit and also unpredictable.

Currently, bank has total 16 buyers in procurement department which 6 buyers assigned to Building team, 6 buyers to General team and 4 buyers to Outsource team. Major problem of the department is high delayed work rate which refers to procurement transactions those have cycle time more than committed service level agreement (SLA). To examine more on this problem, more in-depth data has been collected hereinafter.

From 2012 to 2015, bank has observed that demand of users which can be implied from number of PAs are varied from month to month. PA quantity has been studied and grouped on quarterly basis in order align with regular milestone period and results shown in Figure 13.

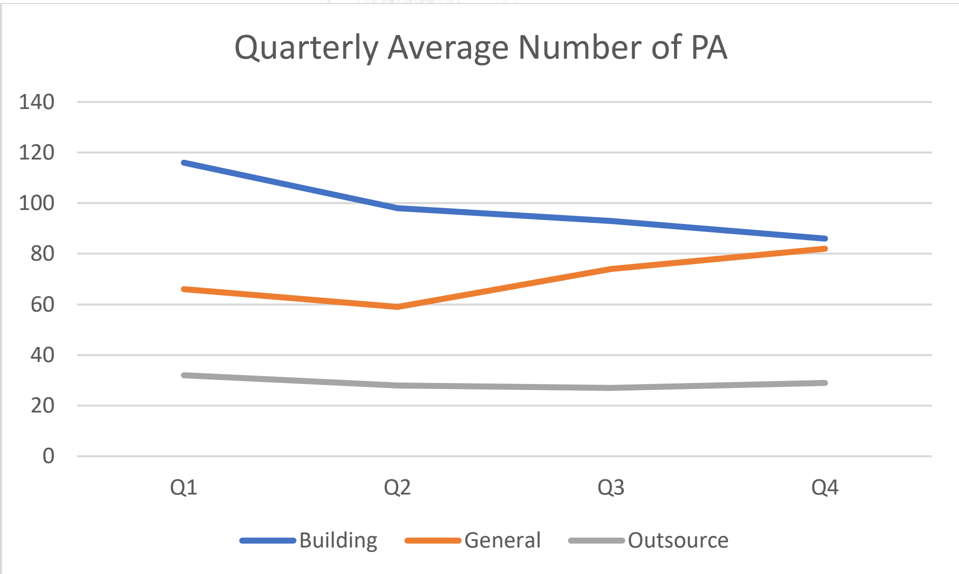


Figure 13 Quarterly trend of PA quantity by team

The result shows pattern of number of transactions which vary between teams. Quantity of work for Building team is high at the beginning of the year and decrease continuously through the end of the year. On the other hand, workload for

General team gradually raise after second quarter meanwhile outsource requirement is quite constant. There are some support reasons of these pattern as it is natural behavior of the jobs. Normally, annual budget for each unit in bank is announced at the beginning of the year and every unit will proceed that budget usage especially project with high priority, high budget immediately. Such as opening new branch and renovation of workspace which related to Building team, this kind of project will be required to be purchased at the beginning of the year. Moreover, staffs are also regularly allocated at the beginning of the year then modification workspace and order of new furniture are also requested during this early period. Once all these jobs are done at the beginning of the year, demand of this type of work will be reduced gradually in the later half the year then it is not surprised to have decreasing pattern for Building team.

For General team which is mainly responsible for premium gift for customer, this type of work is normally required before ending of the year as a preparation of new year gift since bank requires huge amount and wide range of products for their customer. Furthermore, each department tends to spend their remaining budget at the end of the year then demand of General team will get higher during last 2 quarter of the year.

While above mentioned teams have varied trend of workload, demand for Outsource team is quite constant. Main task of this team is to renew expiring contract for outsourcing service which is periodic and manageable. The remaining job which are bidding for new or other ad hoc contract take only small part of workload for this team. As a result, demand for this team has low variability and present in constant trend as shown.

Imbalance work throughout the year imply inefficient and inconsistent utilization of operators. Overutilizing during peak period and underutilizing during low period can lead to stress, fatigue and also dissatisfaction of operators which may results in high turnover rate in long run.

This improper workload also affects bank in operational aspects. During peak period, high utilization of operators can be expected along with higher waiting time. This results in higher cycle time for each transaction. Once UPR entered into system and transformed into PO according to procurement process in figure 9. In order to ensure satisfaction of internal customer, the procurement performance of each transaction will be evaluated from their cycle time which is defined as the duration from receiving UPR until PO issue.

Figure 14 shows trend of average cycle time of each team. Considering Figure 13 and Figure 14 together, quantity of work has strong correlation with the average cycle time of each team. High workload affects higher cycle time for 1st and 2nd quarter of Building team and also 3rd and 4th quarter of General team.

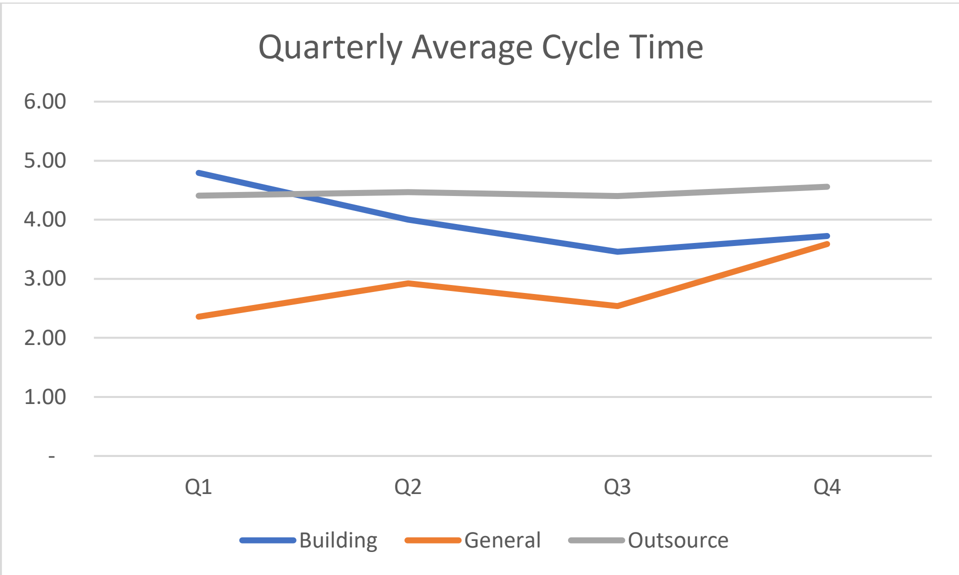


Figure 14 Quarterly Average Cycle time by Team

This higher cycle time has negative effect to overall performance of procurement department. One of quality index to measure performance of this department is number of delayed works. Delay of this department is defined by PA that has cycle time more than committed SLA. Cycle time will be compared against SLA that released by management of organization as shown in Table 1 below.

Table 1 Service Level Agreement of procurement process

Budget Range (THB)	SLA (days)
below 1 million	3
1 to 5 million	5
5 to 20 million	10
20 to 50 million	20
above 50 million	30

SLA is defined in order to ensure fast and responsive procurement for actively support other business units. According to Figure 15, higher budget requires more process and approval authority then management allows higher SLA. Performance of each team against SLA during 2014-2015 has been collected and shown below.

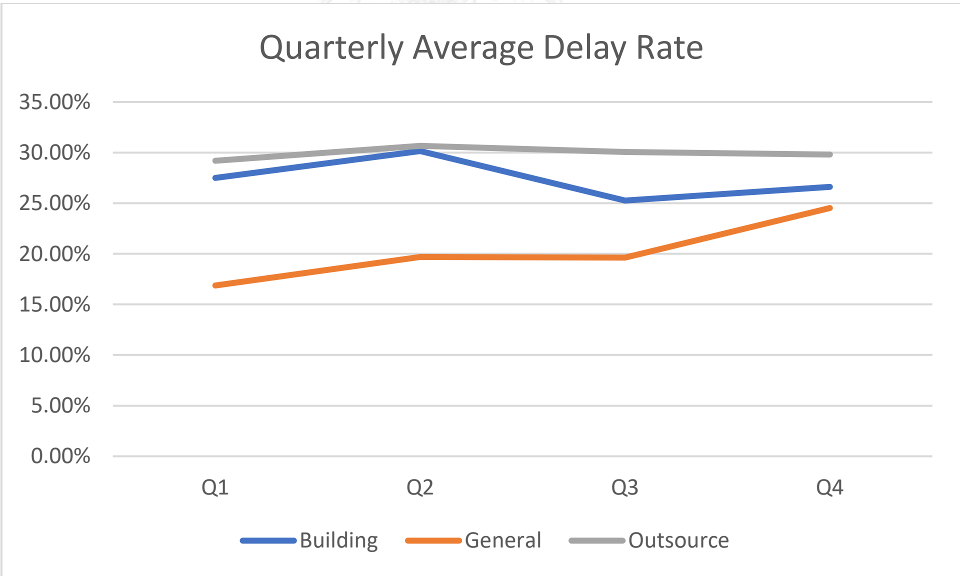


Figure 15 Quarterly Average Delay Rate by Team

Figure 15 presents trend of quarterly delay rate among teams. As a consequence of higher cycle time, the delay rate also grows higher during peak period of each team. Negative effect of high delay does not only take part in procurement department. Delay in procurement can also lead to delay in implementation of bank strategies or even dissatisfaction of customer then correction of this problem should be done immediately.

In conclusion, from presented facts above, requirement of procurement is in growing trend in each year. Well preparation and management within procurement department has to be done in order to cope with growing trend. Moreover, number of requirements is dynamic throughout a year but using of static operator allocation caused imbalance of workload among procurement teams which lead to high cycle time and delayed work.

As a labor-intensive process, number of operators in this department should be well defined since it has strong effect to productivity of the process. Dynamic operator for each quarter will help department to balance utilization along the year. Assigning more operator in peak period can help lower utilization of operators and lead to lower cycle time along with delay rate.

Even procurement department may not have major role in this banking organization but it cannot be ignored since supportive function is also an important factor which supports and drive every company's tasks and goals. Proper determining of manpower decision has to be selected in order to ensure optimal decision which results in higher service level and responsiveness of this function and also business competitiveness in intense and rapidly change market.

4. Literature review

Study of operator allocation has been widely performed and developed in many perspective and industries. Conventional approach that is still widely used is optimization. Optimization by math modeling is method to solve operator allocation problem in deterministic manner. The exact set up of allocation will be defined by optimization between objective function and given constraints. (Kuo and Yang, 2006) conducted study of manpower allocation in TFT-LCD plant using optimization modeling called two-phase formulation. The 1st phase is the optimization of throughput and the allocation decision. Scenarios of operator availability were set and optimization was done in order to find maximum throughput for each product in each scenario. Then result from the 1st phase became input for 2nd phase. In this 2nd phase, demand requirement was created and formulation was performed to minimize the total number of required operators per shift. Finally, the model can effectively help the plant to reduce their required operators up to 20%. Despite the satisfy result, the math model solved the allocation problem deterministically. There is no variation in operating time and also demand in constant.

In real business world, every process has variabilities and uncertainties so there are difficulties to define precise process parameter. Here, deterministic approach may not be able to solve problem with high variabilities properly. Development of modeling to tackle with more stochastically problem has been studied. (Egilmez, Erenay et al., 2014) has done interesting four-phased hierarchical optimization model. Processing times and demand were assumed to be stochastic and normally distributed. Similar to (Kuo and Yang, 2006), the objective of 1st phase is to maximize the production rate with the constrain of bottleneck. Then normal-distributed demand for each product is generated and used for defining capacity requirement in 2nd phase. The output of 2nd phase was capacity requirement with fitted distribution for each product and will be used as input in the 3rd phase to determine the optimal manpower level for each unit and also assign product to units. Then 4th phase was developed to maximize the production rate in case that performance of workers is different.

This model improves weak point of conventional math modeling which is normally able to solve only deterministic problem. But it is still based on some assumption such as normal distribution of demand and also complexity of the model then this method is not widely used in practical problem. In order to handle with more stochastic problem, Simulation technique has been widely applied. Computer Simulation is known as one of effective tool for solving problem in business world as it can visualize process and help management to make decision better (Azadeh, Sheikhalishahi et al., 2013). By given conditions, simulation can illustrate the situation and also provide process summary of desired period of time. It has been widely used for process improvement in many business field e.g. education

(Watanabe, Murasawa et al., 2013), manufacturing (Azadeh, Sheikhalishahi et al., 2013), food industry (Rani, Ismail et al., 2014), health care (Oh, Novotny et al., 2016), etc. This helps user to trial and study effect of any tentative improvement without actual implementation which may disturb the process or not a worthwhile option. Even versatility of its function, simulation still has limitation as it only visualizes the process from give parameters but cannot help user to make decision or comparison between any scenarios. To select the best scenarios, Data Envelopment Analysis (DEA) is selected to be a proper tool for assessing simulation alternatives.

DEA was originally proposed by (Charnes, Cooper et al., 1978) as a nonparametric technique to measure and evaluate the relative efficiencies of a set of entities with common inputs and outputs called decision making units (DMU). Parameters generated by simulation are selected to be input/output of each DMU in DEA. It classifies each DMU from given input/output by efficiency score which 1 will be given to efficient DMU and less than 1 is for inefficient DMU (Azadeh, Sheikhalishahi et al., 2013). Advantage of DEA is to solve problem with multiple inputs and outputs and also helps to choose appropriate weights for inputs and outputs for determining efficient alternatives (Rani, Ismail et al., 2014).

In general, simulation is considered as a tool to provide input/output for utilizing DEA. Model will be developed and run with several decided scenarios to test the process performance of specific conditions. At this stage, simulation can present result of given condition which user can easily select the best scenario from the given result if only one criterion is considered. Comparison of more than one criterion is regularly observed in our business world moreover trade-off decision between two parameters can be expected. Then sometimes it is not an easy task to judge or rank between scenarios. Selected parameters from simulation result will be collected as input/output for further analysis with DEA. DEA as an assessing tool will help to evaluate options based on their relative efficiency then the optimal alternative will be selected based on their efficiency score which maximum at 1. This integration of simulation technique and DEA is also known as “two-phase methodology”(Rani, Ismail et al., 2014).

Normally, simple model of DEA like BCC or CCR is able to solve problem but there are some cases which these models give more than one alternative to be the most efficient. Therefore, additional tools or procedure need to be done in order to discriminate those efficient options. In case of (Rani, Ismail et al., 2014), Multiple Criteria DEA (MCDEA) and AHP method were selected as a discriminating tool while Principle Component Analysis (PCA) and numerical taxonomy were chosen in in (Azadeh and Anvari, 2006). Tijen Ertay developed his own robust and cross efficiency scoring based on BCC to have more discriminating power of scoring. (Ertay and Ruan, 2005)

In modern study of allocation, apart from quantity allocation, wider perspectives of problem were studied to cope with more variabilities. Fuzzy Analytical Hierarchy Process (FAHP) was used in (Rani, Ismail et al., 2014) to evaluate operators' performance once performance of each operators in different tasks is considered not to be equal. Operators will be evaluated by their supervisor and grouped according to their FAHP score then allocation can be made by concerning their performance in particular activities. This helps company to make better decision and get better efficiency as expertness of operators is considered then the allocation is made on "Put the right man on the right job" basis.

Another dimension of operator's skill was concerned. Skill levels of operators can be improved by repeatedly doing same work. This learning effect caused reduction of process time in each iteration. (Azadeh, Sheikhalishahi et al., 2013) considered to integrate this effect into allocations then unnecessary allocation will not be made since it causes higher in process time which align with real behavior of operators. Operator takes some time to get used to their new tasks before stabilize their process time to constant at certain level.

Apart from operator aspects, allocation was studied in more fuzzy manner. input/output from simulation is fuzzified before input them into FDEA. This method utilizes more data from simulation since it is not only crisp data which is average of parameters that will be considered but also their variation then the better allocation can be expected. (Azadeh, Anvari et al., 2010), (Azadeh, Sheikhalishahi et al., 2013)

Data Envelopment Analysis

Data Envelopment Analysis is a nonlinear programing model which determines the efficiency for evaluating alternatives (Charnes, Cooper et al., 1978). DEA has been fast and widely developed and applied in managerial and economic field. In term of operator utilization, DEA is used for evaluation operator allocation plan in many business field and wide range of models e.g. TOPSIS model (Yang, Chen et al., 2007), Fuzzy-DEA (Azadeh, Anvari et al., 2010), Cross Efficiency Model (Ertay and Ruan, 2005), etc. In this study, BCC and MCDEA will be focused and applied to evaluate the alternatives after simulation.

BCC model

This is one of the simplest model of DEA which has been long applied since (Banker, Charnes et al., 1984) proposed this model in 1984. BCC is based on the assumption that the proportional change of inputs and outputs are not the same. This type of change is called "Variable return to scale"

$$\max Z_0 = \sum_{r=1}^{s} u_r y_{rj0} - u_0 \qquad (1)$$

Subject to

$$\sum_{i=1}^{m} v_i x_{ij0} = 1 \qquad (2)$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \,, j = 1, \dots, n \qquad (3)$$

$$u_r, v_i \geq 0 \; for \; all \; r, i \; and \; j$$

Where z_0 is relative efficiency of DMU_0, j is the DMU index, r is the output index, i is the input index, y_{rj} is the value of the r^{th} output for the j_{th} DMU, x_{ij} is the value of the i^{th} input of the j^{th} DMU, u_r is the weight given to the r^{th} output and vi is the weight given to the i^{th} input, DMU_0 is the efficient alternative if z_0 =1

MCDEA model

(Li and Reeves, 1999) has proposed this model in order to increase discriminating power of DEA. MCDEA also results in more reasonable weight of inputs and outputs which eventually leads to more reasonable evaluating results. The objective functions of MCDEA are minimizing d_0, minimizing the maximum deviation (minmax) and minimizing the sum of deviations (minsum) which the model is presented hereinafter.

$$\min d_0 \ or \max h_0 = \sum_{r=1}^{s} u_r y_{rj0} \qquad (4)$$

$$\min M \qquad (5)$$

$$min \sum_{j=1}^{n} d_j \qquad (6)$$

Subject to

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + \ d_j = 0,$$

$$j = 1, \dots, n \qquad (7)$$

$$\sum_{i=1}^{m} v_i x_{ij0} = 1 \qquad (8)$$

$$M - d_j \geq 0 \qquad (9)$$

$$u_r, v_i, d_j \geq 0 \ for \ all \ r, i \ and \ j$$

where d_0 is the deviation variable for DMU_0 and d_j is the deviation variable for the j^{th} DMU, M is the maximum among all of d_j, DMU0 is efficient if h_0 = 1- d_0 equals to 1.

BCC model is one of the simplest DEA model but it is still applicable to use for evaluating operator allocation scenarios. In general, BCC may result in more than one efficient alternatives due to its low discriminating power. Then Multiple Criteria Data Envelopment Analysis (MCDEA) with higher discriminating power is selected to cope with this situation. Multiple objectives of the model increase power of discriminating among alternatives and also force the model to consider weight of input and output in a more reasonable approach. As a consequence, MCDEA is able to handle more complex problem and smaller difference of parameters compared with BCC model.

5. Objective

- Determine the operator allocation that minimizes the number of late works of the procurement process by considering average cycle time, average operator utilization and throughput of the process.
- Design the decision-making framework for operator allocation which can be applied to other departments.

6. Scope of Study

This study is focusing on the effect of operator allocation to the performance of the procurement process then the scope of the study is identified as follows:

1) The procurement process consists of many positions who directly related to the process e.g. managers, support teams, etc. But this study will focus only allocation of buyers which are operators who take major role in procurement process.
2) In order to complete the actual procurement transaction, it may irregularly require cooperation between department e.g. buyers, lawyer, etc. which can be considered as external factors that may not directly relate to the sourcing process then those activities are ignored in this study. Instead, it will focus only process and activity that related with buyers.
3) In fact, buyers have their own specialty or familiarity with some products or suppliers which cause them to perform differently in different transaction even the process is the same in general. In order to eliminate

this individual variability, the performance of buyers within same team are assumed to be equal in this case.

4) From the fact in 3), operators may need more times to learn and get used to the new transaction or suppliers when they are newly assigned into the new team. But this study aims to find the solution in long term which all training should have already done properly then learning effect is not considered.

7. Methodology

This study can be divided into two main parts. At first, the process is studied and data collection is designed especially for the processing time in each stage in order to create simulation model.

The simulation model is constructed according to collected data of normal activities in procurement process. Model validation is performed to make sure the representability of the model to the actual procurement process. Once the model is validated, the operator allocation plans will be applied to study the effect of the allocation to the procurement process. Each of allocation plan or called “scenario” will be assess its performance from following parameters

- Number of delay works
- Average cycle time
- Number of operators
- Number of required movements
- Average utilization of operator
- Throughput (number of finished job)

These parameters are generated and collected as an output from simulation model and will be relatively evaluate using Data Envelopment Analysis (DEA) in order to determine the efficiency of the scenario and identify the best scenario among alternatives. DEA can be considered as assessment tool in the second stage of this study which it helps to evaluate the alternative when multiple criteria are concerned. In DEA, each criteria or parameters are separated into two groups. First, “Input” which does not mean the parameter from the incoming side of the process in this case but it refers to parameters those needed to be minimized instead. On the other hand, another group of parameters is called “output” which is group of parameters those needed to be maximized. In this study, concerned parameters can be categorized into these two groups as shown in Table 2.

Table 2 Group of Parameters from the Simulation

Input	Output
- Number of delay works - Average cycle time - Total number of operators - Number of required movements	- Average utilization of operator - Throughput (number of finished jobs)

Number of delay works can be considered as unwanted or defect in the procurement process then it is put in “input” group since it needs to be minimized along with average cycle time and total number of operators which also need to be controlled at minimum level. Number of required movements refers to total number of times that operator requires to reallocate in the allocation plan which also need to be minimized in order to prevent complication in implementation of the plan. In contrast, the more average utilization of operator can lead to the less idle time of operator then it is classified as “output” which need to be maximized along with throughput.

Once all parameters are classified and put in DEA model, DEA as an assessment tool will evaluate each scenario relatively then finally the model results in efficiency score for each alternative. This score is given based on its input/output for each alternative comparing to others which maximum score is 1 which will be awarded to the alternative(s) that can be considered as efficient alternative(s). In this study, BCC and MCDEA model of DEA is selected to be assessment tool. BCC which is one of two simple DEA model is chosen from its simplicity and should be good enough in evaluating operator allocation. MCDEA is more complicating and better than BCC in term of discriminating power. In some cases, BCC may not be able to distinguish efficiency of alternatives and results in awarding multiple options to be an efficient option with score at 1. MCDEA with multiple objective functions has more discriminating power and should be able to identify the best efficient scenario when efficiency of alternatives is slightly different. Finally, the scenario with score of 1 is selected to be the best efficient alternative and should be implemented in order to improve the performance of procurement process.

In conclusion, the simulation model acts as a parameter generator to generate parameters for each alternative. Each operator allocation plan is input in the simulation and simulate to explicit its effect in the procurement process. Parameters are collected and considered as the output from the simulation which reflects the effect of operator allocation to the procurement process. They are classified into “input” and “output” group then each scenario is evaluated based on its collected parameters in DEA. DEA as an assessment tool evaluate each scenario relatively and award a good efficient performer with score of 1 then it can be defined as an efficient operator allocation.

8. Simulation

Simulation Model

The simulation model which will be used as a parameter generator in this study is constructed using ARENA software. The procurement daily operation is studied and broken down into small stages based on process flowchart in Figure 9. These stages are created in a simulation model as a process which contains both actual process (receiving UPR, negotiation, etc.) and waiting period (waiting for quotation from supplier, etc.) which is not waiting time from queueing but caused by the procurement process itself. Basically, the process can be divided into 3 main parts which are

- *Incoming part* which creates and assigns attributes to PAs e.g. arrival date, team, budget, etc.
- *Sourcing process* which is the main part of this simulation. It consists of the activities of sourcing process which converts UPR to PA including approval process. The sourcing process of each team is separated into 3 lines which are for sourcing product with 3 different budget range. This type of sourcing process is identical among 3 teams.
- *PO process* which may not directly related to sourcing process but need to be included in the model in order to ensure that all steps in procurement process is taken into account then the cycle time of the process can be reflect the actual situation.

Each process will be determined both required resource and process time according to collected data which the data collection will be discussed later. The simulation begins with creation of PA. PA is considered as an entity in the simulation model which flows through all the processes in the model based on its assigned team and budget then attributes of each PA is recorded at the end of the process using read/write option which are

- Serial
- Arrival date
- Assigned budget
- Assigned team
- Approval date
- Finish date
- Replication

These attributes are written into file and will be proceed further in order to determine the cycle time of each PA and also number delay work. For other concerned parameters which will be used in scenario evaluation process, they are available from summary of ARENA itself.

Apart of process, required resources are necessary to define to reflect actual situation of the process. Resources in the process are the concerned staffs those who needs to execute activity(s) in the process which are presented in following table

Table 3 Resources in the Simulation

Resource	Quantity	Responsibility
Building buyer	6	Sourcing process for Building product/service
General buyer	6	Sourcing process for General product/service
Outsource buyer	4	Sourcing process for Outsource product/service
Building manager	1 (Scheduled)	Approve PA of Building Team
General manager	1 (Scheduled)	Approve PA of General Team
Outsource manager	1 (Scheduled)	Approve PA of Outsource Team
Department manager	1 (Scheduled)	Final Approve all PAs
Buyer for PO	2 (Scheduled)	Receive approved PA and issue PO
PO manager 1	1 (Scheduled)	Approve PO
PO manager 2	1 (Scheduled)	Final Approve all POs

Buyer in each team is set at the same amount as existing set up at this stage and will be varied according to allocation plan in the experiment later. Other resources which most of them are managers, the quantity is fixed based on actual amount but capacity in the simulation will be scheduled. Since manager will not be ready for approve every PA immediately once it is issued and they also have other responsibility which may not directly relate to approval process. Moreover, they all have their own pattern of approval behavior which can be seen in collected data then their capacity has to be scheduled based on their actual behavior.

Data Used in the Model

Data is essential in simulation model construction which is used in many parts of the model including incoming rate, proportion assigning, process time, etc. The data used in the model are collected from following method

- *Data collection form* which is the main data source of this study. The form is created and distributed to buyers and managers for them to fill out actual processing time in each step of their daily works. Buyers will mainly provide data of their sourcing process while data of approval process is collected from managers. The data is collected during 1-month period for this study.

Figure 16 Example of Data Collection Form

- *Historical data* which is used mainly used for scheduling incoming PA. The data is provided by support team of procurement department in form of department record and report. Data from this source is used to predict or estimate both quantity and type of PA in the simulation.
- *Interview with buyer* which is used for some process those may not be recorded with data collection form easily. For instance, scope verification with buyer, this process may not be finished within one meeting or one phone call. It may require several conversation or interaction to complete the

process so it causes difficulty and complexity for buyers to record the processing time then the data collection form is not used for this type of process and the estimate from buyers is used to represent the processing time in the model instead.

Since there is no enterprise management software or database system at the department. All of the data has to be clean manually. The data is verified with department record to check the overall cycle time of PAs. For processing time in each stage which filled in data collection form, data is compared with normal processing time from buyer's estimation and also SLA. If there are some abnormal deviation, they have to be clarified with buyers in order to ensure that there is no human error in data recording from user.

Model Validation

Once all data is collected and verified, it will be put in the model to complete the construction of the simulation. The model needs to be validated before using as a parameter generator in order to ensure that it can represent the actual situation of the procurement process.

Firstly, the processing time from data collection form needs to be fitted into distribution. Two-third of data is separated for creating distribution those used in the simulation model while the rest will be set aside as a reference for validation.

In this case, empirical distribution which derived from the probability is used for processing time in processes which are gathered from data collection form because buyers always round their processing time to the closest 5 minutes (e.g. 5, 10, 15 minutes) when they recorded in their data collection form and these data cannot be fitted with any discrete distribution. Then each of distribution is individually validated by generating number from the distribution to compare with the reference that we have already set it aside at the beginning. Hypothesis testing with t-test is used for validating the result with

$$H_0: \quad \mu_{generated} = \mu_{reference}$$

$$H_a: \quad \mu_{generated} \neq \mu_{reference}$$

At α = 0.05 or 95% confidence level, H_0 will be rejected if P-value is less than 0.05 and the distribution cannot be used in the model. The result of this validation and the distribution of each process is presented in the below table.

Table 4 Processing Time and Validation Result

Team	Budget	Process	Unit	Distribution	P-value
Building		Receive UPR	minutes	Empirical Distribution	0.54
		Verification	hours	1.5	-
	<1m	Wait for send requirement	days	Empirical Distribution	0.55
		Wait for quotation	hours	Empirical Distribution	0.42
		Negotiate with vendor	minutes	Empirical Distribution	0.58
		Issue PA	minutes	Empirical Distribution	0.94
		Telephone	minutes	123	-
	1-5m	Verify TOR	minutes	Empirical Distribution	0.39
		Wait for send requirement	days	Empirical Distribution	0.61
		Wait for quotation	days	Empirical Distribution	0.56
		Assign committee	minutes	Empirical Distribution	0.45
		Technical scoring	minutes	Empirical Distribution	0.66
		Brief TOR	minutes	Empirical Distribution	0.55
		Final negotiation	minutes	Empirical Distribution	0.58
		Wait for present PPR	days	1	-
		Present PPR	hours	1	-
		Issue PA	minutes	Empirical Distribution	0.77
		Telephone	minutes	140	-
	>5m	Verify TOR	minutes	Empirical Distribution	0.39

Table 4 Processing Time and Validation Result (Cont'd)

Team	Budget	Process	Unit	Distribution	P-value
		Wait for publish requirement	days	Empirical Distribution	0.61
		Publish requirement	days	3	-
		Wait for quotation	days	Empirical Distribution	0.56
		Assign committee	minutes	Empirical Distribution	0.45
		Technical scoring	minutes	Empirical Distribution	0.66
		Brief TOR	minutes	Empirical Distribution	0.55
		Open envelope	hours	1	-
		Final negotiation	minutes	Empirical Distribution	0.58
		Wait for present PPR	days	1	-
		Present PPR	hours	1	-
		Issue PA	minutes	Empirical Distribution	0.77
		Telephone	minutes	160	-
		Approve 1	minutes	Empirical Distribution	0.81
General		Receive UPR	minutes	Empirical Distribution	0.64
		Verification	hours	1.5	-
	<1m	Wait for send requirement	days	Empirical Distribution	0.47
		Wait for quotation	hours	Empirical Distribution	0.34
		Negotiate with vendor	minutes	Empirical Distribution	0.47
		Issue PA	minutes	Empirical Distribution	0.97
		Telephone	minutes	132	-
	1-5m	Verify TOR	minutes	Empirical Distribution	0.65
		Wait for send requirement	days	Empirical Distribution	0.89

Table 4 Processing Time and Validation Result (Cont'd)

Team	Budget	Process	Unit	Distribution	P-value
		Wait for quotation	days	Empirical Distribution	0.31
		Assign committee	minutes	Empirical Distribution	0.41
		Technical scoring	minutes	Empirical Distribution	0.68
		Brief TOR	minutes	Empirical Distribution	0.48
		Final negotiation	minutes	Empirical Distribution	0.68
		Wait for present PPR	days	1	-
		Present PPR	hours	1	-
		Issue PA	minutes	Empirical Distribution	0.68
		Telephone	minutes	152	-
	>5m	Verify TOR	minutes	Empirical Distribution	0.65
		Wait for publish requirement	days	Empirical Distribution	0.89
		Publish requirement	days	3	-
		Wait for quotation	days	Empirical Distribution	0.31
		Assign committee	minutes	Empirical Distribution	0.41
		Technical scoring	minutes	Empirical Distribution	0.68
		Brief TOR	minutes	Empirical Distribution	0.48
		Open envelope	hours	1	-
		Final negotiation	minutes	Empirical Distribution	0.68
		Wait for present PPR	days	1	-
		Present PPR	hours	1	-
		Issue PA	minutes	Empirical Distribution	0.68
		Telephone	minutes	172	-
		Approve 1	minutes	Empirical Distribution	0.94
Outsource		Receive UPR	minutes	Empirical Distribution	0.53

Table 4 Processing Time and Validation Result (Cont'd)

Team	Budget	Process	Unit	Distribution	P-value
		Verification	hours	1.5	-
	<1m	Wait for send requirement	days	Empirical Distribution	0.64
		Wait for quotation	hours	Empirical Distribution	0.45
		Negotiate with vendor	minutes	Empirical Distribution	0.37
		Issue PA	minutes	Empirical Distribution	0.84
		Telephone	minutes	203	-
	1-5m	Verify TOR	minutes	Empirical Distribution	0.56
		Wait for send requirement	days	Empirical Distribution	0.77
		Wait for quotation	days	Empirical Distribution	0.41
		Assign committee	minutes	Empirical Distribution	0.55
		Technical scoring	minutes	Empirical Distribution	0.47
		Brief TOR	minutes	Empirical Distribution	0.52
		Final negotiation	minutes	Empirical Distribution	0.62
		Wait for present PPR	days	1	-
		Present PPR	hours	1	-
		Issue PA	minutes	Empirical Distribution	0.73
		Telephone	minutes	230	-
	>5m	Verify TOR	minutes	Empirical Distribution	0.56
		Wait for publish requirement	days	Empirical Distribution	0.77
		Publish requirement	days	3	-
		Wait for quotation	days	Empirical Distribution	0.41
		Assign committee	minutes	Empirical Distribution	0.55

Table 4 Processing Time and Validation Result (Cont'd)

Team	Budget	Process	Unit	Distribution	P-value
		Technical scoring	minutes	Empirical Distribution	0.47
		Brief TOR	minutes	Empirical Distribution	0.52
		Open envelope	hours	1	-
		Final negotiation	minutes	Empirical Distribution	0.62
		Wait for present PPR	days	1	-
		Present PPR	hours	1	-
		Issue PA	minutes	Empirical Distribution	0.73
		Telephone	minutes	265	-
		Approve 1	minutes	Empirical Distribution	0.83
Others		Approve 2	minutes	Expression	-
		Receive PA	minutes	1	-
		PO approval 1	minutes	3	-
		Final PO approve	minutes	2	-
		Wait for print	hours	TRIA(0.5,1,1.5)	-
		Print PO	minutes	10	-

Please note that the processes with a specific processing time are the processed that the processing time cannot be collected by data collection form then the interview with buyer has to be used for estimating the processing time instead. As a consequence, the statistical validation cannot be applied for these processing time.

On the other hand, for the processes with distribution of processing time, all of them have the P-value more than 0.05. As a result, these distributions are statistically valid and can be used in the model.

At this stage, all the processing time ad their distribution of the processes in the simulation are defined and validated. The next step is to validate the model in order to ensure the representability of the model. In order to validate the model, outputs from the model such as PA's cycle times are compared with the actual ones. Outputs of the three teams, each with three sourcing methods, are validated separately. All of the settings in simulation such as number of operators in each team, working hours, etc. are set to be the same level as existing level to duplicate the situation of data collection period. The arrival rates and proportion of PAs in each team and budget are presented below

Table 5 Proportion of PAs for Output Validation

Team	Team Proportion	Budget Proportion in Team				
		<1M	1-5M	5-20M	20-50M	>50M
Building	31.82%	55.56%	31.75%	11.11%	1.59%	0.00%
General	59.09%	78.63%	12.82%	3.42%	2.56%	2.56%
Outsource	9.09%	44.44%	33.33%	11.11%	5.56%	5.56%

Table 6 Arrival Rates of PAs for Output Validation

Workday	Arrival per hour	Workday	Arrival per hour	Workday	Arrival per hour
1	6.125	8	0.75	15	0.75
2	1.125	9	0.375	16	0.875
3	0.5	10	1.125	17	0.875
4	0.5	11	1.625	18	0.75
5	2.25	12	0.5	19	1
6	1.25	13	1.125	20	0.375
7	1.625	14	1.25	21	0.125

The arrival rates and proportion of PAs which are used for model validation is the actual data during data collection period. Once all of parameters are set then the model is run for 1-month period (21 workdays) as an actual condition with 20 replications.

According to the nature of actual process, this is the non-terminating process from the fact that there are some jobs those cannot be done within a day and they can be carried over to the next day. As a consequence, warmup period of this process is defined by Welch's procedure and results in 15 days of warmup period. Then the processing time of outputs from each team and sourcing method are separately collected for validation and result is shown as per below table.

Table 7 Result of Output Validation

Team	Budget	Actual		Simulated		P-value
		Mean	Variance	Mean	Variance	
Building	<1m	4.26	12.26	4.57	11.48	0.63
Building	1-5m	4.20	7.22	5.19	12.29	0.25
Building	>5m	9.75	35.64	8.35	18.96	0.45
General	<1m	5.77	20.33	5.00	17.82	0.15
General	1-5m	6.87	20.70	6.20	15.60	0.42
General	>5m	7.60	97.82	5.71	26.41	0.48
Outsource	<1m	2.92	6.99	4.06	6.93	0.21
Outsource	1-5m	9.00	25.20	11.05	14.58	0.29
Outsource	>5m	9.60	56.30	11.78	41.94	0.58

The same method of validation is applied at this stage which is t-test hypothesis testing at 95% confidence level (α = 0.05) with

$$H_0: \quad \mu_{simulated} = \mu_{actual}$$

$$H_a: \quad \mu_{simulated} \neq \mu_{actual}$$

The result in Table 7 shows that outputs from all teams and budgets have P-value more than 0.05 then H_0 cannot be rejected. This model is statistically able to represent the actual situation of data collection period and ready to be used for experiments.

Design of Experiment

The main problem of the department is the high level of delayed work so this study aims to create the operator allocation in order to mitigate this problem by minimizing the number of this delayed works. The delayed work along with cycle time have been studied in quarterly basis as shown in Figure 14 and Figure 15. The result in these two figures reflects the pattern of the delayed work. For building team, the cycle time and delayed work are higher at the beginning of the year and decreased at the end of the year while the trend of general team is vice versa. The dynamic allocation plans are created in order to match with this trend. The allocation plan is also considered the option to add one additional operators into the process. The additional operator will be added in both static and dynamic allocation. Another main concern in creating new allocation plan is implementation stage of this plan. Each of allocation plan in Table 8 is created with a minimal modification to existing setting and also avoid reduction of operator in each team if possible. Finally, the allocation plans are created as shown in Table 8.

Table 8 Scenarios considered in the Experiments

Scenario	Quarter1			Quarter2			Quarter3			Quarter4			Total Operator
	Building	General	Outsource	Building	General	Outsource	Building	General	Outsource	Building	General	Outsource	
0	6	6	4	6	6	4	6	6	4	6	6	4	16
D8887	8	5	3	8	5	3	8	5	3	7	6	3	16
D7776	7	5	4	7	5	4	7	5	4	6	6	4	16
D7766	7	5	4	7	5	4	6	6	4	6	6	4	16
A-B	7	6	4	7	6	4	7	6	4	7	6	4	17
A-G	6	7	4	6	7	4	6	7	4	6	7	4	17
A-O	6	6	5	6	6	5	6	6	5	6	6	5	17
AD8887	8	5	4	8	5	4	8	5	4	7	6	4	17
AD7776	7	6	4	7	6	4	7	6	4	6	7	4	17
AD8877	8	5	4	8	5	4	7	6	4	7	6	4	17

At first, the existing setting of the department is defined in scenario 0 in order to reflect the actual situation as a reference in this research. Other scenarios are designed to demonstrate the possible allocations which created from above mentioned idea. Scenarios are labelled with alphabet and numbers. The alphabet refers to the main modification in the plan. D stands for dynamic operator allocation which operators in these plans are re-allocated dynamically among each quarter to catch up with the demand of each team. A is a label for a plan with additional operator which these scenarios are created in order to simulate the effect of adding operator into each team for the department to make decision without dynamic operator. AD refers to plan with both additional operator and also dynamic allocation is applied.

Meanwhile, the number of in the labelling refers to number of operators in building team in each quarter since this team handle major part of the department.

For instance, D 8887 refers to the scenario with dynamic operator allocation which number of operators in building team in each quarter is 8,8,8 and 7 respectively.

Scenario D8887 is created by considering workload of each team using number of PA weighted with SLA of each budget in each quarter. The number of operators in building team should be increased in the first 3 quarters while operator of outsource team should be reduced according to its low number of PA.

Scenario D7776 is the scenario that try to allocate more operator to building team without reducing operator from outsource team because the reduction of operator may cause complication in actual operation and outsource team already has the smallest number of operators then reduction of operator in outsource team should be avoided if possible. Scenario D7766 is the modified version of D7776 since D7766 is the semi-annual operator allocation which may be more practical than D7776 with only 1-quarter allocation.

Scenario A-B, A-G and A-O is the scenario that add 1 additional operator to building team, general team and outsource team respectively. These options may not be match with the dynamic demand but they are proposed and planned to be tested in case that the dynamic operator allocation is unable to implement at the department.

Scenario AD8887 is created by matching the optimal number of operators in building team from scenario D8887 but there is no need to decrease the number of operators in outsource team in this case since there is one additional operator. In order to avoid reduction of operators in each team, scenario AD7776 is created for minimizing negative reaction and complication which may occur in the operation. Finally, Scenario AD8877 is the modified version of scenario AD8887 but with semi-annual allocation instead of quarter allocation.

Each of these scenarios will be run in the simulation model by scheduling operators which are buyers in each team according to the plan. In each experiment, the model will be run with 1-year duration and 20 replications in order to represent the effect of allocation in all 4 quarters. The daily arrival rate of PA in 2016 is used in order to represent the quantity of incoming work and the proportion of PA is defined by quarterly average of historical data from 2012 to 2015 as per following table.

Table 9 Quarterly PA Proportion by Budget

Team	Quarter	PA Proportion by Budget				
		<1M	1-5M	5-20M	20-50M	>50M
Building	1	86.07%	10.63%	2.42%	0.73%	0.16%
	2	84.05%	12.71%	3.00%	0.01%	0.22%
	3	80.93%	14.73%	3.39%	0.61%	0.35%
	4	80.99%	15.14%	3.33%	0.23%	0.31%
General	1	85.20%	9.69%	4.40%	0.00%	0.72%
	2	86.12%	10.82%	2.49%	0.38%	0.18%
	3	87.04%	8.89%	2.91%	0.63%	0.53%
	4	85.60%	10.96%	2.13%	0.51%	0.80%
Outsource	1	66.58%	13.05%	10.00%	3.40%	6.97%
	2	69.61%	15.04%	9.38%	1.74%	4.23%
	3	76.28%	13.59%	7.37%	1.37%	1.39%
	4	80.67%	9.53%	2.32%	2.32%	5.16%

Table 10 Quarterly PA Proportion by Team

	PA Proportion by Team		
	Building	General	Outsource
Q1	57.90%	29.43%	12.67%
Q2	55.09%	31.99%	12.92%
Q3	50.46%	36.01%	13.53%
Q4	43.85%	42.23%	13.92%

The team and budget proportion of PAs in Table 9 and

Table 10 are input in the model as expressions to assign a team and budget to PA according to its arrival date.

In order to solely reflect the effect of operator allocation in this study, the main external factor which is vendors are assumed to perform at committed level. In this case, they are assumed that they will submit the quotation within the period indicated in the procurement policy according to below table.

Table 11 Request for Quotation Period

Budget of quotation	Submission period
Below 1 million Baht	1 day
Between 1-5 million Baht	2 days
Above 5 million Baht	5 days

Table 11 shows the committed period of request for quotation process which is the duration that all vendors who receive the enquiry need to submit the quotation within this deadline. In the simulation, the quotation submission period is set to these periods constantly. Moreover, operators or buyers are responsible for other tasks in daily operation e.g. following up the outstanding transaction, goods receiving, making report, etc. The time consumed by these non-PA-related activities are removed from the operating hours of the process since the only time for PA-related are considered in this study. As a consequence, the process is set to be active for only 6 hours per day in the simulation. Once all parameters are set then each scenario is simulated in the model. The parameters in Table 2 are collected and will be evaluated with DEA in the next step.

9. Results and Analysis

Results from Simulation

One of the major benefits of simulation is the reflection of process modification without actual implementation. In this case, all of scenarios are tested in the simulation in order to study their benefit to operation though set of parameters. The department is not necessary to make any adjustment to their daily operation which may create complication and negative effect to their performance.

In scenario 0, the operator allocation is set to be as-is condition. The operators are statically set to each team which are 6 operators for building team, 6 operators for general team and 4 operators for outsource team. These teams have to handle the incoming UPR according to proportion of historical data as mentioned above. The proportion of works in each team is presented in the following figure.

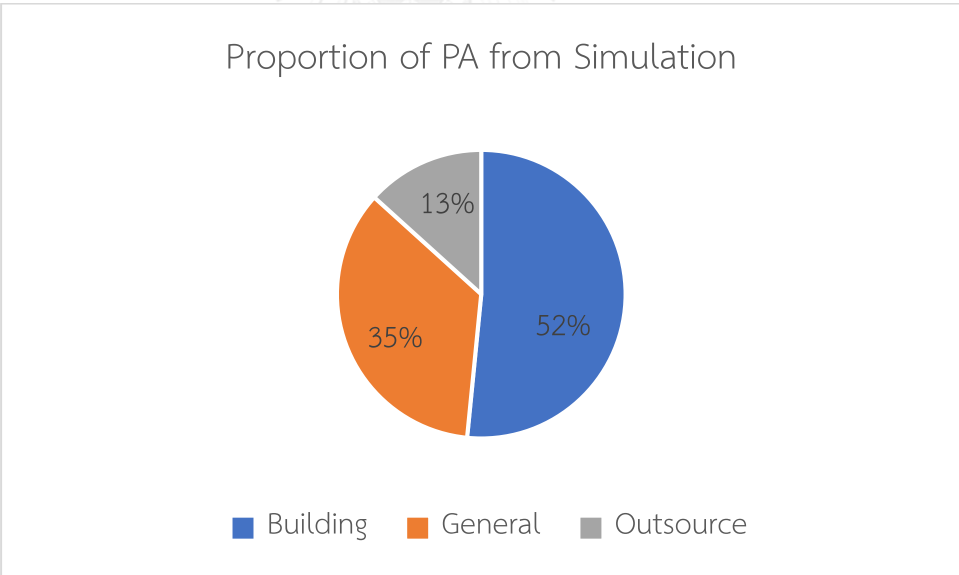


Figure 17 Proportion of PAs from Simulation

Figure 17 shows the proportion of works for each team from the simulation which presents the same proportion as Figure 11. This also reflects the problem of this study which is imbalance workload among teams. Building team has to handle with the most PAs of the department which is 52% of total PAs while outsource team get the smallest number of works at only 13%. This imbalance workload leads to unequal utilization which presented below.

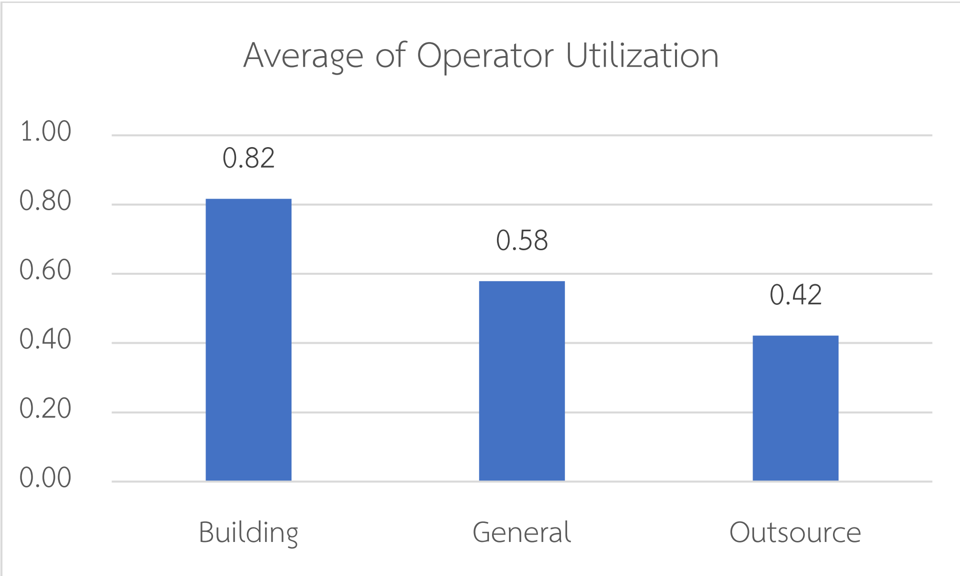


Figure 18 Average of Operator Utilization from Scenario 0

This figure shows imbalance utilization among teams. Building team which hold the highest number of PAs results in the highest operator utilization at 0.82 while outsource team with the smallest number of works shows only 0.42 of operator utilization. At this level of utilization of building team, the high number of delay rate can be expected because of higher waiting time and longer queue. The simulation is also able to present this problem in form of waiting time in the process.

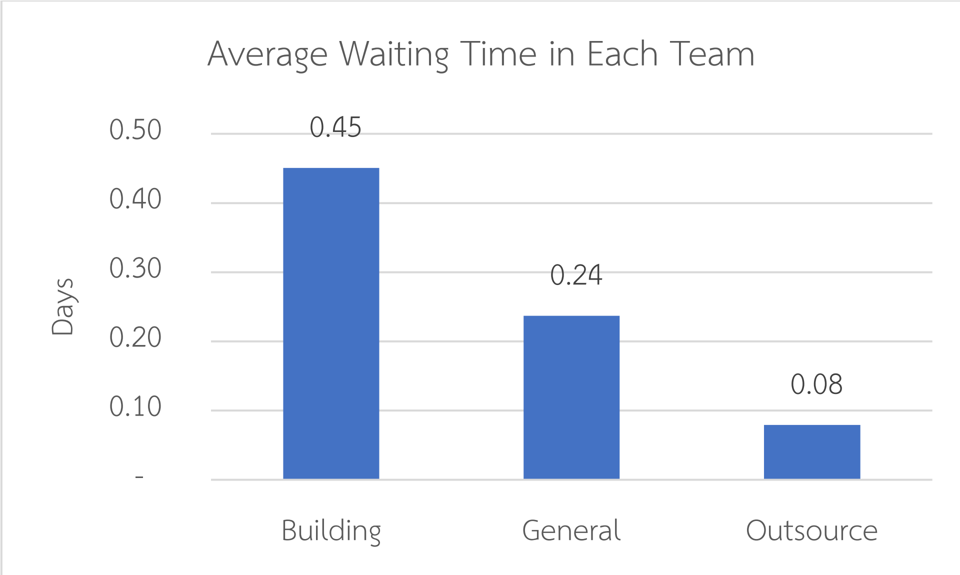


Figure 19 Average Waiting Time in Each Team from Scenario 0

The waiting time in process also responds to the trend of utilization. Building team with the highest utilization gets the highest average waiting time at 0.45 days while outsource team has only 0.08 days of waiting time. The waiting time at almost half of the day of building team shows the problem of non-matching between number of works and operators. Operators in this team do not have enough time to finish the job efficiently which represented from their utilization at high level then it leads to high waiting time. On average, each job of building team needs to wait for almost half of the day before it can be processed and finished all the activities in the procurement process. This can lead to more delay works which the result from simulation is presented hereinafter.

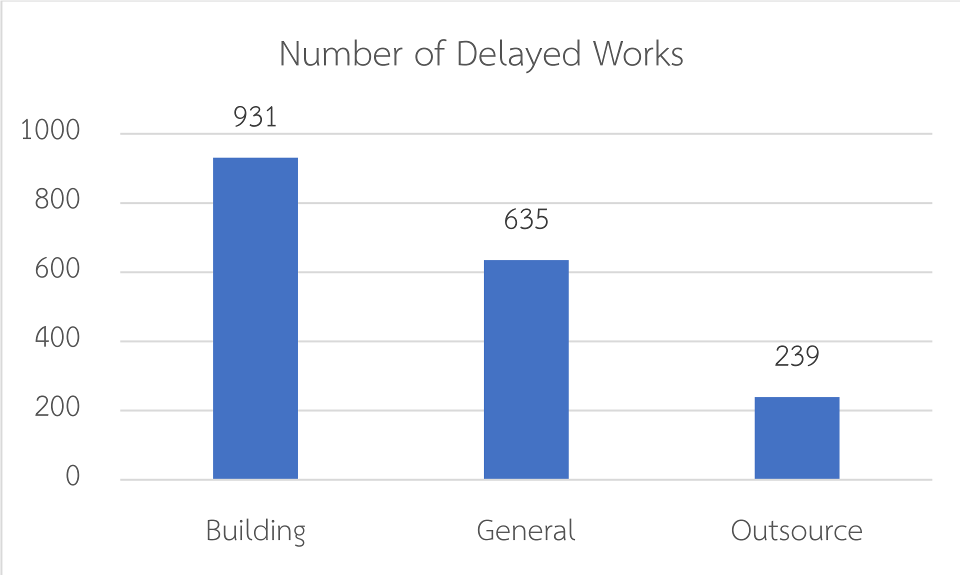


Figure 20 Number of Delayed Works from Scenario 0

The number of delayed works in building team is relatively high compared with other teams. This reflects the actual situation of the procurement team which they are facing with high delayed work rate. The operator allocation in Table 8 is created in order to minimize these kind of works and helps the department to improve their performance.

Scenario D8887, D7776, D7766 are created by studying demand of procurement for each team in quarterly basis. Operators are reallocated in scenarios in order to match with the fluctuated demand and also operation aspects as described in previous section. By assigning more operator to building, this results in less utilization of operators in building team but also increases the utilization of other team as shown in Figure 21 below.

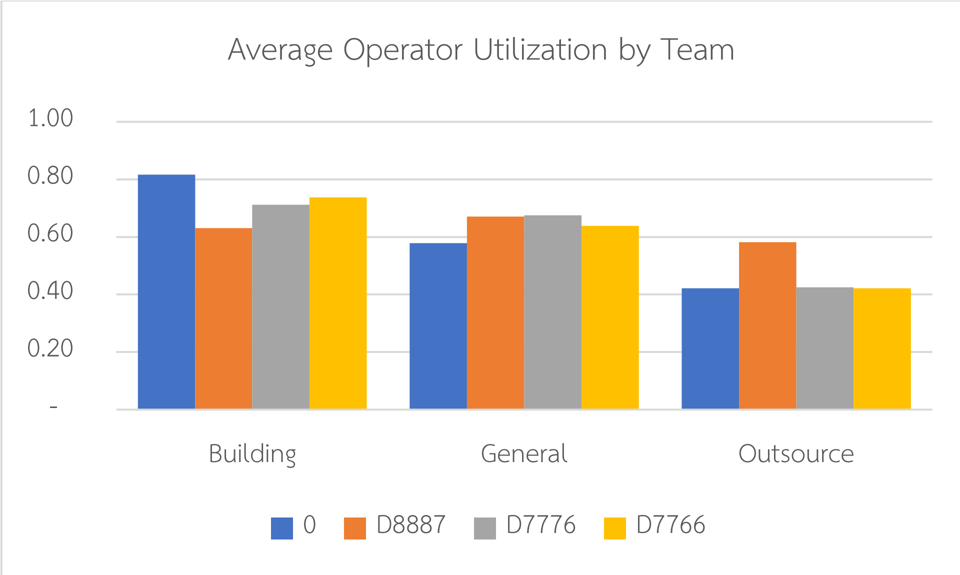


Figure 21 Average Operator Utilization by team from Scenario 0, D8886, D7776, D7766

This figure shows average operator utilization among scenarios which dynamic operator allocation is applied without additional operator. The overall average operator utilization are the same in these scenarios (at 0.63) since they all have 16 operators in the process and the rate of incoming UPR is the same. But with different operator allocation plan, they present variety of operator utilization among teams. Operators in building team of scenario 0 show the highest utilization. In other scenarios, the utilization of building team operator is lower because the allocation mainly moves operator from other team to building team in order to support higher demand. Scenario D8887 shows the lowest utilization among these 4 scenarios while results in the highest utilization of operator in outsource team. This is caused by the additional operator in building team is moved from outsource team then it results in this changing in utilization. For utilization of operators in general team, scenario D8886 and D7776 present the high utilization because these two scenarios allocate one operator to building team in the first three quarters while scenario D7766 shows a little lower utilization since it allocates one operator from this team to building team for only two quarters. By assigning from other teams to building team, this lowers the utilization of building team but also needs trade-off by increasing utilization from other teams.

In scenario A-B, A-G and A-O, one additional operator is added into building, general and outsource team respectively. It helps to lower the utilization of those particular team with additional operator while the rest remains the same as in scenario 0 as shown below.

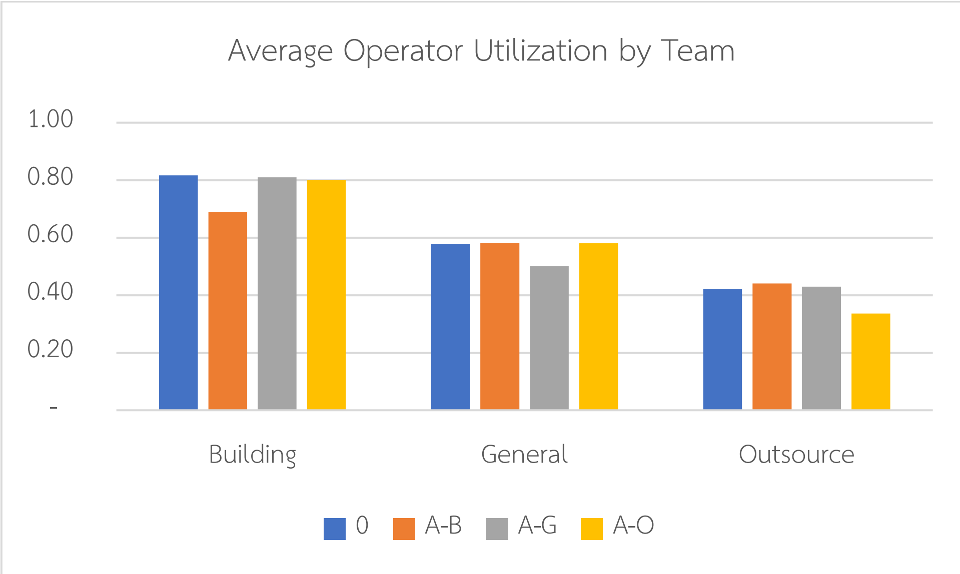


Figure 22 Average Operator Utilization by team from Scenario 0, A-B, A-G, A-O

In scenario with additional operator and dynamic allocation, those scenarios are AD8887, AD7776, and AD8877. The effect of these scenario is quite similar to scenario with dynamic allocation (D8887, D7776, D7766) except the less negative effect of dynamic allocation because of one additional operator then the requirement to reallocate operator to building team is less. The result is shown in below figure.

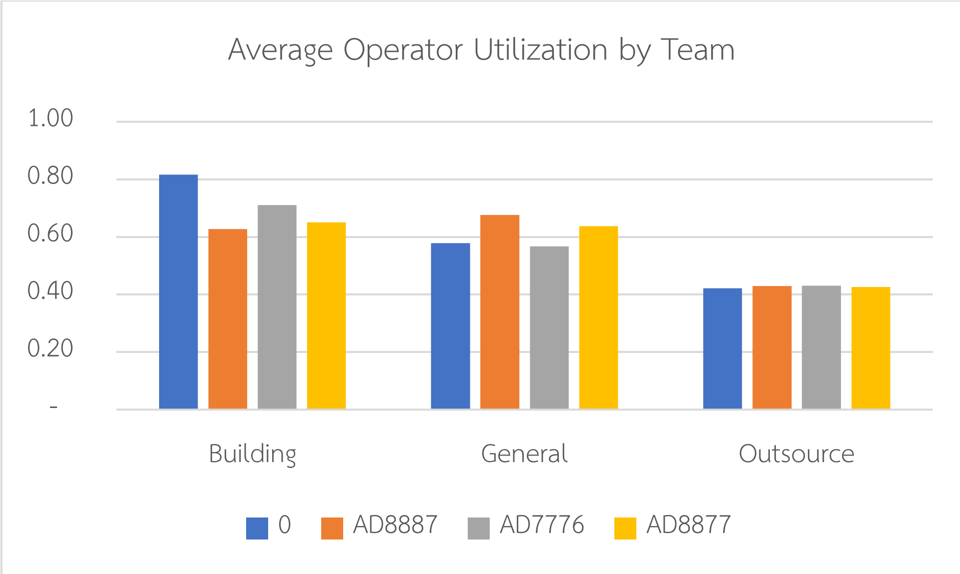


Figure 23 Average Operator Utilization by team from Scenario 0, AD8887, AD7776, AD8877

By allocating more operator to building team, the utilization operator of building team is decreased. AD8887 is the scenario with the most operator in building in this case team then it shows the lowest utilization of building team but it also results in the highest utilization of general team since it requires allocation of operator from general team to building team. While the other two scenarios allocate operators to building team with lower magnitude then they present higher utilization of building team and lower for general team. As mentioned above, the additional operator helps to avoid reduction of operators in each team for dynamic operator allocation. Comparing between D scenarios and AD scenarios with the same allocation of operators in building team, for instance, D8887 and AD8887 are the scenario with the same setting of operator in building and general team which results in same utilization for building team in both scenarios. But the D8887 results in higher utilization for outsource team due to reduction of operator in this team while AD8887 does not require the reduction of operator due to the effect of additional operator. This effect can be found in scenario D7776 and AD7776 also. D7776 requires one operator allocation from general team in order to increase number of operators in building team while additional operator in AD7776 can fulfill this requirement without moving operator out of general team. This causes higher utilization of operators in general team for scenario D7776 while this parameter can be maintained at the current level for AD7776.

The utilization of operators can leads to the average cycle time of each scenarios. Since the higher utilization of operators results in higher waiting time in the process than the higher cycle time of the process can be expected. Since majority of PA in each team are PAs with budget below 1 million (52% on average). This type of PA is selected to represent the relationship between cycle time and the utilization as presented below

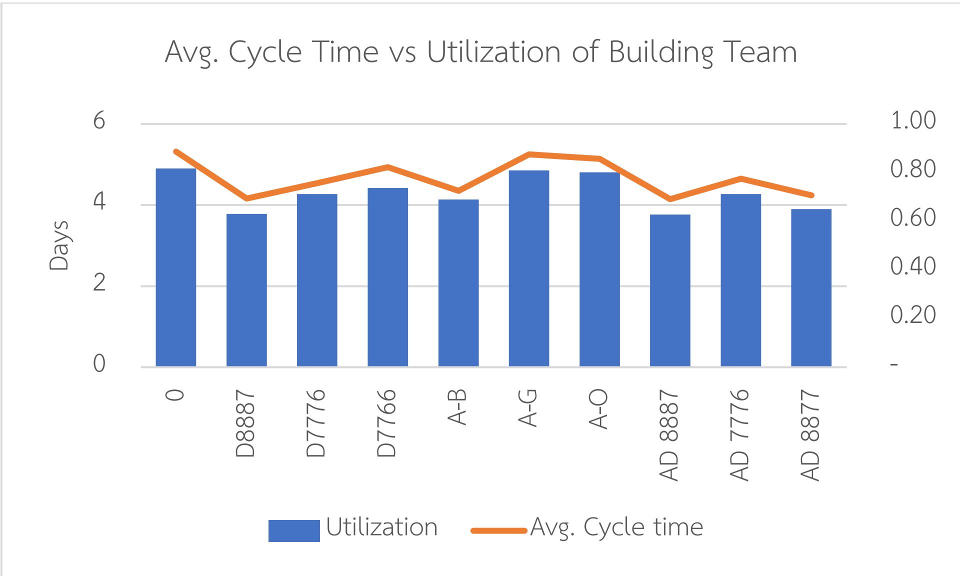


Figure 24 Relationship between Average Cycle time of PAs with budget lower than 1million and Operator Utilization in Building Team

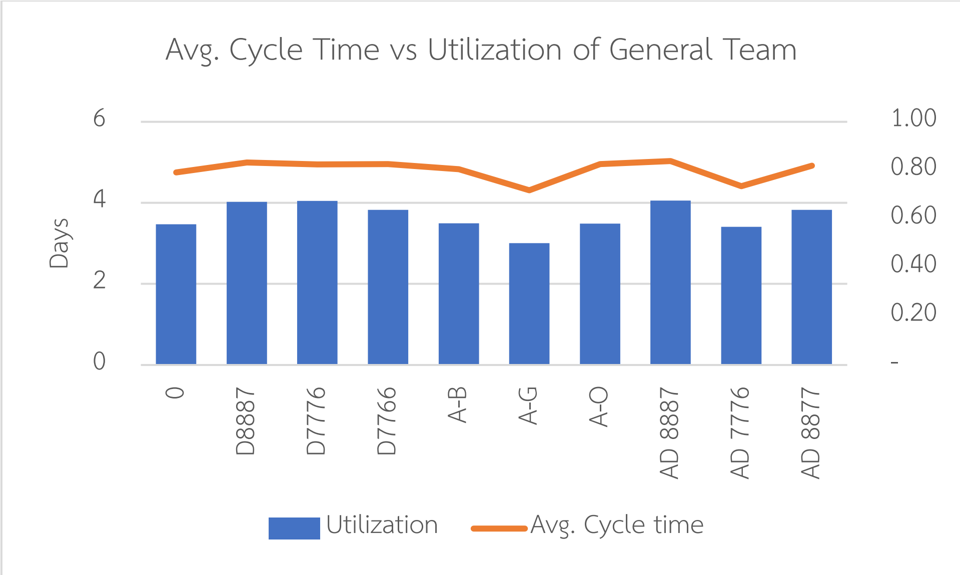


Figure 25 Relationship between Average Cycle time of PAs with budget lower than 1million and Operator Utilization in General Team

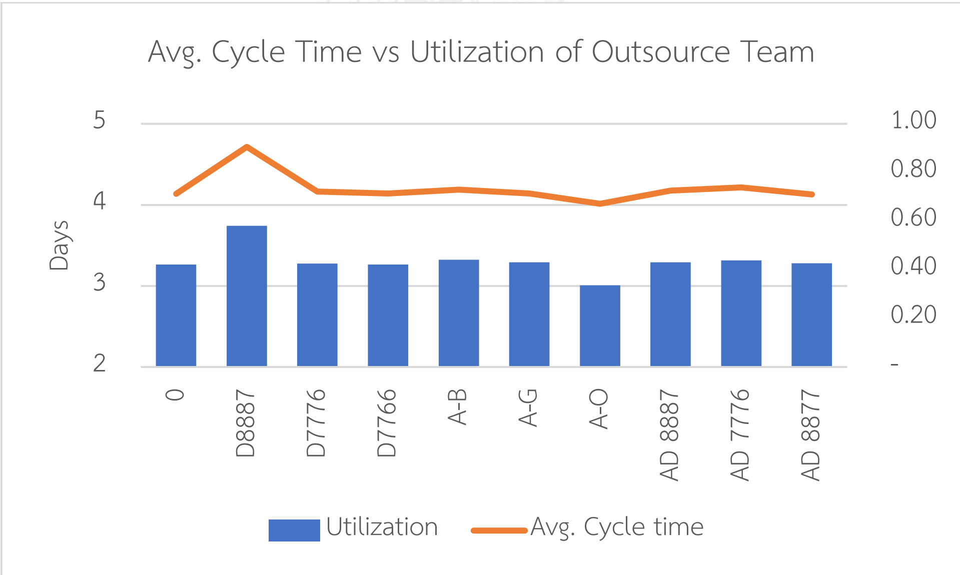


Figure 26 Relationship between Average Cycle time of PAs with budget lower than 1million and Operator Utilization in Outsource Team

Figure 24, Figure 25 and Figure 26 show the relationship between operator utilization and average cycle time. They represent the close relationship between these two parameters by showing the same trend in each team among scenarios. As expected, a lower utilization leads to lower cycle time of process which this trend is also applied to PAs with budget between 1-5 million and above 5 million. By increasing number of operators, the waiting time in process is decreased which leads to lower cycle time as shown in figures above. The correlation between number of operators and average cycle time has been studied in order to support the effect of operator allocation to the cycle time.

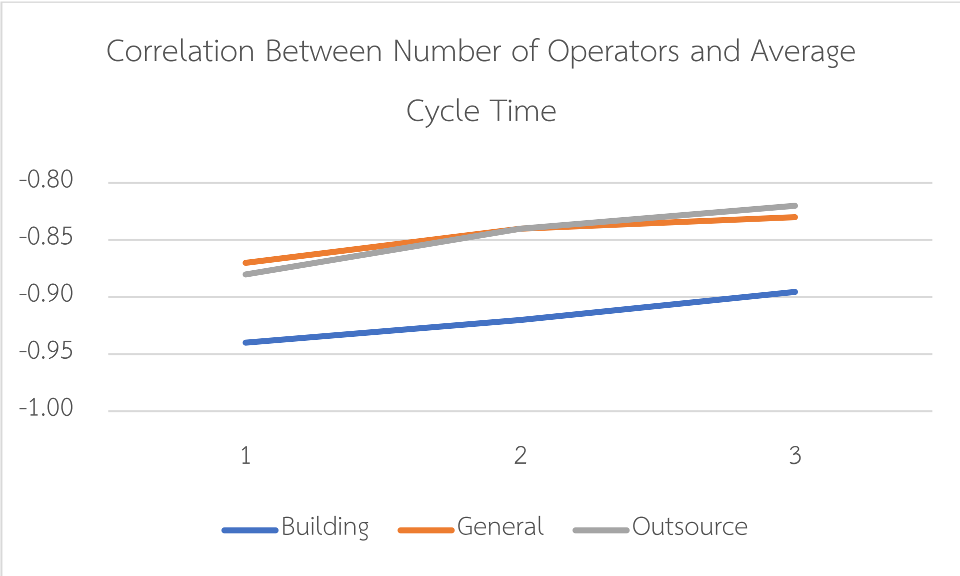


Figure 27 Correlation between Number of Operators and Average Cycle Time

Figure 27 shows the strong correlation between number of operator and average cycle time. The correlation is on negative side because cycle time is decreased when the number of operators is increased. In addition, the correlation is at high level especially for building team which caused by the fact that this team has the highest number of PAs and utilization then changing in the amount of operators can strongly affect to the cycle time of this team. The correlation is weaker when the budget of PAs is increased because of less workload then number of operators has less effect to the process. This can be concluded that the operator allocation has a strong effect to the process performance by improving the cycle time when more operators are assigned which is the objective of this study. However, the operator allocation can reduce significant amount of operator utilization but not the cycle time. Even though, the cycle time has the same trend of improvement as utilization but the magnitude of improvement is not the same level as utilization. This caused by the fact that

- The cycle time of the process is dominated by external factors like quotation submission period, waiting for negotiation, etc. The operator allocation helps to reduce waiting time in operator-related activities by improving utilization of operators. But the fact that these activities may take only hours to complete while non-operator-related activities take days causes the improvement of cycle time to be at low level compared with the operator utilization.
- Approvers normally approve PAs in batch basis which another factor that impede the improvement of the cycle time. As mentioned in previous reason, the operator allocation can only improve the performance of operator-related activities which they are in the scale of hour. But this improvement is also diminished by the batch approval of approver. Since the approver does not approve the PA immediately after the creation of PA from buyer, the improvement on buyer side will be weakened by the waiting time for approval.

Even though the improvement of cycle time does not take significant effect as expected, this reduction of cycle time still helps the department to correct the problem of delayed work. The relationship between cycle time and number of delayed work is presented in below figure.

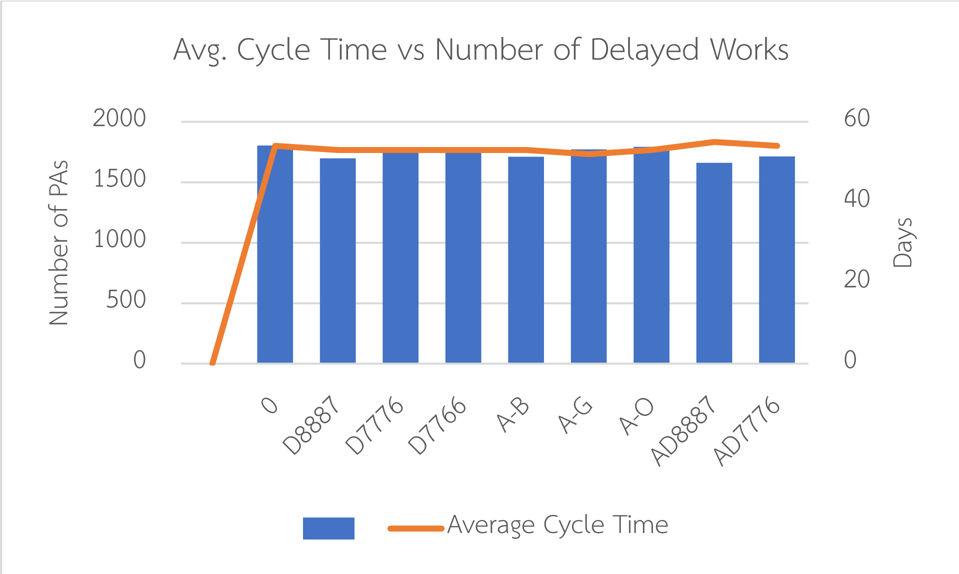


Figure 28 Relationship between Average Cycle time and Number of Delayed Works

Figure 28 presents the relationship between average cycle time and number of delayed works. It shows the similar trend which reflects strong relationship between these two parameters. Even though there is no significant improvement of the cycle time in this case, but the lower cycle time can still help the department by reducing number of delayed works which is the major problem currently. Scenario AD8887 with the lowest cycle time can reduce the number of delayed work from 1,805 cases of scenario 0 to 1662 cases which is 8% reduction.

In conclusion, operator allocation affects to the performance of the procurement process. The additional operator can reduce the utilization of operators by sharing workload within team which leads to better cycle time of the process. This is also supported by the strong negative correlation between number operator and the cycle time of the process. Assigning more operators results in less cycle time from the lower utilization. The dynamic operator allocation which is designed to match with fluctuation of demand for procurement in each team helps to balance the utilization of operators among teams which leads to better cycle time and finally reduces the number of delayed works which is the major problem of this particular procurement department.

Alternatives Evaluation

According to result from previous section, the operator allocation can help the procurement department improving their process by balancing utilization within teams. The different allocation plan creates variety of effects to the process. All of the parameters in Table 2 are considered in ranking basis in order to visualize the performance of each scenario.

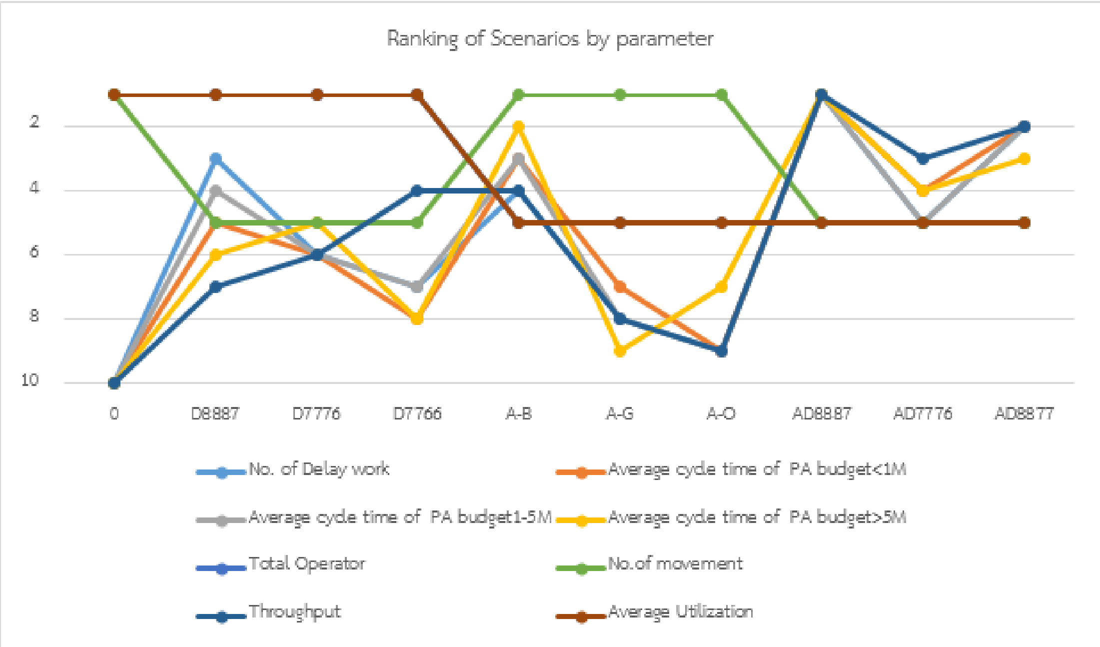


Figure 29 Ranking of Scenarios by Parameter

Scenario AD8887 results in the best improvement among scenarios from many aspects which can reduce the delayed work at 8% but this scenario requires one additional operator and also need one reallocation of operator. Even though, this scenario gives the best outcome but it may not be the most efficient alternative when trade-off between required resources and level of output are considered. D8887 or D7776 can be a candidate for the best alternative since it requires no additional operator but also able to improve the performance of the procurement process. In order to evaluate alternatives considering this trade-off, Data Envelopment Analysis (DEA) model is applied for assessing performance of each scenarios.

DEA is a methodology for empirically measure the productive efficiency of alternatives which can assess each option with multiple criteria simultaneously. DEA will optimize weight for each parameter relatively in order to reflect the efficiency of each scenario by giving efficiency score. The scenario with the score of 1 is considered as the efficient scenario.

Prior to the assessment, each of delayed work should be weighted with its budget in order to reflect the severity of the delay. The weighted scoring for each scenario is presented hereinafter.

Table 12 Weighted Scoring of Delayed Works

Scenario	No. of delayed PA with budget below 1million	No. of delayed PA with budget between 1-5million	No. of delayed PA with budget above 5million	Total no. of delayed works	Weighted delay score
0	1555	197	54	1806	2111
D8887	1465	180	53	1698	1984
D7776	1514	181	53	1748	2035
D7766	1531	183	53	1767	2056
A-B	1470	182	53	1705	1993
A-G	1530	190	52	1772	2066
A-O	1549	191	53	1793	2090
AD8887	1435	172	55	1662	1944
AD7776	1478	182	54	1714	2004
AD8877	1448	181	56	1685	1978

This delay scoring will be gathered with other parameters in Table 2 which are collected from the simulation model for each scenario in order to create evaluation criteria for DEA. The parameters are shown as per below table.

Table 13 Parameters for DEA

Scenario	Input						Output	
	Weighted delay score	No. of delayed PAs with budget below 1million	No. of delayed PAs with budget between 1-5million	No. of delayed PAs with budget above 5million	Total no. of delayed works	No. of movement	Throughput	Average Utilization
0	2,111	4.97	7.34	13.21	16	0	2,137	0.63
D8887	1,984	4.54	6.55	12.78	16	1	2,144	0.63
D7776	2,035	4.65	6.72	12.71	16	1	2,146	0.63
D7766	2,056	4.85	7.09	12.90	16	1	2,147	0.63
A-B	1,993	4.51	6.53	12.52	17	0	2,147	0.59
A-G	2,066	4.77	7.10	12.96	17	0	2,142	0.59
A-O	2,090	4.94	7.21	12.88	17	0	2,139	0.59
AD8887	1,944	4.47	6.36	12.49	17	1	2,151	0.59
AD7776	2,004	4.51	6.62	12.68	17	1	2,149	0.59
AD8877	1,978	4.48	6.47	12.59	17	1	2,150	0.59

These parameters will be put in the DEA model and each scenario will be evaluated based on these parameters. In this stage, BCC model is applied for evaluating each scenario first. BCC is one of the simplest model of DEA which is a good starting model for this assessment. The result from BCC model is presented hereinafter.

Table 14 Result of BCC

	v1	v2	v3	v4	v5	v6	u1	u2	Score
0	0.0005	-	-	-	-	0.0602	-	1.5873	**1.0000**
D8887	0.0005	-	-	-	-	-	-	1.5873	**1.0000**
D7776	0.0001	-	-	0.0642	-	-	-	1.5873	**1.0000**
D7766	-	-	-	-	0.0625	-	-	1.5873	**1.0000**
A-B	0.0004	-	0.0204	-	-	0.0714	-	1.6949	**1.0000**
A-G	0.0002	-	-	-	0.0313	0.0320	0.0005	-	0.9812
A-O	-	-	-	0.0375	0.0304	0.0228	0.0005	-	0.9827
AD8887	0.0005	-	-	-	-	-	0.0003	0.5685	**1.0000**
AD7776	-	0.1688	-	-	0.0136	0.0073	0.0005	-	0.9930
AD8877	-	0.7602	-	-	0.2324	0.0074	0.9990	-	0.9990

v1 to v6 are the weight of inputs and u1 to u2 are the weight of outputs in Table 13. The objective function of BCC is to maximize the score in each scenario by optimize the weight of input and output. One of the drawbacks of BCC is the bias which may occur in the optimization. In order to maximize the score for particular scenario, some of parameters are excluded from the analysis by given the weight at 0. Then there are high possibilities that more than one scenarios are awarded as an efficient scenario with score of 1. This situation is called low discriminating power of BCC which refers to the situation that BCC cannot distinguish efficiency of scenarios by giving multiple score of 1. In this case, there is no significant different in parameters in each scenario due to the external factors as mentioned then the BCC with low discriminating power cannot distinguish efficiency among scenarios. 6 out of 10 scenarios are awarded as an efficient scenario which some of them are considered only 3 parameters. The scenario selection cannot be made with this multiple-awarded result. Then Multiple Criteria Data Envelopment Analysis (MCDEA) model will be applied in order to distinguish efficiency of these scenarios. The result of MCDEA is presented as per following tables.

Table 15 Result of MCDEA – max score objective

	v1	v2	v3	v4	v5	v6	u1	u2	Score
0	-	-	0.1433	-	-	0.0614	-	1.5873	1.0000
D8887	-	-	0.1433	-	-	0.0614	-	1.5873	1.0000
D7776	0.0001	3E-06	-	0.0599	0.0011	0.0496	-	1.5873	1.0000
D7766	-	-	-	2E-07	0.0551	0.1186	-	1.5873	1.0000
A-B	3E-06	7E-08	1E-07	4E-07	0.0551	0.1232	-	1.6949	1.0000
A-G	-	7E-08	1E-07	4E-07	0.0588	0.1282	-	1.6949	1.0000
A-O	-	7E-08	1E-07	4E-07	0.0588	0.1282	-	1.6949	1.0000
AD8887	0.0001	7E-08	1E-07	0.0421	0.0186	0.0068	0.0005	-2E-07	1.0000
AD7776	-	0.1688	1E-07	-	0.0136	0.0073	0.0005	-	0.9930
AD8877	-	0.1698	5E-07	-	0.0137	0.0074	0.0005	-	0.9990

Table 16 Result of MCDEA – minmax objective

	v1	v2	v3	v4	v5	v6	u1	u2	Score
0	3E-11	-2E-07	0.1349	-	5E-08	0.0246	0.0002	0.6814	0.9066
D8887	5E-05	1E-07	0.1348	3E-07	3E-07	0.0269	0.0003	0.7312	1.0000
D7776	3E-05	0.0002	0.1348	3E-07	3E-07	0.0252	0.0002	0.7156	0.9756
D7766	1E-05	0.0002	0.1349	3E-07	3E-07	0.0217	0.0002	0.6901	0.9271
A-B	1E-05	0.0002	0.1348	-	0.0057	0.0235	0.0003	0.5606	0.9980
A-G	8E-06	0.0002	0.1349	0.0018	-	0.0231	0.0002	0.7027	0.9189
A-O	1E-06	0.0002	0.1349	0.0018	-	0.0220	0.0002	0.6945	0.9029
AD8887	-	-	0.1288	-	0.0066	0.0693	-	1.6156	0.9532
AD7776	-	-	0.1349	-	0.0053	0.0166	0.0003	0.5584	0.9643
AD8877	-	-	0.1302	-	0.0020	0.0454	-	1.4759	0.9491

Table 17 Result of MCDEA – minsum objective

	v1	v2	v3	v4	v5	v6	u1	u2	Score
0	-	-	0.1307	-	-	0.0418	-	1.4252	0.8979
D8887	-	-	0.1486	-	-	0.0270	0.0002	0.7479	1.0000
D7776	-	-	0.1449	-	-	0.0263	0.0002	0.7293	0.9757
D7766	-	-	0.1376	-	-	0.0250	0.0002	0.6925	0.9265
A-B	-	1E-07	0.1488	-	0.0016	0.0271	0.0003	0.7129	0.9964
A-G	-	1E-07	0.1408	-	-	0.0256	0.0002	0.7090	0.9191
A-O	-	1E-07	0.1386	-	-	0.0252	0.0002	0.6979	0.9040
AD8887	-	2E-07	0.1488	-	0.0016	0.0271	0.0003	0.7143	0.9990
AD7776	-	2E-07	0.1470	-	-	0.0267	0.0002	0.7401	0.9612
AD8877	-	2E-07	0.1488	-	0.0006	0.0271	0.0003	0.7362	0.9831

According to above tables, more parameters are considered through multiple objective of MCDEA compared with single objective of BCC. The multiple objective of MCDEA can reduce bias of the model which try to maximize efficient score of alternative by removing parameter from the analysis. Multiple objective functions force the model to consider parameters in more perspectives for granting efficient score. This results in higher discriminating power of MCDEA. In this case, there is only one scenario which is awarded as an efficient alternative from BCC and all objective functions of MCDEA. Even though scenario AD8887 shows the best outcome in term of the lowest cycle time and number of delayed works but it is not awarded as an efficient alternative. On the other hand, scenario D8887 does not give the best outcome among 10 scenarios but it can be considered as the best scenario without adding additional operators.

Finally, with the best efficient allocation which is D8887, the procurement department can reduce their number of delayed works by 6% (from 1805 cases to 1698 cases) without additional operator.

Discussion

This study only focuses on the improvement of procurement process by operator allocation which is the internal process that can be directly managed by the department itself. Operator allocation is the process improvement which affects to only operator-related activities. But in practice, procurement process is the process that involves several parties both internal parties (e.g. law and regulation, security, building management, marketing, etc.) and external parties especially suppliers.

Suppliers or vendors play an important role in procurement process by supplying required product/service to the bank according to enquiry sent by buyers. The procurement process requires vendors to submit their quotation prior to delivery of the product/service in order to comparing offers from at least 3 different vendors. After enquiry is sent from buyer to vendors, buyer need to wait for quotation from suppliers which can be considered as an idle time of buyer. Moreover, this period can cause higher cycle time from longer waiting time if supplier does not send quotation within the period in Table 11. The quotation submission period of the PA with budget below 1million is selected to be a case study from its high proportion in total PA (52%). In addition, PA with budget below 1million has less complexity in requirement or specification from user compared with PA with higher budget which is more complex and may require more clarification and communication with vendor. Then vendor who receive the enquiry of product/service with budget below 1million should be able to create quotation and submit to buyer within the desired duration.

According to data from data collection form, it shows that currently there are some jobs that vendors submit the quotation beyond the commit period as shown in the following figure.

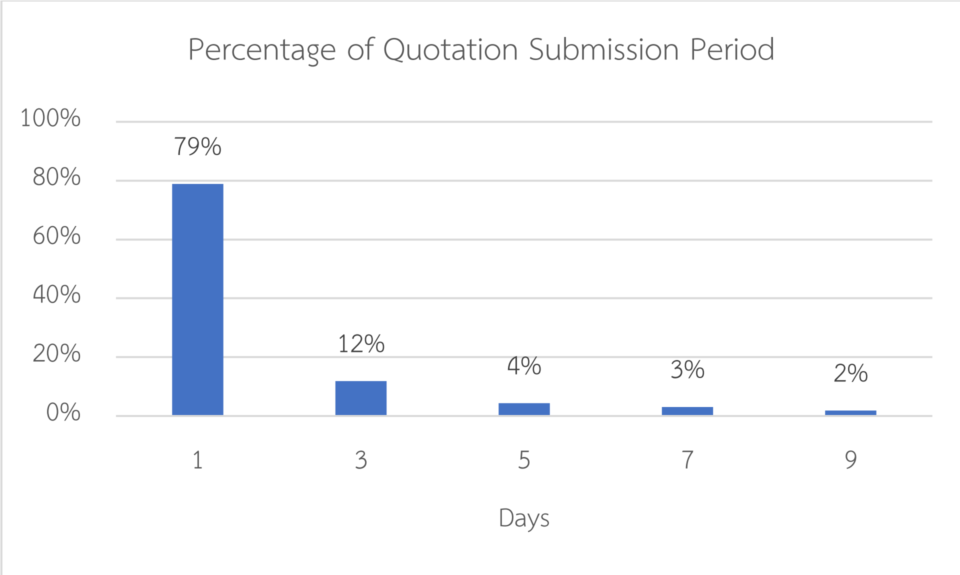


Figure 30 Percentage of Quotation Submission Period

According to the procurement agreement for PA with budget below 1million, vendors should submit their quotation within 1 day after receiving procurement enquiry from user. But from the data presented in Figure 30, it shows that there are 21% of total jobs that vendors submit the quotation beyond the agreed time which can be implied that 21% of works are certainly delayed from vendors and buyer cannot do anything to shorten the cycle time for these cases.

In order to minimize the delayed works, management and buyers need to coordinate with vendors in order to minimize the quotation submission period by following means.

- *Introduce more bulk bidding:* Bulk bidding is the bidding method for some regular items those need to be purchase regularly through the year. The bidding takes place only once at the beginning of the year. The price from this bidding will be applied every time the item need to be purchased within a year. This eliminates time consumed by repeat sourcing process of the same item.
- *Set up vendor ranking system:* Ranking system can help to award vendors who perform and cooperate well according to the procurement policy which promptly submit quotation is also one dimension of evaluation. The ranking

will incentivize the vendor to submit quotation within designed period for getting other benefit of higher ranking.

- *Sign more long-term contract with vendors:* Close and long-term relationship with vendor help to improve the performance process since the vendor has already known the regulation and culture of the department then they should be able to perform according to the policy of the department.
- *Implement forecasting for regular purchased items:* Using forecasting technique can prevent delay of quotation submission by sending enquiry to vendors in advance. Buyer will know the estimate quantity and also the period that user may want the product/service from forecasting result then the enquiry can be sent to vendors prior to creation of UPR from user.

With above mentioned method, the department should be able to decrease the delay of quotation submission which leads to reduction of number of delayed works eventually. The estimate of improvement has been done in the simulation model and the result is presented hereinafter.

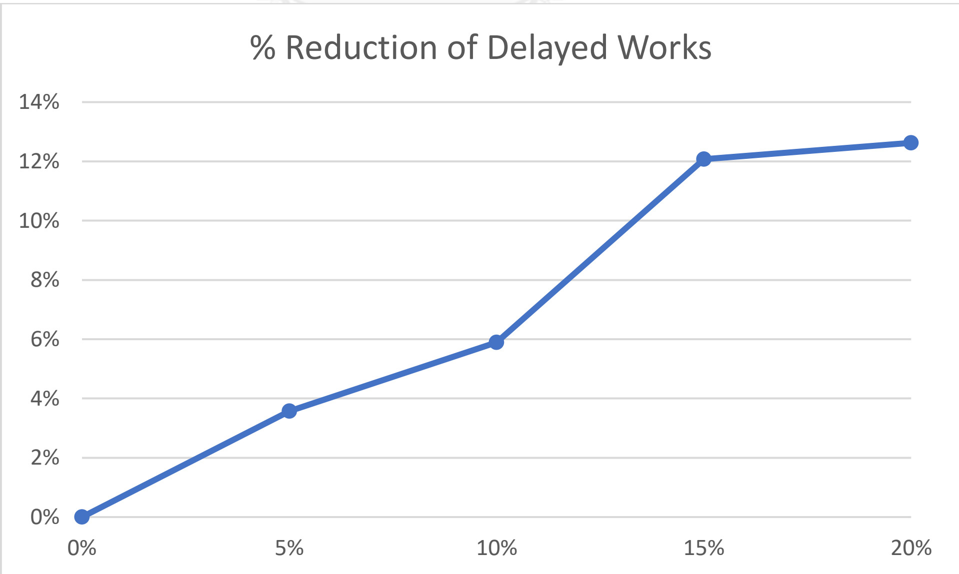


Figure 31% Reduction of Delayed work when the delayed quotation submission period is increased.

Figure 31 shows the relationship between total number of delayed works and % of delayed quotation submission. The horizontal axis is the percentage of delayed quotation submission while the vertical axis shows changing percentage of total number of delayed works. More of delayed quotation submission results in more of delayed works. On the other hand, the number of delayed works can be decreased by reduction of delayed quotation submission. Finally, the total number of delay should be reduced by 12% if all of the quotations are submitted within the desired period which is a great improvement of the department if they can achieve at this level.

In conclusion, the delayed works of the procurement department should be rectified in order to ensure the satisfaction of both internal and external customers. The improvement of performance can be done by improving internally and managing external party. In term of internal improvement, operator allocation can improve the process by balancing operator utilization which lead to lower cycle time and also number of delayed works. For managing external parties, performance of vendors should be focused especially for quotation submission period. Currently, there are 21% of quotations those submitted beyond the deadline which creates delayed of PAs. By eliminating this delay, the procurement department can reduce the number of delayed works up to 12% through strategic procurement policy and better cooperation with vendors.

10. Conclusion and Recommendation

Currently, the procurement department in this case study is facing with high delayed rate of procurement tasks which caused partly by the imbalanced workloads among its three teams and the fluctuation of demands over the year. This study applies an operator allocation in order to tackle this problem. The dynamic operator allocation plans are proposed in order to match the unequally distributed workload and demand fluctuations.

By applying Computer Simulation and Data Envelopment Analysis (DEA), each allocation plan is simulated and evaluated based on set parameters. BCC and MCDEA model is used and really help to evaluate multiple criteria by considering efficiency between input and output simultaneously which is better than consider some criteria individually which may result in the alternative that give only some best parameters.

The combination between computer simulation and DEA can be considered as a powerful tool to simulate and evaluate any option prior to actual implementation. Organizations can use this tool to assess alternative when multiple criteria need to be concerned and foresee expected situation which also helps to avoid unpredicted loss or disturbance in an actual operation.

In this case, BCC and MCDEA, they obviously present their discriminating power. BCC with lower discriminating power cannot distinguish efficiency of alternatives with slight different performances. While MCDEA with multiple objective functions can reduce bias of the model and results in a higher discriminating power.

Finally, scenario D8887 is awarded to be an efficient option by getting score of 1 from BCC and all of the objective functions of MCDEA. Even though, this scenario does not give the lowest number of delayed works and cycle time but it requires no additional operator and produces reasonable outcome. The scenario AD8887 may result in the lowest number of delayed works but scenario D8887 gives slight higher in a number of delayed works but requires no additional operator and also produces a higher operator utilization.

As a consequence, scenario D8887 is awarded from DEA model to be an efficient scenario in this case. The procurement department can reduce their number of delayed works by 6% with this allocation plan.

Normally, operator allocations in many departments of the bank were made by the management of the department in order to solve daily operation problem such as delay reduction, lowering utilization of operators, etc. As a consequence, the allocations are regularly able to cope with only one objective from the fact that the management has no decision-making tool to make an efficient operator allocation plan. Moreover, adding operators to the process is always an option for the management since additional operators can help to lower workload of operators and complication in the process. But additional operator also requires higher resources in term higher fixed cost and training period.

According to the result of this study, the scenario with the best performance in some parameters may not be the best alternative in term of efficiency considering tradeoff between its required resources and outcomes. The bank can apply this framework for the next operator allocation in order to create a more efficient allocation plan. By in-depth studying of the process, simulating desired allocation plan or estimating the effect of the allocation to the output of the process, evaluating efficiency of each alternatives with DEA, this framework should lead to a more efficient alternative which may not require an additional operator as presented in this study. Eventually, this decision-making framework should help the bank to make an efficient decision which leads to better business performance with the lower resources.

For future improvement of this research, data collection should be done in wider duration for representing behavior of system in more varieties of condition in order to get more reliable results. Moreover, other models of DEA can be applied for controlling the weight of each parameter. Number of delayed works should be more focused and the weight of this parameter should be given at higher rate in order to reflect the importance of this parameter. Then evaluation can be made based on the give importance of each parameter.

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