Web App -- Decision Support System for Improving Drug Acquisition Price

Apisara Tirajitto
International School of Engineering
Chulalongkorn University
Bangkok, Thailand

Pamaree Laowong
International School of Engineering
Chulalongkorn University
Bangkok, Thailand

Kunwadee Sripanidkulchai
Computer Engineering
Chulalongkorn University
Bangkok, Thailand

***Abstract*—Healthcare industry, considered as a public utility, is one of the important fields involved with the quality of people's lives. In Thailand, we have the most successful healthcare models in Southeast Asia, however, there are still some challenges in health disparities due to the high cost of healthcare services. The cost of pharmaceutical products is one of the largest contributors of the operating costs. So, providing a system that allows healthcare organizations to monitor and manage their medicine cost along with their purchasing capability would help them to enhance their services, make it more efficient, and provide accessibility to all patients. "PAC-DSS (Pharmaceutical Acquisition Capability Decision Support)" is an existing system providing abilities to run drug price analytics on websites. Our project is to enhance the existing system by implementing more data analytics and data visualization dashboard including more factors for decision making. In this paper, we describe some calculations from the existing system that will be used in our analysis. We also describe our system design which includes data preparation, data analysis and visualization. Additionally, we elaborate on the user interface design, and website implementation.**

Keywords—pharmaceutical analysis, visualization, dashboard, decision support system, PAC, Gini

I. Introduction

In Thailand, the problems of inequalities in healthcare services are still a big challenge for the government. One of the majority costs for providing services is the medicine cost. When the cost of medicine increases, Hospitals would face a heavy financial burden from the higher purchasing prices. Moreover, the patients are also affected as they have to end up receiving medications since they cannot afford for it.

The better decision making and policy planning, the more reasonable and less spending drug purchasing they can get. If the drug cost decreases, the healthcare service cost should be lower as well. So it means that the patients can pay less when they get treatment, which can help to reduce the gap of health disparities. Also for the healthcare organizations, they can use this amount of money that they can save from drug purchasing to improve or invest in other sessions.

In this project, we implement the existing system called "PAC-DSS (Pharmaceutical Acquisition Capability Decision support services)" [1]. This existing system provides the abilities to run analytics on drug prices and help the hospital to know their bargaining power. However, this system doesn't provide some other information that could be considered as a factor for decision making (e.g. number of patients, historical purchasing quantity, total spending cost) and doesn't have the dashboard for showing the overall relationship.

To enhance this system, we plan to add more data analytics and represent the result in the data visualization dashboard. Our goal is to provide information as much as possible to help them have better decision making and planning and also provide the best way to visualize the data.

II. Background/Motivation

This section provides background of the existing system and also motivation of this project.

Back in 2012, a website called PAC-DSS (Pharmaceutical Acquisition Capability - Decision Support System) [2] was created in the purpose of helping healthcare organizations to monitor the drug price mechanism like price dispersion issue and also improve their efficiency in drug purchasing at the same time.

Last year, 2019, the updated website (Figure 1) which is still in a developing process came out with a more user-friendly and modern design, however, the overall system and data visualization still remain the same.

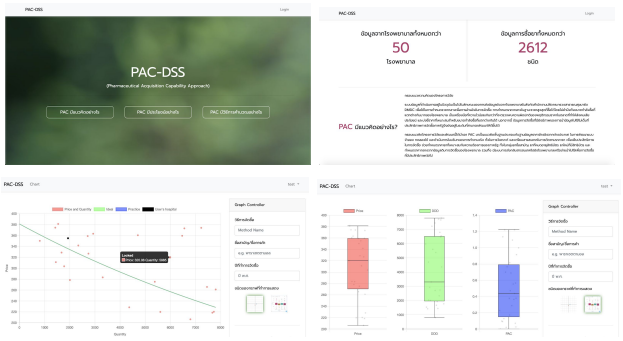


Figure 1, existing website (2019)

This system uses "Pharmaceutical Acquisition Capability (PAC)" index concept and "economic inequality measurement (Gini coefficient)" as the indicator for their analytics.

A. Pharmaceutical Acquisition Capability (PAC)

PAC concept comes from implementing the Capability Approach (Sen, 1993) [3] which is considered about developing the ability to get better results. In this concept, it's considered about the purchasing capability and volume discounting which are the factors affecting price discrimination. Since the old calculation of drug market price directly used the prices themselves and did not concern the purchasing capability of each hospital, then the calculated results come out not so accurately and not follow the actual trend of market price.

PAC index can be calculated by using PAC equation below:

$$PAC_i = \frac{-\ln(P_i/P_{max})}{(Q_i/Q_{max})}, \begin{cases} \text{for every } P_i > P_{min} \\ \text{adjust } PAC_i = PAC_{max}, \text{ when } P_i = P_{min} \end{cases} \quad (1)$$

Where P_i = Price that buyer i make a purchasing
P_{max} = max $\{P_1, P_2, P_3, \ldots, P_n\}$
Q_i = quantity purchased by buyer i
Q_{max} = max $\{Q_1, Q_2, Q_3, \ldots, Q_n\}$
PAC = the average PAC of the target market

PAC index is indicated as how much purchasing capability a user has. It means that in the same amount of drug, someone who has a high PAC index makes a better bargain and can buy at a cheaper price than someone who has a low PAC index. On the contrary, less PAC index means that you have to purchase more drugs in order to negotiate to get the same price as the one who has a higher PAC index.

B. Gini Coefficient

Gini Coefficient [4] is one of the economic inequality measurements which usually measure the inequality of income or wealth of people. By using its basic idea implemented with individual PAC index, the Gini coefficient equation (2) gives a result that can be used as a screening tool to display the dispersion and inequality of drug price in the market.

$$G = |1 - \sum_{i=1}^{N} (\sigma Pi\text{-}1 + \sigma Pi)(\sigma Qi+1 - \sigma Qi)| \quad (2)$$

Where N = Number of observations
σP_i = Cumulative proportion of price/unit
σQ_i = Cumulative proportion of quantity Purchased

In this system, it fixes the critical G value at 0.5 which means that if the G value is more than 0.5, the price inequality is high in that drug market. In other words, we can say that hospitals buy drug X in a large volume, however, they still get a high price which is kind of unreasonable and there could be some problems with their purchasing. And for the case that G value equals to 0, it means that this drug has a fixed price not depending on the drug volume.

So, we can conclude that the PAC concept is used to support setting the drug price standard. In addition, the result of G value, which represents drug price dispersion or drug market behavior, can help users decide better about their policy of purchasing drugs.

III. System Design

In this section, it narrates the system design in this project which consists of 2 parts: (A) Data Preparation, and (B) Data Analysis and Visualization.

A. Data Preparation

The data that we got from existing system (PAC-DSS) consists of basic factors for drug purchasing such as budget year, purchasing method, hospital ID (7 digit number), drug name & ID in GPU (Generic product use) and TPU (Trade product use), drug price per unit, and drug purchasing quantity.

To give an overview of the data relation in this project, we provide the ER-diagram showing in Appendix A.

B. Limitation

Since the original data is not clean enough and provides only a year timestamp, we can not extract much insight (i.e. seasonal trends) from it. So, we tried to find some additional data that can be used for analysis from other sources instead.

From the Ministry of Public Health Website [5], we got the set of data consisting of hospital details such as region, province name, hospital name, type of hospital, number of inpatient and outpatient. We integrated this set of data into our database and used it for the analysis.

C. *Data Analysis and Visualization*

From data that we have, we tried to analyze from these 3 steps: define users, define what they want to know, and find what can answer that question.

In the system, there are 2 types of users who can pass through the authentication part: policy maker user, and hospital user. The guest user cannot access this part because of the privacy and security issue in sensitive data. Policy maker users can access all data while hospital users can access only their own data.

To cover all users, we considered the question separately depending on users and data accessibility.

Analyzing tools that we used are Python which is used in the calculation part, Microsoft Excel which is used to generate the simple graph and table, and SQL server which is used to find the relation in the database.

To get more detail in analysis and visualization of each question that we chose for each user, we'll discuss in the next part.

IV. Policy Maker User Design

In this section, it explains about the detail of analysis and visualization for policy maker users.

Since these users focus on the overall picture of the entire country, the questions will be separated into 2 sides: (A) Drug-related, and (B) Hospital-related.

A. *Drug-related*

- Which drug has high price dispersion?
  - What can answer : We can use the Gini coefficient as an indicator (If G value is more than 0.5, there is a high price dispersion problem in that market).
  - How to visualize : Representing data in the form of a Top 10 table that allows the user to sort data in each column. (as shown in the Figure 2 below).

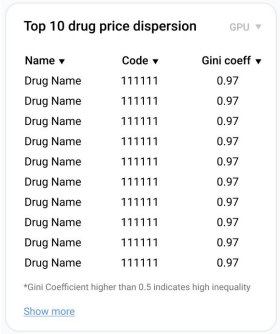


Figure 2, Price dispersion chart

- If using the suggested price, how much does it save?
  - What can answer : Since the suggested price is calculated from the average PAC using drug quantity, then we can compare between the suggested price (from calculation) and the real purchasing price (from actual record).
  - How to visualize : Computing the saving price in percentage to easily understand and clearly see the difference, and displaying in a table with the detail of each drug. The sorting feature is also provided. (Figure 3)

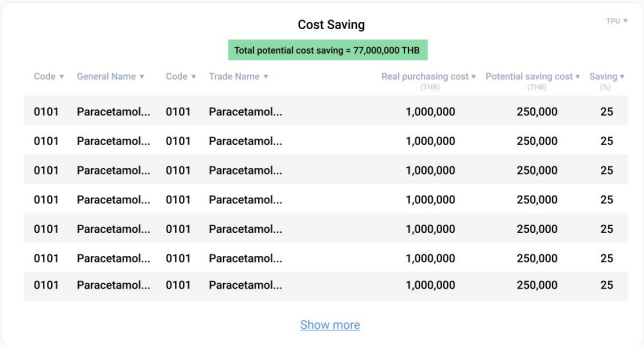


Figure 3, Saving Cost table

- Total annual spending
  - What can answer : The Summary of all spending in each year.
  - How to visualize : Using a line chart to display historical data so that we would be able to observe the trend. (Figure 4)

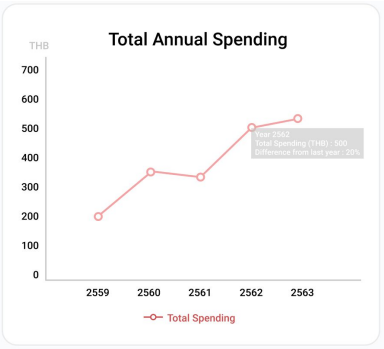


Figure 4, Total annual spending line chart

B. *Hospital-related*

- How is the purchasing power of the whole country in the specific drug? Does any region or province have a problem with low purchasing power?
  - What can answer : The PAC index is used as an indicator since it can represent how much purchasing capability a user has. We separate PAC value into each region or each type of hospital. Then, for each group, we cluster PAC value into 3 subgroups; High purchasing power, Medium purchasing power, and Low purchasing power.

- How to visualize : Using the 100% stacked bar chart so that it would be compared easily. (Figure 5, 6)

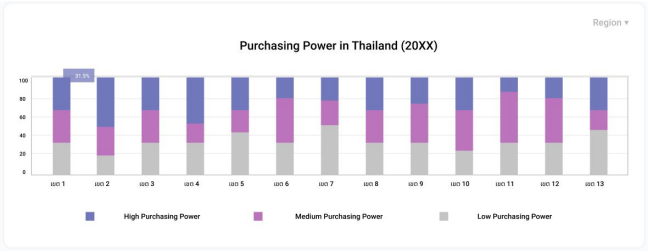


Figure 5, Purchasing power comparing between regions

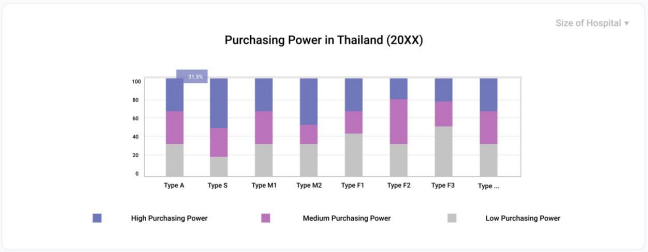


Figure 6, Purchasing power comparing between type of hospital

- Does the information of each hospital (e.g. number of patients) affect the demand of drugs?
  - What can answer : Finding a correlation coefficient [6] between the number of patients and the purchasing amount using the equation below.

$$r_{xy} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \quad (3)$$

Where r_{xy} = the correlation coefficient of the linear relationship between the variables x and y
x_i = the values of the x-variable in a sample
$\bar{x}$ = the mean of the values of the x-variable
y_i = the values of the y-variable in a sample
$\bar{y}$ = the mean of the values of the y-variable

The correlation coefficient is used to indicate the strength of the relationship between 2 variables. Normally, a correlation coefficient greater than 0.7 is considered a strong correlation, between 0.5 and 0.7 is a moderate correlation, and less than 0.4 is a weak correlation. For a negative correlation coefficient, it would be considered as an inverse relationship.

  - How to visualize : Displaying as a line graph together with an interpreted result. (Figure 7)

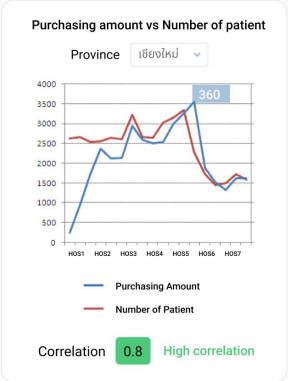


Figure 7, Relation between number of patient and purchasing amount

After we calculated and analyzed data, we discovered some interesting points of using correlation coefficient. Since correlation index is used to indicate how strong a relationship of 2 data is, this helps us find out some interesting trends or patterns between the data, for example, in our case, we used correlation coefficient to represent the relationship between number of patients and purchasing quantity of each hospital. If these 2 data are not related, this will be able to state out that something might go wrong because normally, in the commonly used drug (i.e. paracetamol), the drug purchasing quantity should be directly related to the number of patients. However, this is only a 2-dimensional comparison. There are still many more factors affecting the purchasing quantity i.e. the distance between hospital and drug store which can impact the shipping time and cost, or the type of common sickness in that area.

Apart from the calculated results such as PAC and Gini coefficient, some general details are also required and could be considered as the factors for decision making.

- Which drugs have a high unit price?
  - How to visualize : Showing data in a table ordered from highest price to lowest price (show only 10 drugs per page) (Figure 8)

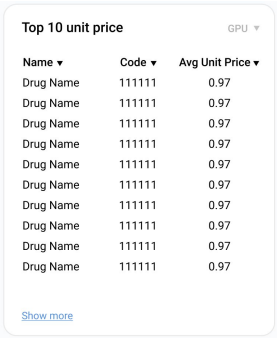


Figure 8, Top 10 high unit price table

- The ratio of drug purchasing amount

- How to visualize : Displaying in pie chart (Figure 9)

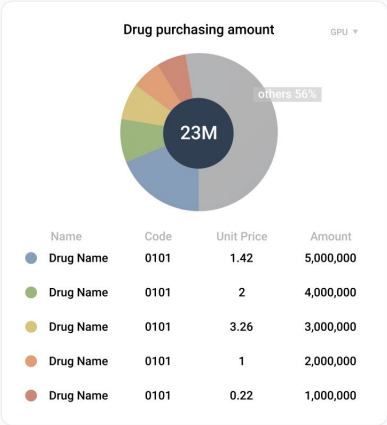


Figure 9, Drug purchasing amount chart

- The specific drug purchasing quantity and price based on region.
  - How to visualize : Illustrating data in a geographic map dashboard. (Figure 10)

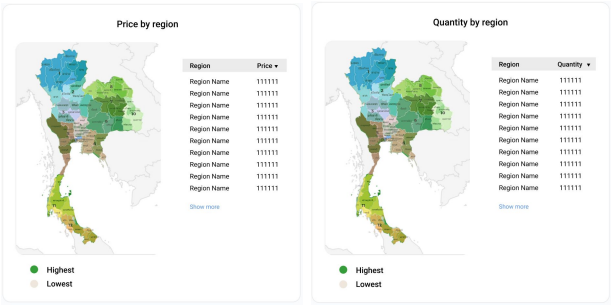


Figure 10, Price and Quantity by region map

V. Hospital User Design

This part elaborates on the analysis and visualization design for hospital users.

Due to the limitation of data accessibility and privacy concern, these users could see only their own hospital data. So the question can focus only on their own hospital problems.

- Overall of purchasing performance
  - What can answer : PAC index can indicate how good of purchasing performance of the hospital. If the actual purchasing price is higher than the suggested price calculated by average PAC value, it would be categorized as a bad performance.
  - How to visualize : Counting the number of bad and good purchasing performances for every drug that were bought by the hospital and showing the result percentage in a 100% stacked bar chart. (Figure 11)

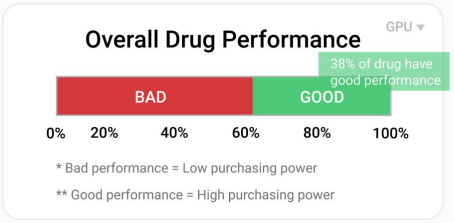


Figure 11, Overall performance chart

- Saving cost if using the suggested purchasing price
  - What can answer : Similar to the saving cost dashboard for policy maker users, comparing between the suggested price and the actual purchasing price.
  - How to visualize : Showing the difference in the bar chart and then interpreting the result (saving percent) in a donut chart. (Figure 12)

Figure 12, Saving cost of each hospital chart

VI. Website Implementation

This section explains how we implemented this project into the existing website: (A) the user interface design, and (B) Implementation.

A. User Interface Design

To get the result quickly, using a free template is a better choice to do. AdminMart Free Bootstrap 4 Admin theme [7] is an open source dashboard design having a basic license which costs $0.

To provide sufficient information for users, we added 3 new tabs in the existing system: (1) Dashboard, (2) Drugs, and (3) Hospitals.

1) Dashboard tab : showing the overall picture and stating the outstanding points.

- User interface of Policy maker user

It includes top5 drug price dispersion, top5 unit price, total annual spending chart, drug purchasing amount chart, and cost saving table. (Figure 13)

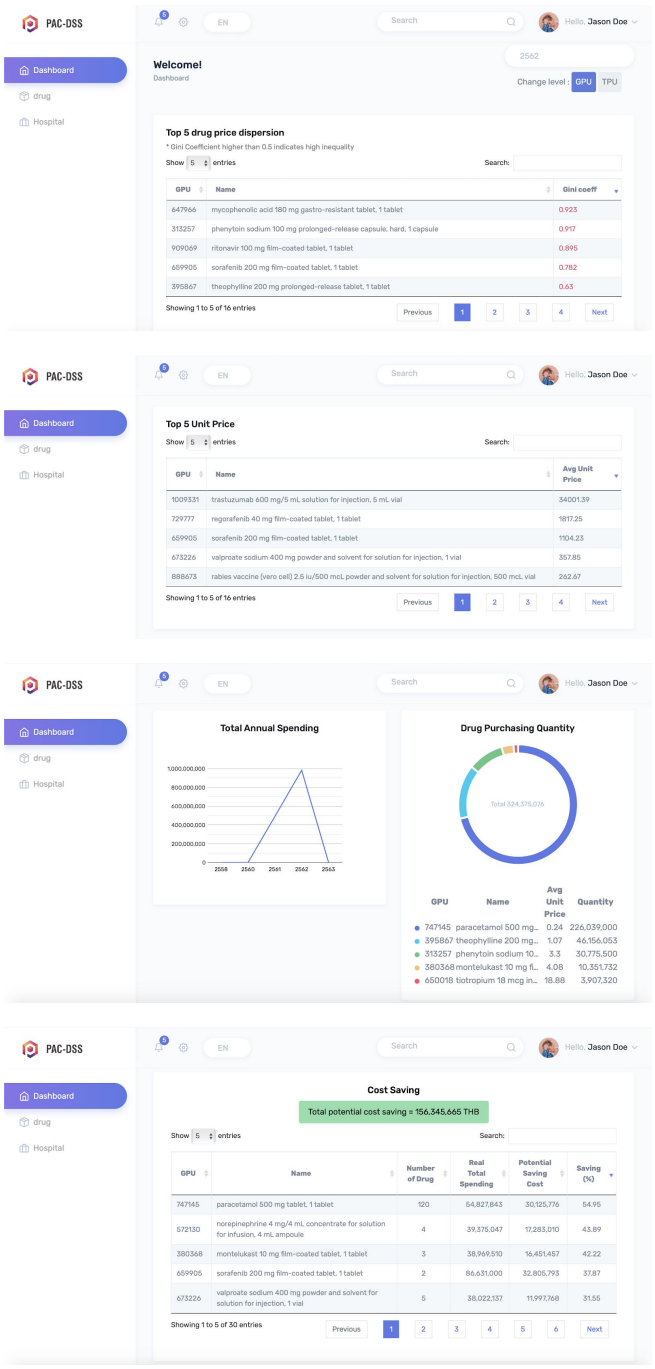


Figure 13, Policy maker user Dashboard tab

- User interface of Hospital user

It includes a drug purchasing amount chart, total annual spending chart, overall drug performance chart, hospital information, potential saving cost chart, and list of cost saving table. (Figure 14)

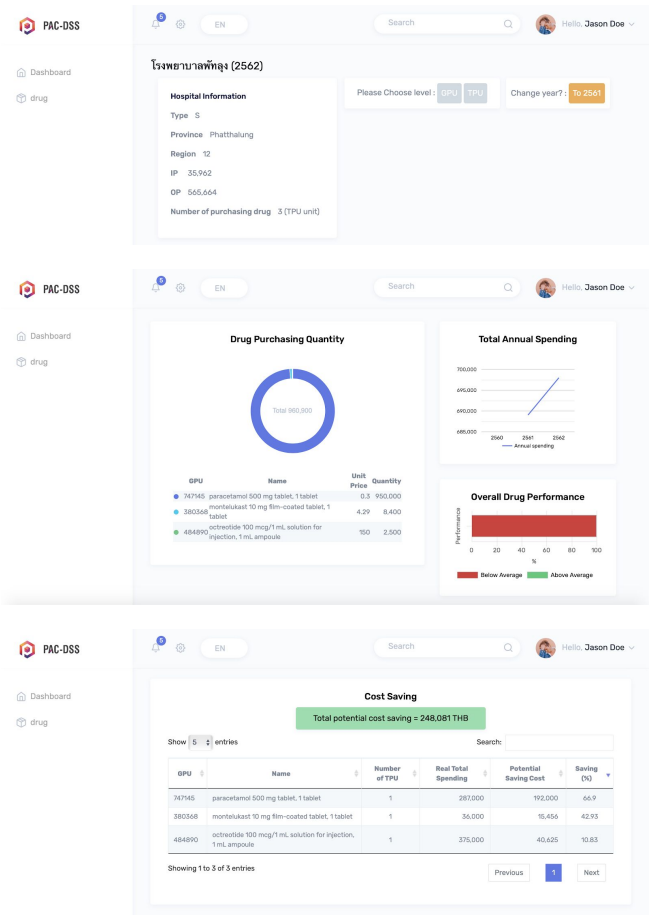


Figure 14, Hospital user Dashboard tab

From this tab, users can see the overall picture and know which area has a problem and where to focus next. Then, they could find more deeper details by searching the drug tab and hospital tab.

2) Drugs tab : The purpose of this tab is to drill down more detail of each drug. So, we added the filter function to let users choose any drugs freely. Users can filter from generic name, GPU code, trade name, TPU code, year, or purchasing method to get the specific drugs detail.

The drug detail table (Figure 15) includes GPU code, GPU name, TPU code, TPU name, purchasing method, average unit price, total purchasing amount, total spending, and the level of price dispersion which shows in 3 colors: green(Gini index < 0.5), yellow(Gini index = 0.5), and red(Gini index > 0.5).

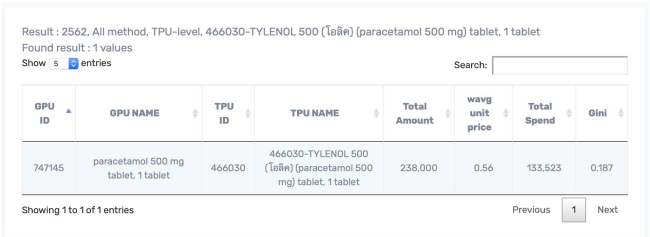
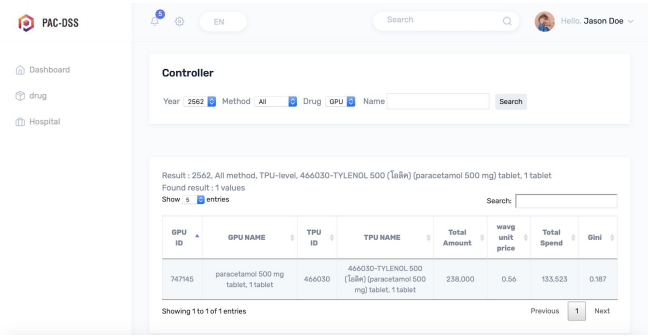
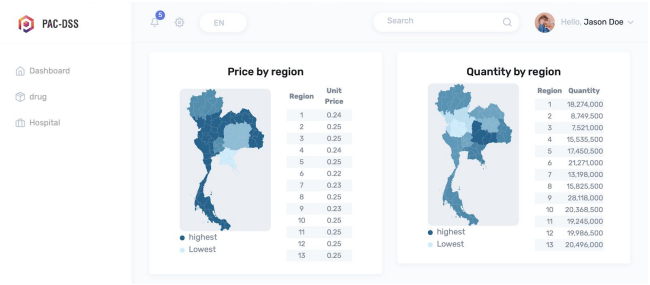


Figure 15, Drug detail table

- User interface of Policy maker user

It includes an acquisition capability chart, price and quantity of all regions (Figure 16) which can drill down by clicking into a particular region, then it'll browse to the page for that specific region (Figure 17).





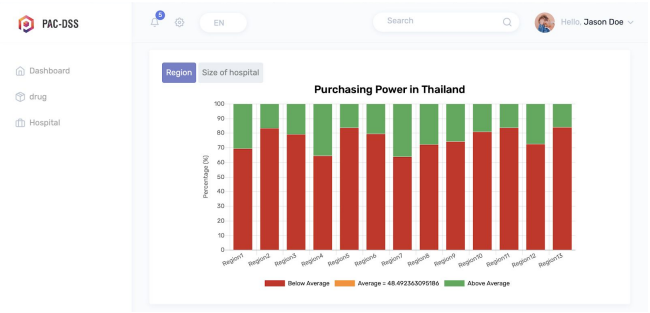
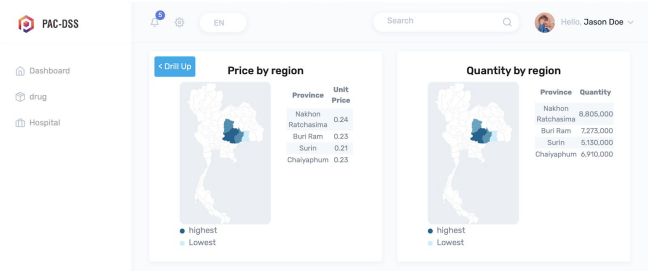


Figure 16, Policy maker user Drugs tab (Country-level)



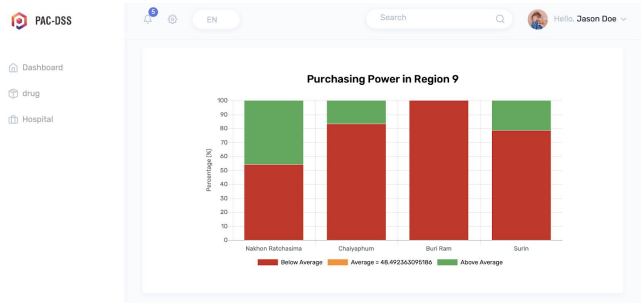


Figure 17, Policy maker user Drugs tab (Region-level)

In addition, it can drill down more into province-level (Figure 18) which also shows a list of hospitals that buy this drug with the purchasing power of them and the correlation graph between the number of patients and purchasing drugs.

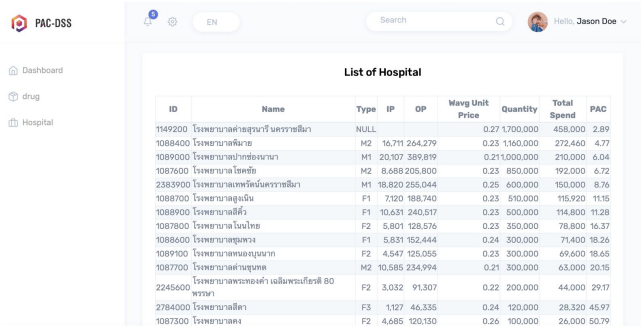


Figure 18, Policy maker user Drugs tab (Province-level)

- User interface of Hospital user

It includes the detail of cost saving (Figure 19) of the selected drug. Furthermore, the drug detail table is appended with itself performance levels; green(high acquisition capability), yellow(medium acquisition capability), and red(low acquisition capability).

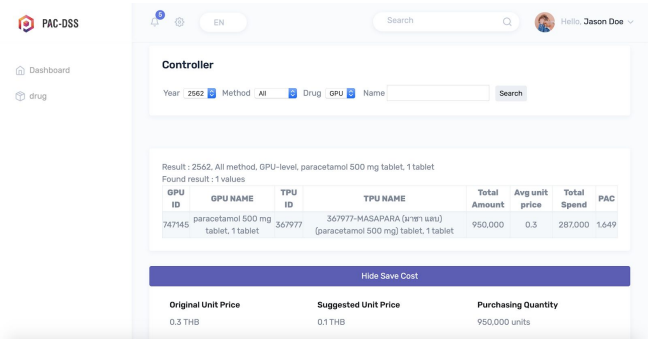


Figure 19, Hospital user Drugs tab

3) Hospitals tab : Since hospital users can access only their own data, then they don't have a hospital tab.

This tab (Figure 20) provides the details of each hospital by filtering the year, region, province, type, and name. The result table shows the general information of that hospital e.g. inpatient (IP), outpatient (OP), and total spending. Moreover, it can link to each hospital dashboards allowing policy maker users to observe each hospital performance.

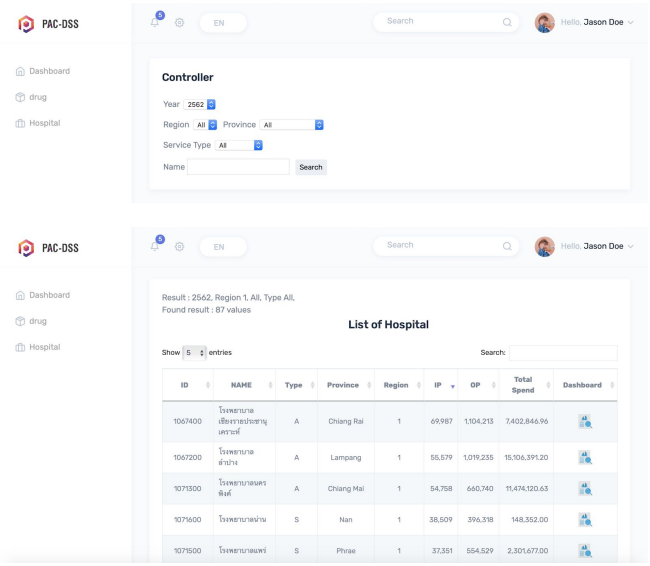


Figure 20, Hospital tab

For the whole interface, there is a switch function to choose the year in order to look through the past data (the default year is the current year). In the drug-related part, it can change from GPU to TPU, and vice versa.

B. *Implementation*

We used Laravel [8], a structured PHP framework, to implement this project because it is a language used in the existing system. To decorate and make it look like the designed user interface, we used CSS and BootStrap.

To collaborate programming work in a team, we used GitHub[9] for managing and merging code.

VII. EVALUATION

This particular section focuses on the evaluation in the website design, content and feasibility.

To get real feedback and additional comments, we conducted a review session and asked pharmacists, who are related in this field and familiar with the existing system since they are the creator and researcher of the original PAC-DSS project[1], to join in this session.

The purpose of this review session were to make sure that: 1) we provide enough content; 2) the design is good enough to follow by and easy to understand; 3) the website is practical for the real user to use in real situations.

The evaluating method that we used was a walkthrough, presenting the prototype to users and explaining how it works, and during the demo, users can interrupt anytime to ask any question or give any advice. At the end of the session, we gave them a survey to rate their satisfaction in Google Form.

Moreover, apart from the pharmacist review, there is another feedback from professors who are professional in data analytics and visualization. The evaluation method is the same as we used in pharmacist's review session which is a walkthrough method. So, we got some additional advice from this.

VIII. IMPLICATIONS

In this part, it discusses the feedback after the 2 review sections in 3 topics; content, UI/UX design, and practical usage.

For content, the main feedback is about some technical terms used in the website that might be hard to understand. They suggested showing the technical meaning and description in tooltips, or writing below the graph to provide meaning and explain how the results were calculated. Moreover, they suggested adding a column of the number of hospitals in the cost saving table to give more insight and make it more useful. Furthermore, about the correlation between number of patients and purchasing quantity, they said that number of patients is not the only one factor for drug purchasing. There are some other factors that hospitals have to consider when determining drug purchasing quantity, for example, drug price, shipping cost, shipping time, specific need of drugs in that area (Figure 21).

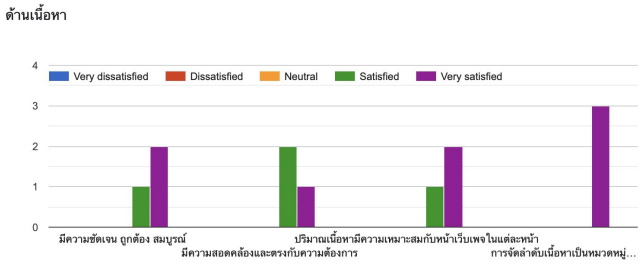


Figure 21, Satisfied rate of content part

For the UI/UX comment, there were only some minor parts that they wanted to add in. For example, adding a thousand separator comma to make it easier to read. However, in the score of the pharmacist's survey, we can say that the overall user interface is already satisfied (Figure 22).

Moreover, we got some additional suggestions from the professor for the UI design, they suggested us to summarize some data visualization in the dashboard tab and let the user click to drill down only the data that they want to see more details. Doing this way, it will help to shorten the table that contains too much detail.

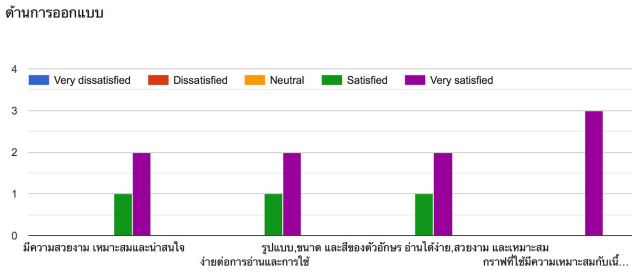


Figure 22, Satisfied rate of design part

For the practical usage, we got positive feedback from the survey comment. They said that our website is useful and practical for real usage (Figure 23). However, it would be even better if we can implement all their suggestions into the website.

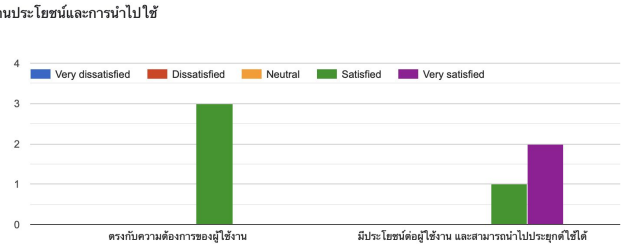


Figure 23, Satisfied rate of practical usage *part*

Due to the time limit, we tried to revise the important part first which is about the technical terms problems. In future work, we can implement more in the remaining part such as showing who has best/worst practice, which drug has a monopoly market, which brand has high market share in the market or is a single brand, and a page that hospital users can search and see drugs other than the one they bought.

IX. Related Work

This section discusses the other related work of this project.

There is a website called “DOH Dashboard” [10] which is from Thailand Department of Health (กรมอนามัย). It provides the dashboard about Thai health issues. Even though we can look only at the public page (Figure 22) since we don’t have access to log-in through the inside system, we can see that they also use similar methods to illustrate the information to users by various types of charts and color.

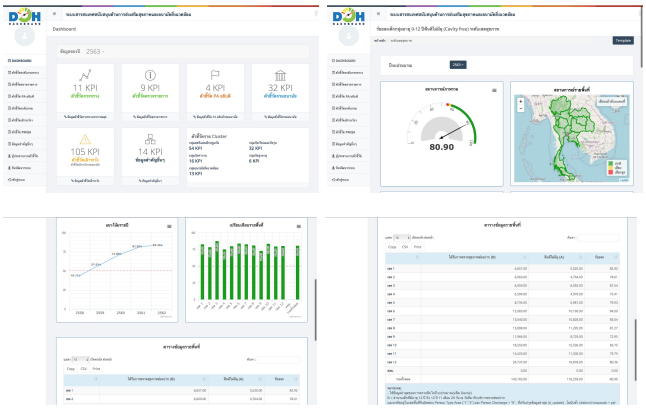


Figure 22, DOH Dashboard website

X. Conclusions

This web-app, which is enhanced from the previous PAC-DSS system by appending more data analytics and data visualization dashboard, has the objective to help healthcare organizations enhance their efficiency on drug purchasing and provide a better health service to all citizens. Our project starts from doing analysis with 3-step: define users, what they want to know, and what can answer their questions. Then find how to visualize the analysis to users and design the user interface based on the open source template to easily and quickly implement the system. In the new design, we add 3 more tabs; dashboard, drugs, and hospitals. The dashboard tab gives the overview and points out the problem which makes users know where to find out more at the drugs tab and hospitals tab in the next step. Users can filter to find the particular drugs and hospitals in the drugs tab and hospitals tab respectively to get more deep details. Lastly, we implemented the design into the real website. With all the additional functions and the existing system together, we hope that we can help users to make a right decision on drug purchasing and save more money.

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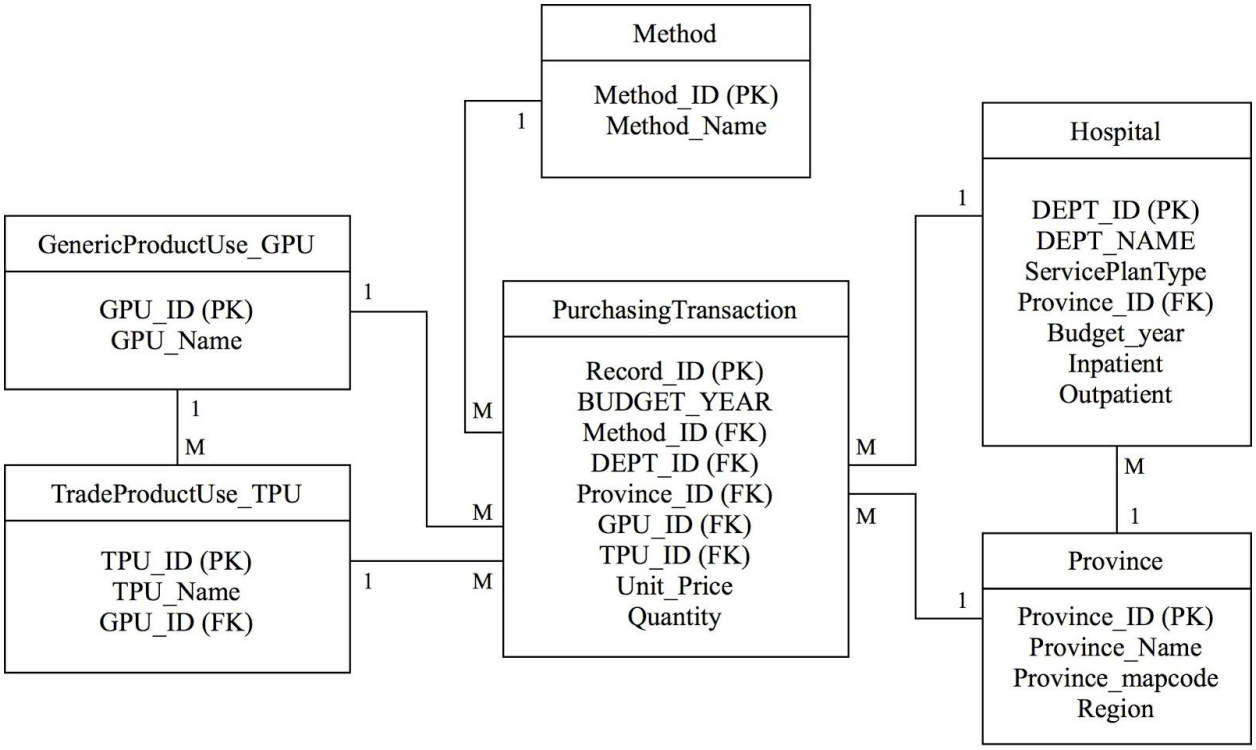
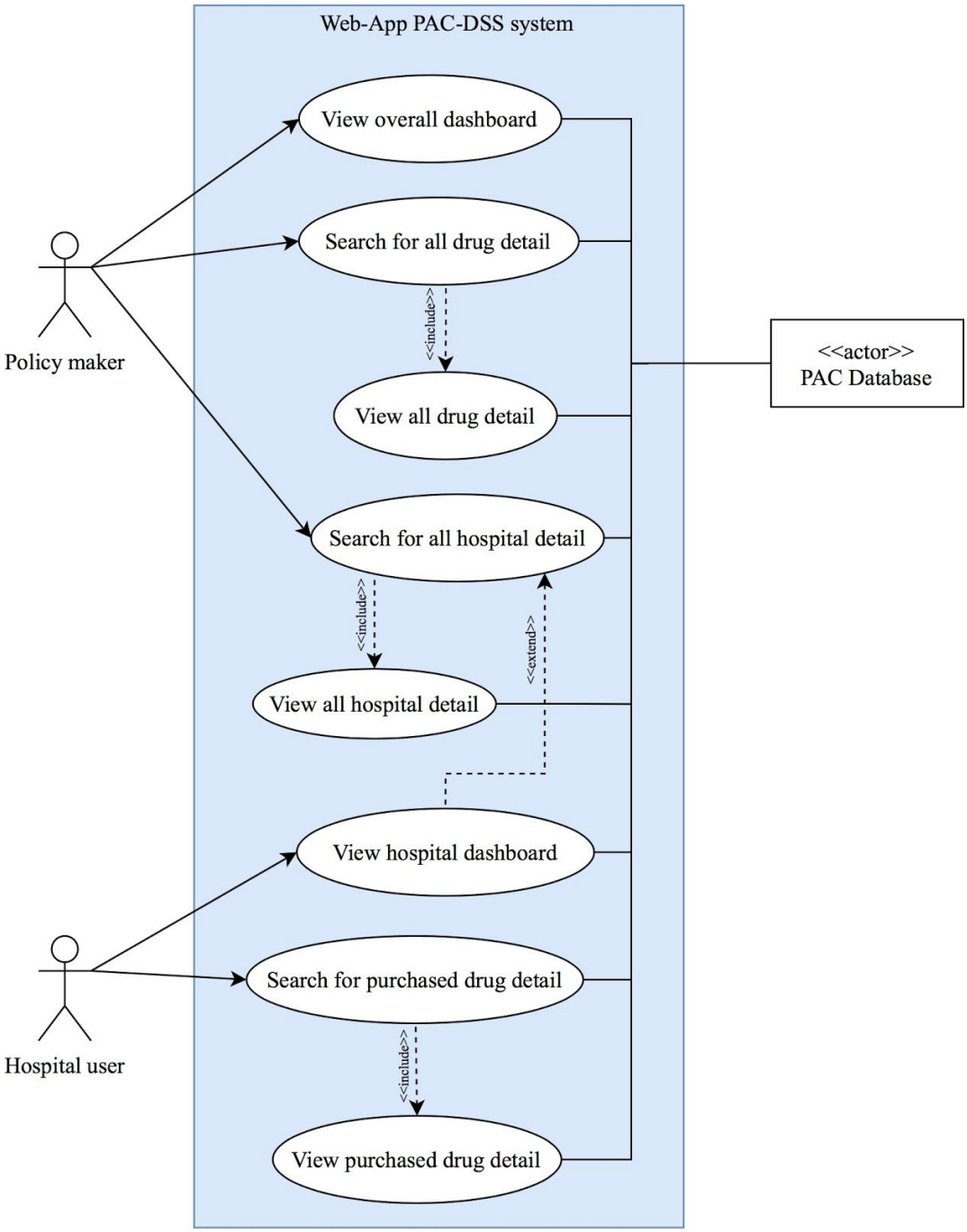
Appendix

Appendix A
ER-diagram



Appendix B

UML diagram (use-case diagram)



Appendix C

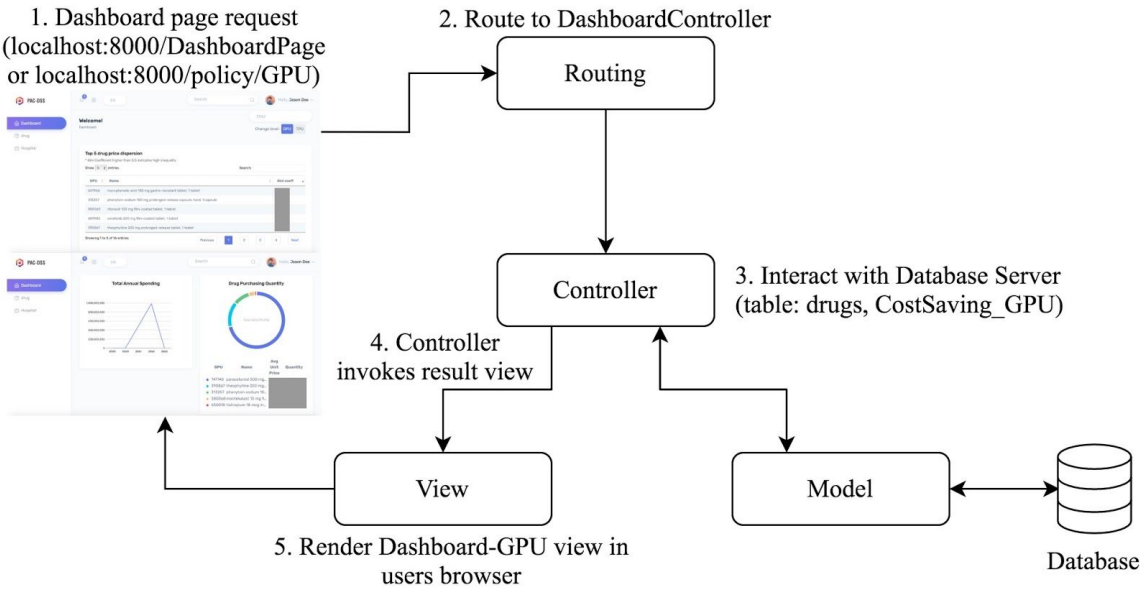
Github link which provides workflow and how to use our code in Readme file

https://github.com/pamareel/PAC-Project-Demo

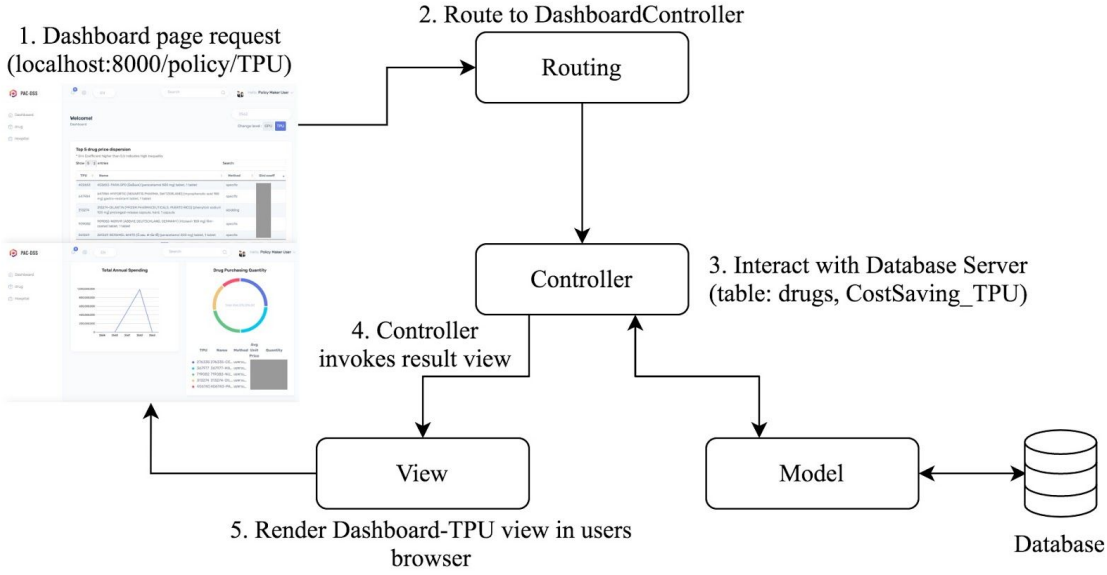
Appendix D

Model-View-Controller diagram of this system

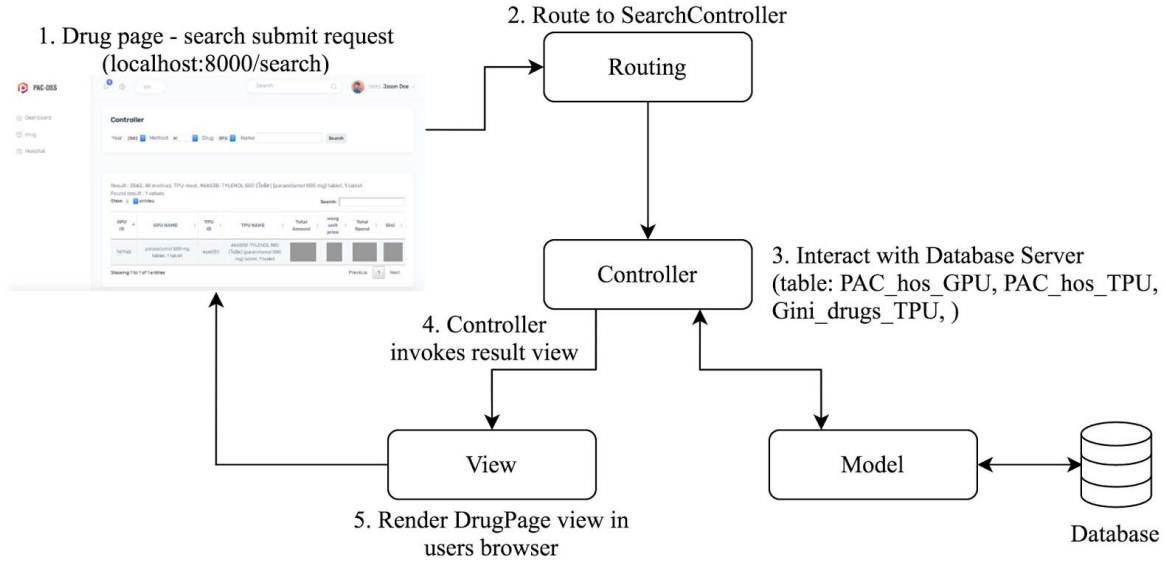
1. *GPU Dashboard Page (Policy Maker User)*



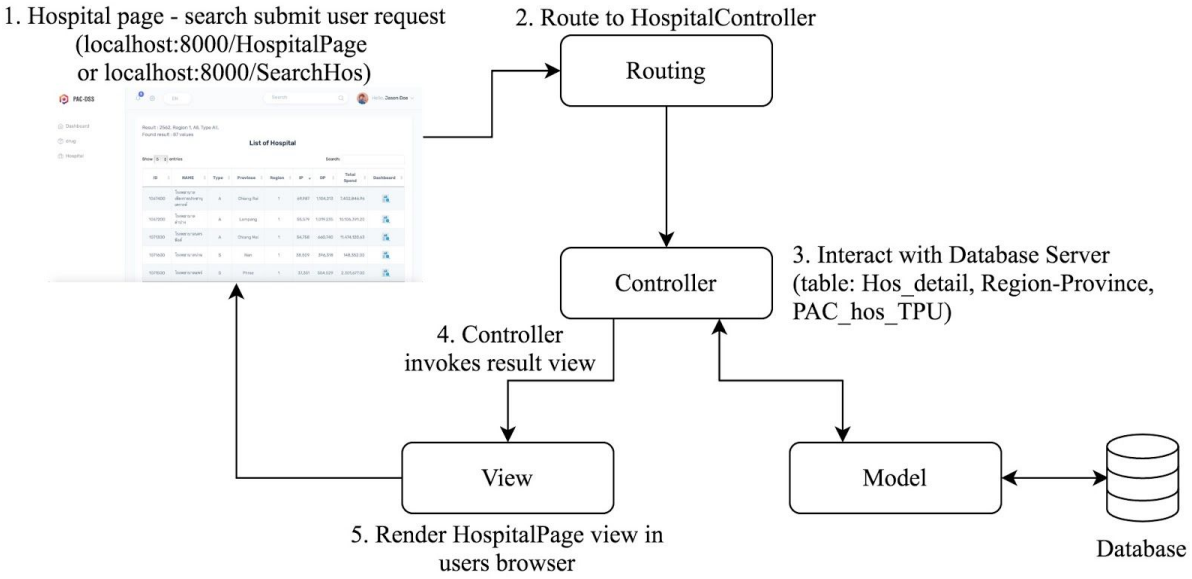
2. *TPU Dashboard Page (Policy Maker User)*



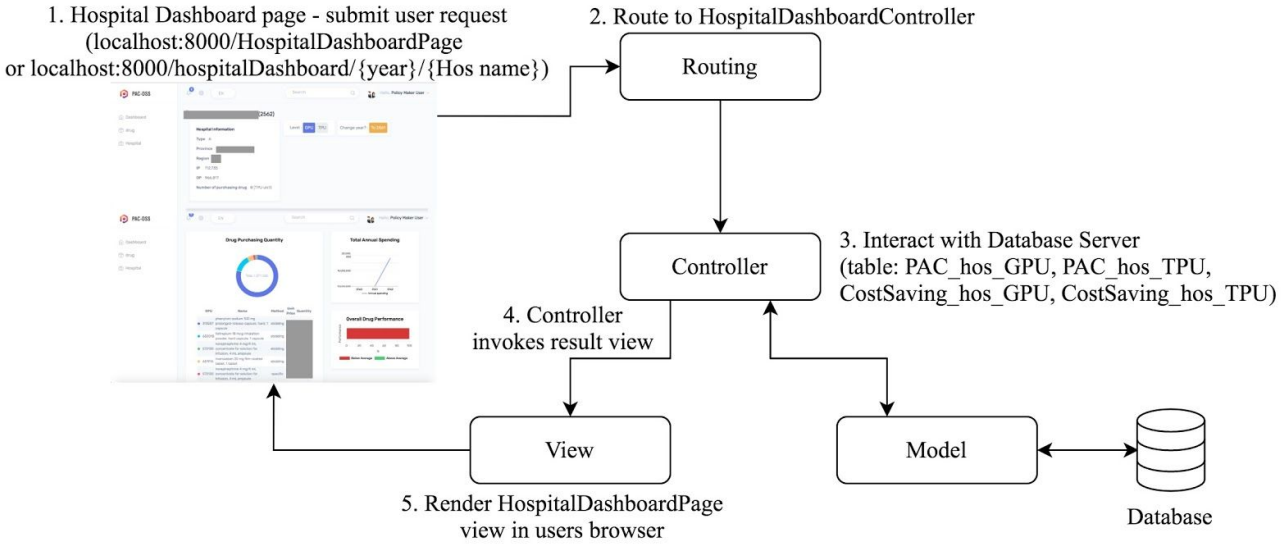
3. Drug Search Page (Policy Maker User)



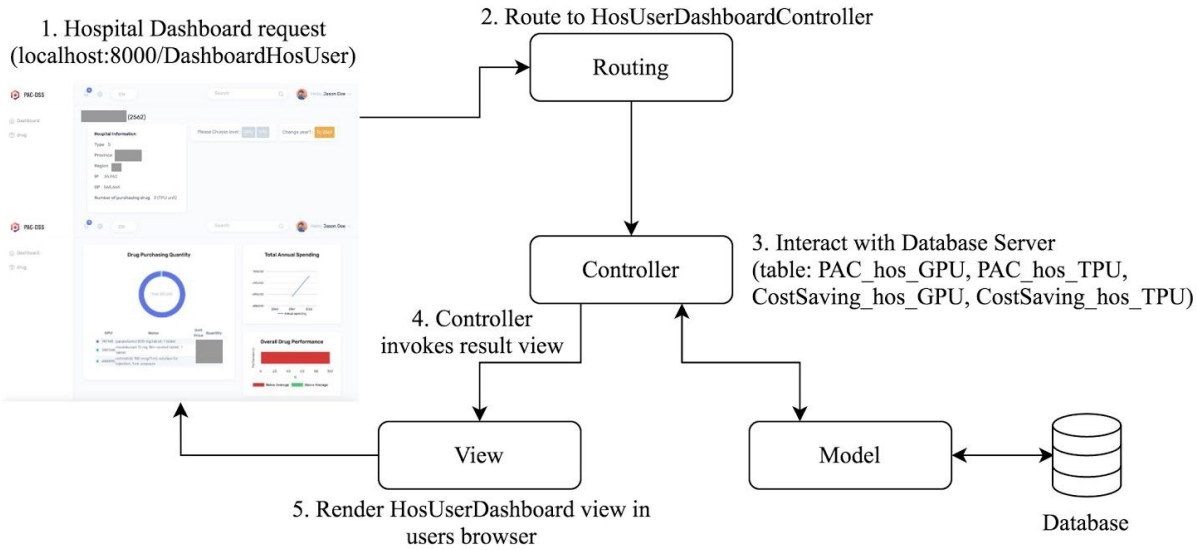
4. Hospital Search Page (Policy Maker User)



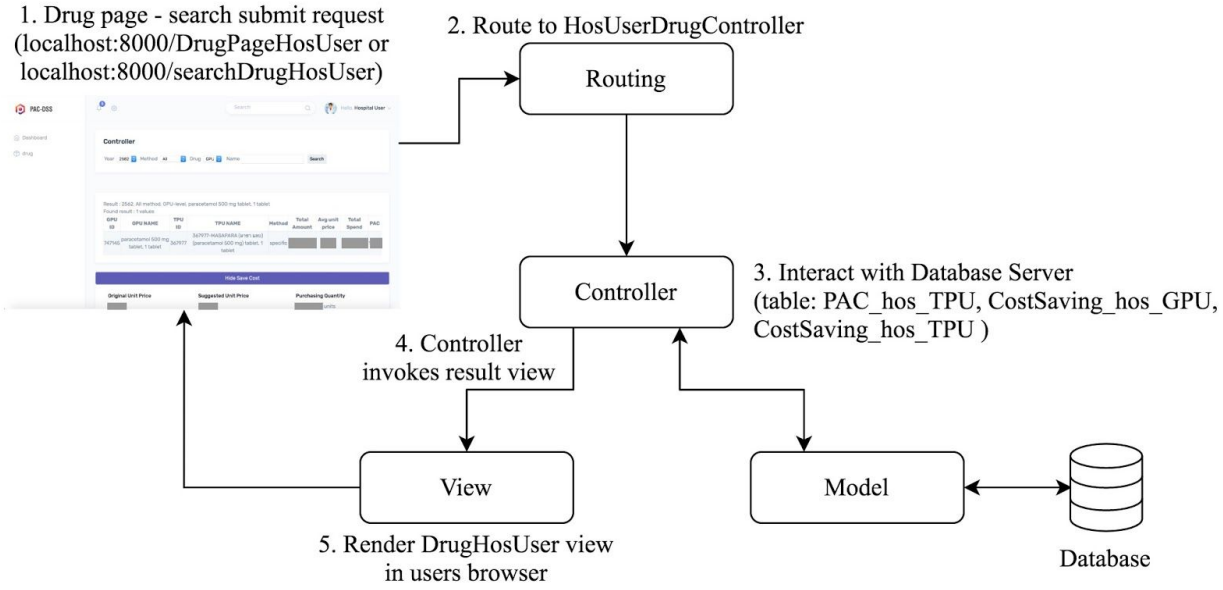
5. Hospital Dashboard Page (Policy Maker User)



6. Hospital Dashboard Page (Hospital User)



7. *Drug Search Page (Hospital User)*



Appendix E

Requirement list for future plan

- Adding best/worst practice hospitals in the dashboard page for policy maker: calculated from each hospital drug's performance
- Adding more drug's market detail
    - Single brand (monopoly): calculated from the number of TPU (Trade product use) in each GPU (Generic product use). If 1 GPU has only 1 TPU, it means that there is a monopoly market.
    - Market share: calculated from finding the ratio of each TPU drug purchasing quantity from all hospitals in the same GPU.
- Allowing hospital users to search for all drugs (not only their purchased drug).
- Shortening the table that contains too much detail by summarizing some data visualization in the dashboard tab and letting the user click to drill down only the data that they want to see more details.