Determinants of Bank Profitability: Evidence from Lao Commercial Banks

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Abstract

The determinants of bank profitability are very important, as bank profitability significantly affects the economies of countries. This study aims to examine the internal determinants (bank-specific characteristics) and external determinants (macroeconomic factors) of bank profitability in the Lao PDR. The study uses unbalanced panel data from 35 banks in Laos of ten years covering the period from 2012 to 2021. The relationship is estimated using a random effects approach. The results show that policy rate (macroeconomic factors), bank size and organizational structure (CEO) have a significant and positive impact on the profitability of Lao banks. Meanwhile, capital adequacy, credit risk, liquidity, operating expenditure, and technology have a significant negative influence on bank profitability. To the authors' knowledge, this study is considered one of the earliest studies of its kind, in which the main factors affecting Lao bank profitability are determined. That said, this paper makes a significant

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contribution to the theoretical literature, the industry, and policymakers, so that the performance of Lao commercial banks can be improved.

Keywords: Bank profitability, Commercial bank, Lao PDR

Introduction

Commercial banks are important to the economy as a channel for transferring capital from those who have surplus capital to those who need capital in order to use those funds for economic activities. Lao PDR has evidence in the steady increase in the ratio of commercial banks' deposits to gross domestic product (GDP) from 48.90% in 2012 to 75.50% in 2021. Similarly, the ratio of loans to GDP also increased from 35.15% to 50.93%. This suggests that commercial banks are playing a vital role in supporting capital accumulation and economic growth in Laos. For commercial banks to continue to play this role, they need to be profitable. This means that they need to generate enough revenue from their operations to cover their costs and make a profit. The more profit that commercial banks make, the more loans they can provide to businesses and individuals, which will help to stimulate economic growth. Therefore, Regulators can formulate effective policies to ensure that commercial banks can continuously support the growth of Laos economy. Meanwhile it is crucial for management of commercial banks to know the drivers of bank profitability in order to set strategies aiming at increasing revenues from commercial banking operations for sustainable growth in the future.

Unit: Million kip

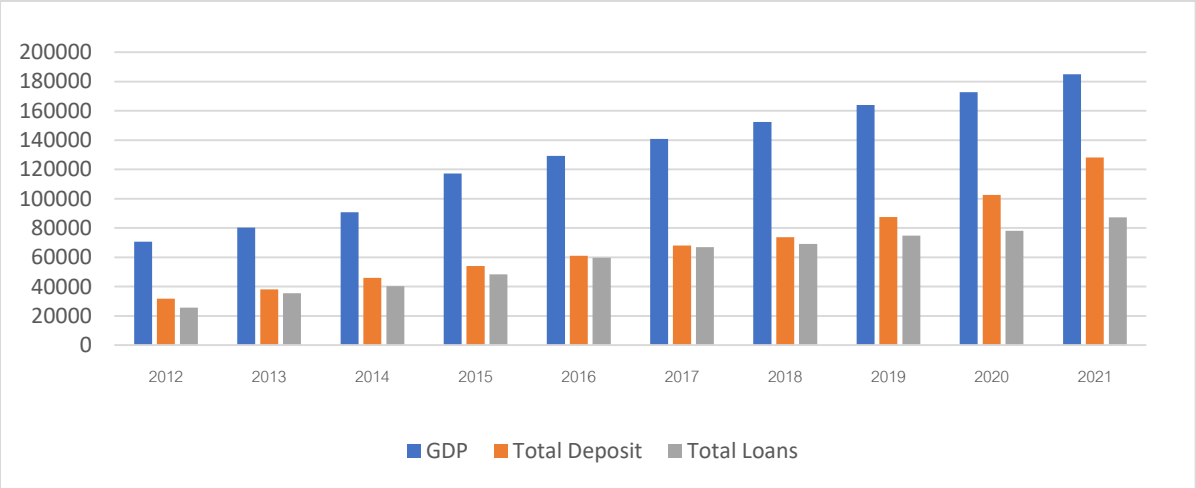

Figure 1: Role of commercial banks in Lao economic during 2012-2021.

Source: Bank of Lao PDR

Furthermore, this study also intends to explore the impact of the implementation of policy rate measures in 2015 on commercial bank profitability in Lao PDR. This policy measures was implemented by Bank of Lao PDR which started using the policy rate as a financial policy tool to promote the economy. The central bank noticed that the inflation rate in the past was at a low level. But interest rates on domestic deposits and loans remained high compared to inflation which can be observed from the average annual rate of inflation, deposit, and loan for period 2012 to 2014 are at 5.58%, 11.31% and 18.17%, respectively. In addition, the National Economic Development Plan wanted to promote the business sector to access capital more conveniently and to reduce domestic financial costs. Finally, the Bank of Lao PDR set a reference interest rate for commercial banks in 2015 by a 1-year deposit rate, compared to the average inflation rate of the previous year, adding no more than 2%. Loan interest rates of commercial banks plus increase deposit rates shall not exceed 4%. The Monetary Policy Department of the Bank of Lao PDR will calculate the average inflation rate of the past year. As a result of the implementation of central bank, the average annual loan interest rate in 2015 to 2021 is at 10.18% which may affect commercial banks profitability.

Meanwhile, there are numbers of studies that have investigated the determinants of commercial bank profitability in countries around the globe such as (Saona, P. H, 2011) investigated determinants of the profitability of the US banking industry; (Molyneux, P. and Thornton, J., 1992) and (Petria, N., Capraru, B. and Ihnatov, I., 2015) investigated the determinants of European bank profitability; (Roman, A. & Danuletiu, A. E., 2013) investigated determinants bank profitability in Romania (Dietrich, A. and Wanzenried, G., 2009) examined the determinants of bank profitability before and during the crisis in Switzerland. In Asia countries, (Lu, Jing, Alatengsudao, and Yin Yuming., 2013) and (Li, Ming, 2017) examined determinants of Bank Profitability in China (Sufian, F & Habibullah, M. S., 2009) conducted a study in Bangladesh; (Thota, N., 2013) investigted determinants of commercial bank profitability in India. However, there has been no study conducted about the determinants of commercial bank profitability in Laos.

The above issues left some interesting questions for the Laos context. This includes question like (i) what are bank specific characteristics that influence commercial bank profitability in Laos? (ii) what are the macroeconomic determinants that influence commercial bank profitability in Laos? (iii) does the implementation of central bank policy have an impact on the commercial bank profitability in Laos?

Literature Review and Hypotheses Development

Determinants of profitability of commercial banks in Lao PDR can be explained by two components: One component concerns the macroeconomic factors which are, as external factors, not under the control of bank management, but it reflects the economy of the country that influences the performance of financial institutions, which consist of growth rate of gross domestic product, inflation rate, central bank policy, and government policy. The other component concerns specific characteristics of banks, which are internal factors reflecting the Bank's performance, including Bank size, management efficiency, capital adequacy, credit risk and liquidity.

Gross Domestic Product (GDP): The GDP is one of the crucial factors which has influence on the business of a commercial bank, because the growth in economic activity may indirectly affect the need of banks to provide more loans to the public. In return the bank can generate more income through increasing interests. (Sufian, F & Habibullah, M. S., 2009) investigates the factor that influences the profitability of financial institutions in Bangladesh. It suggests that higher economic growth encourages banks to lend more money, enables them to charge higher interest rates, and raises asset quantity, which has an impact on bank profitability. Similarly, (Roman, A. & Danuletiu, A.E., 2013) investigated bank profitability in Romania from 2003 to 2011 and found that economic growth rate has an important impact on bank profitability. Thus, this study hypothesizes that:

H_1: Gross domestic product has a positive relationship with commercial bank profitability in Laos.

Inflation rate: The influence of inflation on interest rates has a significant impact on the bank's profitability. A higher rate of inflation results in higher loan interest rates and, as a result, increased bank profitability. raising the interest rate. Studies by (Wallich, 1980), and (Tan, Y. and Floros, C., 2012) show that high inflation rates lead to higher bank profitability. Additionally, (Ramadan, I. Z., Kilani, Q. A., & Kaddumi, T. A, 2011) examines the nature of the relationship between the profitability of the Jordanian banks and the characteristics of internal and external factors. Their findings demonstrate that inflation has a positive effect on ROA and ROE. Based on these findings, the hypothesis that could be tested is:

H_2: Inflation rate has a positive relationship with commercial bank profitability in Laos.

Central Bank Policy: Since year 2015, bank of Lao PDR introduced a set of policy rate measures as an initiative to use as a reference interest rate for commercial banks to determine the interest rate for commercial banks' loans at appropriate levels. Theoretically, the policy rate measures might influence commercial bank lending negatively. Also, previous studies of (Cargill, T. F & Mayer, T., 2013) investigate the effect of central bank policy on bank lending in the context of America and the findings conclude that the bank tends to reduce its earning assets. Similar (Lathaporn R. and N. Ananchotikul, 2018) studies the effects of central bank policy on the bank profitability in Thailand during the period 2004-2017 found that lower interest rates tend to reduce profitability, more so for small banks. The effect works mainly through the impact of the interest rates on bank net interest income. Thus, this study hypothesizes that:

H_3: central bank policy has a negative relationship with commercial bank profitability in Laos.

Covid- 19: as measures by COVID- 19 Pandemic as a result, the Lao government announced a lockdown in 2020 causing the business sector to be unable to operate normally and incomes to decrease. This led to repayment of the loan to the bank. Previous studied of (Md. Abu Issa Gazi, 2022) investigate the impact of COVID-19 on financial performance and profitability of banking sector in special reference to private commercial banks in Bangladesh found that during the outbreak of COVID-19, the rate of non-performing loans increased. A large amount of hedge funds is causing the bank's profitability to decrease. (Elnahass, M., Trinh, V. Q., & Li, T., 2021) also conducted the impact of COVID-19 on financial performance and financial stability using the measures of accounting-based, market-based, and risk- based indicators before and during the pandemic. The studied focuses on 1090 banks from 116 countries over the period of the first quarter of 2019 to the second quarter of 2020. The results show that the COVID-19 crisis significantly reduced bank profitability, cost efficiency, financial stability, and stock market valuations. Consistent with the study of (Haider, J., & Mohammad, K. U, 2022) investigate The Effect of Covid-19 on bank profitability determinants of developed and developing economies. thus, this study hypothesizes that:

H_4: government policy has a negative relationship with commercial bank profitability in Laos.

Bank size: Natural logarithm of total assets as a measure for bank size. Total assets have been used as a proxy to examine the factors that influence the profitability of commercial banks. Specifically, authors (Lu, Jing, Alatengsudao, and Yin Yuming., 2013), (Gremi, Eliona, 2013), (Ul Mustafa, A. R., Ansari, R. H., & Younis, M. U., 2012) and (Li, Ming, 2017), found that bank size variable effects positively on profitability because larger banks have greater product

and loan variety than smaller banks, which reduces risk and maximizes the benefits of economies of scale. Consequently, the two elements result in greater operational effectiveness. 0n other hand, (Syafri, 2012) discovers that the size of the bank has a negative on profitability as banks grow in size, the phenomenon of diseconomies of scale manifests, making it harder for management to perform surveillance and increasing the amount of bureaucracy that has a detrimental effect on bank profitability. Theoretically, A sizable bank might establish economies of scale that cut average costs and boost bank profits. Thus, this study hypothesizes that:

H_5: bank size has a positive/negative relationship with commercial bank profitability in Laos.

Capital Adequacy: One issue unique to banks that might affect the earnings a commercial bank can make is capital. The capital ratio is recognized by the international prudential regulation as a crucial measure for determining capital adequacy and represents the overall soundness of banks. As a result, banks with high capitalization levels may lower their funding costs, which will increase their profitability. (Dhouibi, R., 2016) investigated bank transparency and capital adequacy ratio in Tunisa found that maintaining a high level of capital adequacy may reflect a positive impact on the bank's profitability and operating efficiency. while low capital levels may reflect negative effects. Similarly, Masood, O., & Ashraf, M. (2012) analyzed data from 25 banks representing 12 countries for a period of 2006 to 2010 and concluded that capital sufficiency, loans to assets, and asset management outcomes lead to a positive and substantial association with return on assets (ROA) and return on equity (ROE), which is crucial for the profitability of Islamic banks. However, some studies show that there is a negative relationship between capital and bank profitability (Saona, P. H, 2011); (Qin, X., & Pastory, D., 2012). Thus, this study hypothesizes that:

H_6: Capital Adequacy has a positive/ negative relationship with commercial bank profitability in Laos

Operating cost efficiency: Administrative expenses, employee wages, and property expenditures are included in operating costs, which are proxy by operating costs to income ratio. excluding losses due to bad and non-performing loans over total generated revenues (Dietrich, A. and Wanzenried, G., 2009). Operating cost ratios are also used by scholars to as proxies to measure the profitability of commercial banks. In expenses management, CIR plays a key role in terms of efficiency. Operating costs result in lower profits. There are previous studied (Bansal, R., Singh, A., Kumar, S. and Gupta, R., 2018) used costs to income ratio reduced the profitability of private banks in India. Kosmidou (2008) also examined the profitability of

Greek banks during the period of EU financial regulations from 1990 to 2002. Employed Unbalanced pooled time series data set of 23 banks was analyzed and concluded that expenses management ratios had a significant negative impact on profitability. (Ali, K., Akhtar, M. F. and Ahmed, H. Z., 2011) supported the same in relation to Pakistan commercial banks over the period from 2006 to 2009 and (Weerasinghe, V. and Perera, T. R., 2013) and (Sufian, F & Habibullah, M. S., 2009) found that operational cost significantly made a negative impact on the profitability of commercial banks operating in Sri Lanka which is measured by return on assets. (Swarnapali, N., 2014) concluded that operating expenses is negatively related with Sri Lankan bank profitability from 2009 to 2012. On other hard, (Tan, Y. and Floros, C., 2012) discovered a positive relationship between bank profitability and cost effectiveness for 84 city commercial banks and 12 joint banks in China covering the period 2003 and 2009. Similar (AL-Omar, H., and AL-Mutairi, A., 2008) using the operational cost to total assets ratio of seven national Kuwaiti commercial banks for the years 1993 to 2005. Suggested that Kuwaiti commercial banks' operating expenses had a substantial influence on their profitability. Theoretically, A higher cost-to-income ratio might reduce bank profitability. Thus, this study hypothesizes that:

H_7: Operating cost efficiency has a negative relationship with commercial bank profitability in Laos.

Credit Risk: as measures by non-performing loan when a loan's planned loan repayment is more than 90 days late and no longer generates interest income for the bank, it is referred to be a non-performing loan (Rose, P. S., & Hudgins, S. C, 2013). Loan loss provisions are viewed as barriers to the capital of banks. The possibility for poor loans is similarly assigned security through loan loss provisions and expanding loss reserves. While having loan loss provisions would be comparable to maintaining a robust protection against bankruptcy risks. This is crucial and useful in the event that the bank has major asset quality issues and there aren't enough loan loss reserves to cover all bad loans. In this case, the excess must be deducted from shareholders' equity, (Golin, J., & Delhaise, P., 2013). Previous studied (Molyneux, P. and Thornton, J., 1992) revealed that credit risk has a negative impact on profitability and that bigger loan loss provisions are needed for riskier loans. This lessens the banks' capacity to produce profits (Athanasoglou, P. P., Asimakopoulos, I., & Georgiou, E., 2005) found that credit risk has a negative impact on the banks' profitability in Greece during the period of 1985 to 2001. (Gremi, Eliona, 2013) also found that the proportion of non-performing loans affected the bank's profit. Because banks need to deduct provisions for non-performing

loans. causing the bank's revenue to decline. Similar detrimental effects were shown by (Kosmidou, K., Pasiouras, F.,& Tsaklanganos, A, 2007) with regard to United Kingdom commercial banks during the period from 1995 to 2002. (Sufian, F., & Noor Mohamad Noor, M. A., 2012) also identified that non-performing loans have a negative impact on the Korean banking sector. Petria, N., Capraru, B. and Ihnatov, I. (2015), (Sufian, F & Habibullah, M. S., 2009), (Molyneux, P. and Thornton, J., 1992), and (Sufian, F & Habibullah, M. S., 2009) also supported this argument with their studies. However, (Ali, K., Akhtar, M. F. and Ahmed, H. Z., 2011) found a positive impact on the profitability of 22 private and public commercial banks in Pakistan. Thus, this study hypothesizes that:

H_8: Credit Risk has a positive/negative relationship with commercial bank profitability in Laos.

Liquidity: the ratio of liquid assets to short-term liabilities is used to investigate the effect of liquidity risk on bank profitability. As the financial crisis periods prove, low liquidity ratios can easily cause bankruptcies. On the other hand, higher liquidity ratios usually generate lower rates of return a number of researchers have included (Bansal, R., Singh, A., Kumar, S. and Gupta, R., 2018) used the same quick ratio as a measure of profitability and concluded quick ratio enhanced the profitability of 39 public and private banks. he found that liquid assets have negative with banks profitability. (Petria, N., Capraru, B. and Ihnatov, I., 2015) also had concluded that liquidity risk negatively impacts EU banks. However, (Thota, N., 2013) and (Sufian, F., & Noor Mohamad Noor, M. A., 2012) revealed that liquidity affected positively impacted on the profitability of Sri Lankan and Pakistan commercial banks between the period of 1997 to 2008 performance liquidity ratios to their studies. The above literature has led the authors to develop the following hypothesis that:

H_9: Liquidity has a positive/negative relationship with commercial bank profitability in Laos.

Organization structure: Executive Director Organizations can increase their international competitiveness by diversifying globally with the aid of global experience. Directors are prepared to deal with new concerns and unforeseen situations thanks to their expertise. Therefore, having international experience has become necessary for a CEO (Bass B. M., Bass Bernard M., 1985), (Black J. S., 1999). According to (Sanders W. G., Carpenter M. A., 1998) and (Oxelheim L., Gregoric A., Randoy T., Thomsen S., 2013), as globalization progresses, a company will modify the structure of its management by include more foreigners in its highest ranks. In such a manner, organizations try to draw foreign directors to add managerial abilities and particular skills (Sanda A., Garba T., Mikailu A., 2008). Assume that CEOs from diverse backgrounds, especially in terms of nationality, can inspire organizations to recognize broad

sensitivities, which aids them in breaking into new international markets (Carter D. A., 2003), (Hillman A. J., Dalziel T., 2003), (Pfeffer J., 2003), (Abu S. O., Okpeh A. J., Okpe U. J., 2016), (Scheppink A., 2018). As a result, both CG and corporations prefer to assign directors with overseas nationality or experience (Oxelheim L., Gregoric A., Randoy T., Thomsen S., 2013), (Masulis R. W., 2012), (Rose C., 2016), (Ware D., 2016), (Rahman H. U., 2018). Previous research has shown that foreign executives are positively correlated with an organization's financial performance in the Netherlands (Overveld M. N., 2012), Nigeria (Abu S. O., Okpeh A. J., Okpe U. J., 2016), Korea (Choi J. J., Park S. W., Yoo S. S., 2007), and Kenya (Karani M. A., 2015), among other countries (Rosenstein S., Wyatt J. G., 1997), (Carter D. A., 2003), (Oxelheim L., Gregoric A., Randoy T., Thomsen S., 2013). On the other hand, due of their location away from the country, foreign directors are reported to have minimal engagement and a weak monitoring function. Their efficacy is further hampered by linguistic barriers and a lack of familiarity with or knowledge of the local culture, market, and economy. As a result, in developing countries like Turkey, Indonesia, and Pakistan that have growing economies, foreign CEOs have no discernible influence on the stock market or the market value of organizations. This study further explores the connection between foreign CEO and bank performance in developing nations like Pakistan since the limited and varied literature that focuses on established economies is inconsistent with those in these developing nations. Additionally, examine the investigation builds up the accompanying hypothesis.

H_{10}: Organization structure has a positive relationship with commercial bank profitability in Laos

Technology: as measures by commercial banks has own application. In the Lao context, there are a total of 11 commercial banks that have their own applications that provide payment for goods and services, including Banque Pour Le Commerce Exterieur Lao Public, BIC Bank Lao Co., Ltd, Joint Development Bank, Lao-Viet Bank CO.,LTD, Indochina Bank LTD, MARUHAN Japan Bank Lao Co.,ltd, Military Commercial Joint Stock Bank - Lao Branch, Kasikornthai Bank Sole Limited, Acleda Bank Lao.,LTD, Phongsavanh Bank LTD, and VietinBank Lao limited. Technological-based products provide significant advantages to the banks (Zhang, Y., Weng, Q., & Zhu, N., 2018). Previous studies found that (Tunay, K. B., Tunay, N., & Akhisar, I, 2015) and (Zengin, S., & Yuksel, S., 2016), the bank may see cost benefits, higher profitability, and reduced risks compared to traditional banking products due to when there are enough consumers to support the demand for technology-based goods, the return times on bank investments in this sector are significantly quicker. The results of applied research conducted

in a number of nations show that banks function better when using electronic banking services. However, it is also observed that the anticipated outcomes are not accessible due to the propensity of clients to conventional branch-based banking, since several poor and developing nations are unable to invest necessary infrastructure (Long, P., O'Connor, A., & Tuyen, P. D., 2017), (Yuksel, S., Dincer, H., & Emir, S., 2017). Based on the above literature has led the authors to develop the following hypothesis that:

H_{11}: Technology has a positive relationship with commercial bank profitability in Laos.

Profitability (ROA, ROE and NIM): as measures by three variables. There are return on assets (ROA), return of equity (ROE) and net interest margin over total assets (NIM). The first alternative measure of profitability is ROA. The ROA measures net income as a share of total assets. It shows the earnings per assets and indicates how successfully the bank's assets are handled by authorities to create income. According to (Jahan, N. , 2012) and (Golin, J., & Delhaise, P., 2013), ROA is used to assess a bank's operational efficiency and competency by looking at the returns on its investment in assets. The second alternative measure of profitability is ROE which is described as the percentage ratio between equity capital and net earnings. This is the shareholders' return on equity, however according to the research, it's not the most accurate indicator of profitability (Dietrich, A. and Wanzenried, G., 2009). The final alternative measure of profitability is the NIM which is characterized as the difference between interest received and interest paid by a bank divided by its total assets. This ratio is known as the net interest margin over total assets. (Dietrich, A. and Wanzenried, G., 2009) assert that the NIM displays the revenue generated by interest-related activities.

Conceptual Framework

According to hypotheses developed based on the extant literature review on the relationship between bank characteristics and macroeconomic factors (independent variables) and banks' profitability (dependent variable), the conceptual framework for the study is presented in figure 2.

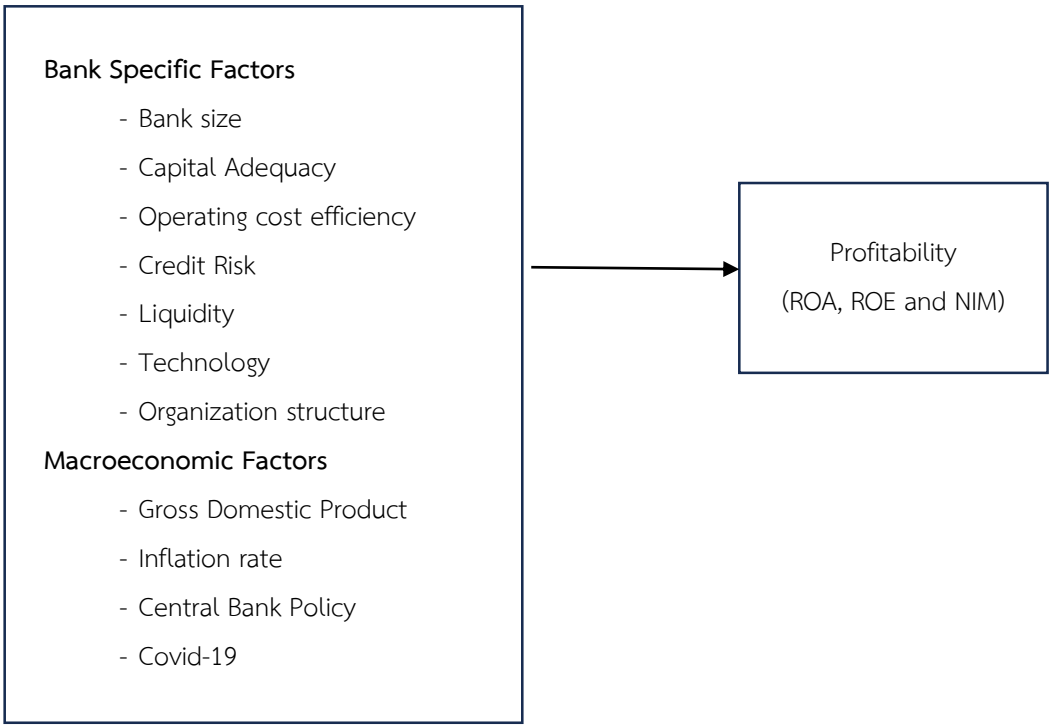

Figure 2: Conceptual Framework

Methodology and Data

Data

This study employs unbalanced panel data over the period of 2012-2021 in order to investigate the determinants of commercial bank profitability in Laos. The annual financial data of all commercial banks were extracted from the respective bank's income statement and balance sheets which were downloaded from the commercial bank's official website. Moreover, The World Bank website and bank of Lao PDR website were used to gather the macroeconomic data, which includes Lao's GDP, central bank policy and government policy.

Sample

A sample of commercial bank in Laos is utilized in this study to examines the determinants of commercial bank profitability in Laos. There are 35 commercial banks operating in Laos which consist of one state-owned commercial bank, 3 joint state commercial banks, 7 private commercial banks, 8 subsidiary commercial banks and 16 foreign commercial banks branch.

List of commercial banks in Laos which are used as a sample in this study.

	Commercial Banks	Status
1	Banque Pour Le Commerce Exterieur Lao Public	State-Owned
2	Lao-Viet Bank Co,Ltd	Joint State
3	Banque Franco-Lao Ltd	Joint State
4	Lao China Bank Co.,Ltd	Joint State
5	Joint Development Bank	Private
6	Phongsavanh Bank Ltd	Private
7	Indochina Bank Ltd	Private
8	Booyoung Lao Bank Ltd	Private
9	MARUHAN Japan Bank Lao Co.,ltd	Private
10	BIC Bank Lao Co., Ltd	Private
11	ST BANK LTD	Private
12	Acleda Bank Lao.,Ltd	Subsidiary
13	RHB Bank Lao Limited	Subsidiary
14	Kasikornthai Bank Limited	Subsidiary
15	Saigon Thuong Tin Bank Lao Co.,Ltd	Subsidiary
16	VietinBank Lao limited	Subsidiary
17	Saigon-Hanoi Bank Lao Limited	Subsidiary
18	Vietcombank Laos Limited	Subsidiary
19	Canadia Bank Lao Co.,Ltd	Subsidiary
20	Bangkok Bank Public Co.,Ltd Vientiane Branch	Foreign
21	Krung Thai Bank Ltd Vientiane Branch	Foreign
22	Bank of Ayudhya pcl., Vientiane Branch	Foreign
23	Siam Commercial Bank Ltd Vientiane Branch	Foreign
24	Public Bank, Vientiane Branch	Foreign
25	Public Berhad Bank Ltd, Wattay Branch	Foreign
26	Public Berhad Bank Ltd, Savanakhet Branch	Foreign
27	Military Commercial Joint Stock Bank - Lao Branch	Foreign
28	ICBC Limited Vientiane Branch	Foreign
29	Public Bank, Pakse Branch	Foreign
30	Cathay united bank Vientiane Capital Branch	Foreign
31	Bank of China Limited, Vientiane branch	Foreign
32	First Commercial Bank LTD, Vientiane Branch	Foreign
33	Malayan Banking Public Limited Company Lao Branch	Foreign
34	ANZ Banking Group Limited, Lao Branch	Foreign
35	Taiwan Cooperative Bank LTD, Lao Branch	Foreign

Regression Model

A baseline regression model is developed to investigate the determinants of commercial bank profitability in Laos.

$$\text{Bank Profitability}_{it} = \beta_0 + \beta_1 \text{Log(TA)}_{it} + \beta_2 \text{OPR}_{it} + \beta_3 \text{CAR}_{it} + \beta_4 \text{NPL}_{it} + \beta_5 \text{LIQ}_{it} + \beta_6 \text{TECH}_{it} + \beta_7 \text{CEO}_{it} + \beta_8 \text{GDP}_t + \beta_9 \text{INF}_t + \beta_{10} \text{PR}_t + \beta_{11} \text{COVID-19}_t + \varepsilon_t$$

$\text{Bank Profitability}_{it}$	Return on asset (ROA), return on equity (ROE) and Net Interest Margin (NIM) of bank i at time t.
$\text{Log(TA}_{it})$	The logarithm of total assets of bank i at time t.
OPR_{it}	Operating cost of bank i at time t.
CAR_{it}	Capital of bank i at time t.
NPL_{it}	Non-performing loan of bank i at time t.
LIQ_{it}	Total liquid assets of bank i at time t.
TECH_{it}	Dummy for bank has application at year t, where 1 and 0 for bank do not any application.
CEO_{it}	Dummy for foreigner CEO at year t, where 1 and 0 Lao CEO
GDP_t	Annual growth rate of Lao Gross Domestic Product at time t.
INF_t	The annual average inflation rate at time t.
PR_t	Dummy for policy rate measures 2015 at year t, where 1 for the period of 2015-2021 and 0 for the period of 2012-2014
COVID-19_t	Dummy for government policy announced to lockdown in 2021, where 1 in 2021 and 0 for the period of 2012-2020
ε_t	The error term of regression.

Table 1: Summary of Variables

Variables	Symbol	Measurement of Variables	Expected sign
Dependent Variable			
Profitability	ROA	Net profit after tax divided by total assets	Not applicable
	ROE	Net profit after tax divided by shareholders' equity	Not applicable
	NIM	Difference between interest earned and interest expended by a bank divided by its total assets	Not applicable
Independent Variable			
Bank Specific Characteristic			
Bank Size	TA	Natural logarithm of total assets	+/-
Operating cost efficiency	OPR	Operating cost of bank divined by total income	-
Capital Adequacy	CAR	Shareholders' equity divided by total assets	+/-
Credit Risk	NPL	Ratio of non-performing loans to total loans	+/-
Liquidity	LIQ	Ratio of Liquidity to total assets	+/-
Technology	TECH	Dummy for bank has application, where 1 and 0 for bank do not any application	+
Organization structure	CEO	Dummy foreign CEO at year t, where 1 and 0 Lao CEO	+
Macroeconomic factors			
Gross Domestic Product	GDP	The annual growth of Lao gross domestic products	+
Inflation	INF	The annual average inflation rate	+
Central bank policy	PR	Dummy for policy rate measures 2015, where 1 for the period of 2015-2021 and 0 for the period of 2012-2014	-
Covid-19	COVID-19	Dummy for government policy announced to lockdown in 2021, where 1 in 2021 and 0 for the period of 2012-2020	-

Technique of Analysis

The Random Effect Model is employed in this study to examines the relationship between bank specific characteristics and macroeconomic variable with the commercial bank profitability in Laos from year 2012 to year 2021. This is because Random Effect Model enables the study to efficiently account for any remaining serial correlation which arises from unobserved time-constant factor (Wooldridge, J. M., 2002). Furthermore, the Random Effect Model also infers that the entity of error term does not correlate with the predictors. There are some benefits for using Random Effect Model to analyze the data of this study. First off, according to (Torres-Reyna, 2007) the Random Effect Model allows time-invariant variables to function as the model's explanatory variable. As it is not necessary for the study to determine the N cross-sectional intercepts, the Random Effect Model also offers inexpensive degrees of freedom (Gujarati, D. N., & Porter, D., 2009). Random Effects model also impose much more assumptions than those need for pooled OLS, which the Random Effect Model are strict exogeneity in addition to orthogonally between the error term and the explanatory variables (Wooldridge, J. M., 2002).

Empirical Results

Table 2 presents the descriptive statistics for the variables in this study, including 350 observations. The means that the ROA, ROE and NIM ratios are 0.006567, 0.046821 and 0.023203 respectively. The smallest ROA value is -0.5422543, while the largest is 0.054557. Regarding the ROE ratio, the smallest is -0.8599631 and the largest is 0.52222. Regarding the NIM ratio. The smallest NIM value is 0, while the largest is 0.077502. The mean bank size (TA) is 4.971364, the mean Capital Adequacy (CAR) is 0.261818, the mean operating cost ratio (OPR) is 008432, the mean Liquidity (LIQ) is 0.160080, the mean credit risk (NPL) is 0.027236, the mean of dummy technology (TECH) variable is 0.314285, the mean of dummy of organization structure (CEO) variable is 0.874285, the mean GDP is 0.0311, the mean inflation (INF) is 0.03265, the mean of dummy central bank policy variable (PR) is 0.7, and the mean of the dummy COVID-19 pandemic variable is 0.1.

Table 2: Descriptive Statistics

Variables	Obs	Mean	Std. Dev	Min	Max
ROA	350	.006567	.0342795	-.5422543	.054557
ROE	350	.046821	.0232038	-.8599631	.52222
NIM	350	.023203	.0185849	0	.077502
TA	350	4.97136	2.455476	0	7.8345
CAR	350	.261818	.2710407	0	0.852589
OPR	350	0.32769	.6767043	0	.79586
LIQ	350	.160080	.1562105	0	.703511
NPL	350	.027236	.1454577	0	.6279
TECH	350	.314285	.4648954	0	1
CEO	350	.874285	.3320017	0	1
GDP	350	.0311	.0251641	-.0179	.0602
INF	350	.03265	.017059	.0083	.0637
PR	350	.7	.4589136	0	1
COVID-19	350	.1	.4005727	0	1

Source: Test by Stata

Table 3 reports the correlation coefficient matrix of the independent variables employed in this study. As a result, all correlations between the independent variables are less than 0.8, according to the finding. Consequently, the result met the 0.8 rule of thumb, indicating that there are no problems with multicollinearity between the independent variables.

Table 3: Correlation Analysis

	ROA	ROE	NIM	TA	CAR	OPR	LIQ	NPL	TECH	CEO	GDP	INF	PR	COVID-19
ROA	1.000	-	-	-	-	-	-	-	-	-	-	-	-	-
ROE	0.1154	1.000	-	-	-	-	-	-	-	-	-	-	-	-
NIM	0.1826	0.007	1.000	-	-	-	-	-	-	-	-	-	-	-
TA	0.100	0.284	0.531	1.000	-	-	-	-	-	-	-	-	-	-
CAR	-0.007	-0.185	0.549	0.320	1.000	-	-	-	-	-	-	-	-	-
OPR	-0.143	-0.129	-0.015	0.226	0.297	1.000	-	-	-	-	-	-	-	-
LIQ	0.128	0.139	0.315	0.465	0.337	0.088	1.000	-	-	-	-	-	-	-
NPL	0.101	-0.060	0.124	0.063	0.167	0.027	0.105	1.000	-	-	-	-	-	-
TECH	-0.055	-0.004	-0.020	0.247	-0.238	0.090	-0.00	-0.045	1.000	-	-	-	-	-
CEO	-0.046	0.035	-0.010	-0.229	0.181	-0.123	-0.103	0.019	-0.560	1.000	-	-	-	-
GDP	0.052	0.074	0.038	-0.051	0.020	0.071	-0.135	-0.038	0.000	-0.009	1.000	-	-	-
INF	-0.026	0.022	-0.139	-0.219	-0.121	-0.114	-0.076	0.056	-0.000	-0.015	-0.018	1.000	-	-
PR	-0.013	0.063	0.069	0.392	0.154	0.093	0.238	-0.016	-0.000	0.033	0.058	0.636	1.000	-
COVID-19	-0.059	-0.007	0.187	0.151	0.042	-0.026	0.225	0.006	-0.000	0.017	0.081	0.336	0.327	1.000

Source: Test by Stata

Random Effect Regression

Table 4 presents the regression results from the random effect estimation by using commercial bank profitability (ROA, ROE and NIM) as the dependent variable to analyze the determinants of commercial bank profitability in Laos. As a result, Table 4, bank size (TA) has a positive relationship with return on asset (ROA), return on equity (ROE) and Net Interest Margin (NIM) and statistically significant at 5%, 1% and 5% levels, respectively. Implies that bank size induces economies of scale by making larger banks more profitable and economies of scale will reduce the cost of gathering and processing information. This result is consistent with previous research by authors (Lu, Jing, Alatengsudao, and Yin Yuming., 2013), (Gremi, Eliona, 2013), (Ul Mustafa, A. R., Ansari, R. H., & Younis, M. U., 2012) and (Li, Ming, 2017)

Capital Adequacy (CAR) has a negative and significant relationship with return on equity (ROE). The coefficient of Capital Adequacy (CAR) shows that the 1% increment of Capital Adequacy (CAR) will cause return on equity to decline by 10.19%. The finding implies that which is inconsistent with the hypothesis set. This is because the ratio of capital adequacy is high from the policy of commercial banks and the regulations of the central bank, especially in 2018, commercial banks must increase their registered capital from 300 billion kip to 500 billion kip, foreign branch banks must have their registered capital from 100 billion kip to 300

billion kip, so banks must maintain increased capital in order to have capital adequacy and the increase in capital is not able to generate additional income as well as liquidity because banks must maintain more liquidity, resulting in low capital in lending (the main income of the bank) to the people. This result is consistent with previous research by (Saona, P. H, 2011); (Qin, X., & Pastory, D., 2012)

Operating cost efficiency (OPR) has a negative and significant relationship with return on asset (ROA), return on equity (ROE) and Net Interest Margin (NIM) and statistically significant at 1% levels. This is because operating cost-to-income ratio increases, it will affect the bank's ability to make a profit which was consistent with previous research by (Bansal, R., Singh, A., Kumar, S. and Gupta, R.,, 2018), (Kosmidou., 2008), (Ali, K., Akhtar, M. F. and Ahmed, H. Z., 2011), (Weerasinghe, V. and Perera, T. R., 2013) and (Sufian, F & Habibullah, M. S., 2009)

Liquidity (LIQ) has a negative and significant relationship with Net Interest Margin (NIM). According to the result, 1% increment of the commercial bank's liquidity will cause the profit by commercial banks will decline to 0.92%. The finding implies that the more liquid assets held by the commercial banks, the lower the loans that will be granted to the customers which will affect the bank's income which was consistent with previous research by (Bansal, R., Singh, A., Kumar, S. and Gupta, R.,, 2018) and (Petria, N., Capraru, B. and Ihnatov, I., 2015)

Credit risk (NPL) has a negative and significant relationship with Net interest margin (NIM) and statistically significant at 5% levels. increment of the commercial bank's non-performing loan will cause the return on asset by commercial banks to decline to 3%. It should be clear that an increase in bad debts would require banks to increase reserve spending and deal with an increase in credit risk, which would reduce bank earnings. Additionally, the overall amount of bad loans has a direct impact on the net interest revenue of commercial banks. This result is consistent with the studies of (Molyneux, P. and Thornton, J., 1992), (Athanasoglou, P. P., Asimakopoulos, I., & Georgiou, E., 2005), (Gremi, Eliona, 2013), (Kosmidou, K., Pasiouras, F.,& Tsaklanganos, A, 2007), (Sufian, F., & Noor Mohamad Noor, M. A. , 2012), (Petria, N., Capraru, B. and Ihnatov, I. (2015), (Sufian, F & Habibullah, M. S., 2009), (Molyneux, P. and Thornton, J., 1992), and (Sufian, F & Habibullah, M. S., 2009)

Technology (TECH) has a negative and significant relationship with return on equity (ROE) and statistically significant at 10% level. The finding implies that which is inconsistent with the hypothesis set. Because commercial banks have applications to facilitate financial transactions which will have high administrative costs If created, it is not popular with customers. At the same time, it still in the early stages where the banks established their own applications,

causing expenses to be greater than revenues, thus affecting commercial banks' performance in a negatively.

Organization structure (CEO) has a positive and significant relationship with return on equity (ROE), return on equity (ROE) and Net Interest Margin (NIM) and statistically significant at 10% levels. This is because the foreign CEO has experience in managing banks in order to maximize the benefits of existing assets. In addition, foreign CEO less assets management and low cost. For example, there are no service units, no branches, and no complex financial products. This result is consistent with the studies of (Overveld M. N., 2012), (Abu S. O., Okpeh A. J., Okpe U. J. , 2016), (Choi J. J., Park S. W., Yoo S. S., 2007), (Karani M. A., 2015), (Rosenstein S., Wyatt J. G. , 1997), (Carter D. A., 2003) and (Oxelheim L., Gregoric A., Randoy T., Thomsen S., 2013

Central bank policy (PR) has a negative and significant relationship with Net Interest Margin (NIM) and statistically significant at 5% level. Central bank began to set reference rate for commercial banks in 2015, as a result loan interest rates has decreased significant which affects commercial bank profitability due to credit is the main income of commercial banks. This result is consistent with the studies of (Cargill, T. F & Mayer, T., 2013) and (Lathaporn R. and N. Ananchotikul, 2018)

Table 4: Regression Results

Variables	ROA	ROE	NIM
	Coefficient	Coefficient	Coefficient
TA	**0.0019****	**0.0175*****	**0.0040****
CAR	-0.0017	**-0.1019*****	-0.0249
OPR	**-0.0098*****	**-0.0239*****	**-0.0068*****
LIQ	0.0228	0.0422	**-0.0092****
NPL	-0.0305	-0.0251	**-0.0324****
TECH	-0.0053	**-0.0344***	0-.0046
CEO	**0.0090***	**0.0468***	**0.0072***
GDP	0.1944	0.5243	0.1487
INF	-0.2565	-1.2320	0.1696
PR	0.0049	-0.0227	**-0.0053****
COVID-19	-0.0017	-0.0428	-0.0001
Constant	0.2365	0.17617	0.0300
R-squared	0.1944	0.2541	0.4871
Prob>chi2	0.0011	0.0000	0.0000
No. Obs		350	

Notes: ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively

Conclusion

This study investigates the determinants of commercial bank profitability in Laos covering the period from year 2012 to year 2021. The findings of this study conclude that on the one hand, bank specific characteristics like bank size and organization structure have a positive and significant effect on profitability. Bank size has more credibility to raise large amounts of deposits and distribute those funds to maximize returns. While foreign CEO have business management experience from foreign banks, such as how to manage existing assets for maximum profit. On the other hand, capital adequacy and liquidity have a negative relationship to bank profitability as these ratios increase, so that banks have to make more capital reserves resulting in less capital to lending (main income). Similarly operating cost and non-performing loans have a negative relationship to profitability. The higher this ratio, the higher the cost that affects the bank profits. Meanwhile banks introduced technology measures by using their own applications which have a negative impact on bank performance, causing expenses to be greater than revenues, thus affecting commercial banks' performance.

In the aspect of macroeconomic determinants, the results that the central bank's reference interest rate determination policy has started since 2015 affected the net interest margin of commercial banks in a negative direction. This is because the central bank has adjusted the deposit and loan interest rates to suit economic conditions, especially for businesses and individuals to access low-cost financing. Therefore, commercial banks cannot adjust loan interest rates as in the past. As a result, loan interest rates have decreased significant which affects commercial bank profitability due to lending is the main income of commercial banks. For other macroeconomic factors the results were not significant for the profitability of commercial banks in Lao PDR

Recommendations

Recommendations for policymakers

This study suggests that central bank policy, which was introduced in 2015, had the opposite direction with regard to bank's performance, especially the net interest margin. In fact, this is a successful central bank policy because it allows businesses to borrow at low cost to produce goods and services. However, it might impact on small and medium-sized enterprises (SMEs) cannot be able to access funding sources as banks consider more rick, so

policy makers may need to develop policies to support this matter, such as designation of agencies to consider underwriting risks of small and medium-sized enterprises in accessing capital. Consideration should be given for the establishment of a specialized bank or agency to promote funding sources for SME businesses. Meanwhile central banks may use this financial instrument to solve current economic problems, especially inflation meaning when there is too much money circulating in the economy. The central bank may increase loan interest rates, which results in a decrease in demand for money. On the contrary, if the economy is in recession, the central bank may lower its policy rate to encourage more access to funding. As a result, the economy has good liquidity and circulation.

Creating a good economic environment, especially to promote investment, leads to convenience in doing business. When the business goes well, it must expand the business to generate more income and profits. Ability to pay back loans to banks, these banks will reduce the problem of following-up and resolving bad debts and deducting reserves of bad debts. This will make the bank more profitable, and the government will earn revenue from various economic activities, especially taxation.

Recommendations for commercial banks

Most commercial banks using their own applications to perform financial transactions in real-time; require many users in order to achieve economic of scale which can make a profit. However, this is still in the early stages where the banks established their own applications. As a result, there will be a sunk cost. Therefore, this study suggests that the bank should consider adding more services that are core businesses, such as digital lending service, because many banks already have their customer information, which are available to be used to create benefits and increase business profits

Commercial bank managers should control expenses more efficiently, especially expenses that have been invested but without benefits for banks, such as branch expansion or service units that people use less often, which are not worth the cost. In addition, the managers should also increase investment in technology instead of supporting consumers' behavior that has changed according to the era, which will result in long-term profits.

Commercial bank managers have to focus on a credit quality policy emphasizing that credit quality must be more important than credit growth. If banks focus too much on lending volume without quality, it will lead to non-performing loan (NPL), which requires deduction of provisions for bad loans, resulting in lower bank earnings.

Chief Executives Officer (CEOs) of state- owned or private banks to increase the importance of formulating management strategies to be more internationalized, professionally connected and sharing international lessons.

Commercial banks have to focus on maintaining liquidity at an appropriate level or as already determined by the central bank's rules, invest money to create other higher return.

The study found that the size of the bank has a positive relationship with the profitability of commercial banks in Lao PDR or banks with large assets will result in the profitability of the bank's main assets which come from deposits. Therefore, commercial banks should use effective strategies to attract more customers making more deposits, such as the development of deposit products using strategies for raising deposits and deposit management to facilitate lending which is the main income of the bank.

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A Comparative Study of User Requirement Analysis in Smart Parking Systems: Integrating Stakeholder Ranking, Analytic Hierarchy Process, and Quality Function Deployment

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Abstract

This research employs a mixed-methods approach to comprehensively analyze user requirements for smart parking systems in Bangkok, Thailand. A diverse group of 304 stakeholders participated in an online survey to collect data on user preferences and priorities. The survey findings indicate that stakeholders prioritize the Mobile Application and Reservation and Payment and Transaction groups, while the Security and Safety and Analytics and Reporting groups are ranked lower in importance. Additionally, Analytic Hierarchy Process (AHP) analysis from an engineering perspective highlights the criticality of the Analytics and Reporting and Security and Safety groups. The study recommends integrating stakeholder preferences and engineering considerations to develop a customer-centric smart parking system. Key strategies include focusing on user-friendly interfaces, convenient reservation and payment processes, leveraging data analytics for optimized operations, implementing robust security measures, fostering collaboration, adopting an iterative development process, and prioritizing user experience and comprehensive security. The Quality Function Deployment (QFD) process is proposed for translating user requirements into technical specifications and implementation strategies. By following a decision-making strategy that maximizes customer satisfaction, enhances user experience, optimizes operational efficiency and security, considers financial viability, and embraces continuous improvement, stakeholders can effectively develop a smart parking system that meets user expectations.

Keywords: Smart Parking Systems, User Requirement Analysis, Stakeholder Ranking Analysis, Analytic Hierarchy Process (AHP), The Quality Function Deployment (QFD), Bangkok.

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Introduction

In the rapidly evolving urban landscape, the concept of a Smart Parking System has emerged as a beacon of hope amidst the complex challenges of urbanization. It represents a well-structured framework, seamlessly integrating diverse application platforms within embedded systems [3]. As we delve into the intricacies of this innovative system, we discover how it addresses the critical facets of urban life and contributes to the development of smarter and more sustainable cities.

G1 - Parking Availability and Information: At its core, a Smart Parking System is designed to alleviate the frustration of urban residents searching endlessly for parking spaces [3]. With real-time updates on parking availability, this system empowers drivers to make informed decisions and minimize the time spent circling crowded streets, thereby reducing traffic congestion and its associated environmental impact [3][4].

G2 - Mobile Application and Reservation: Beyond the conventional parking experience, this system introduces a user-friendly mobile application [18]. It offers a seamless reservation process, ensuring that users can secure parking spots with ease, right from their smartphones [18]. In doing so, it not only enhances convenience but also minimizes the hassle associated with parking [7][8].

G3 - Payment and Transaction: The system simplifies payment processes, allowing users to settle parking fees effortlessly through the application [18]. Gone are the days of scrambling for change or dealing with complicated payment methods. This simplicity enhances user satisfaction and streamlines the transaction experience [7][8].

G4 - Security and Safety: Safety is paramount in any urban environment. Here, the Smart Parking System goes beyond parking availability and offers security features [18]. It is equipped to detect potential threats like fire and gas leakages, ensuring the safety of both vehicles and users [18].

G5 - Analytics and Reporting: In the age of data, the system leverages advanced analytics to provide valuable insights [3][4]. It gathers data on parking usage, user preferences, and traffic patterns, offering a treasure trove of information for urban planning and management [3][4].

As we navigate the bustling streets of Bangkok, a city known for its unique challenges in parking and traffic management, the implementation of a Smart Parking System becomes a beacon of hope [1][2]. The success of such a system hinges on its ability to deliver quality services [5][6]. We, therefore, embark on a journey to evaluate the service quality of this innovative solution using the Quality Function Deployment (QFD) model [9][10]. Through surveys, feedback, and prioritization using the Analytic Hierarchy Process (AHP), we aim to identify the features essential for a Smart Parking System tailored to the vibrant and dynamic context of Bangkok [9][10][11].

In this pursuit, we emphasize not only the importance of service quality but also the pivotal role played by the QFD model in shaping a system that meets customer expectations, enhances urban living, and paves the way for a more efficient and sustainable urban future.

Methodology

Research Design: The research employed a mixed-methods approach to comprehensively analyze user requirements for smart parking systems in Bangkok, Thailand. It combined qualitative and quantitative methods to gather insights from key stakeholders in the smart parking field [Figure 1].

Survey Development: An online survey was developed using Google Forms to collect data on user preferences and priorities. The survey questionnaire was carefully designed to capture the importance of five function groups: G1 (Parking Availability and Information), G2 (Mobile Application and Reservation), G3 (Payment and Transaction), G4 (Security and Safety), and G5 (Analytics and Reporting). The survey also included demographic questions to gather background information on the participants.

Participant Recruitment: A diverse group of 304 stakeholders involved in the smart parking ecosystem, including government officials, parking operators, technology providers, and users, were recruited to participate in the survey. Recruitment efforts were made through professional networks, industry associations, and social media platforms to ensure a representative sample.

Data Collection: Participants completed the online survey at their convenience, providing rankings for the function groups based on their perceived importance. The survey

also collected demographic information to gain insights into the participants' backgrounds and roles.

Data Analysis: Descriptive statistics were used to summarize the demographic information of the participants. The ranking data for the function groups were analyzed to determine the relative importance as perceived by the stakeholders. Stakeholder rankings were averaged to rank the function groups based on their importance.

Analytic Hierarchy Process (AHP): AHP methodology was employed to determine the final priorities for the function groups. AHP involved conducting pairwise comparisons of the function groups to assess their relative importance from an engineering and developer standpoint. Factors such as technical feasibility, resource requirements, and development complexity were considered in the analysis.

Comparison and Integration: The stakeholder rankings and the AHP-derived priorities were compared and integrated to identify any alignment or discrepancies between stakeholder preferences and the engineering perspective. This process provided a comprehensive understanding of user requirements and engineering considerations.

Quality Function Deployment (QFD): QFD was utilized to translate the identified user requirements and engineering priorities into technical specifications and implementation strategies for the smart parking system. QFD facilitated effective strategy development by aligning user needs with system design and implementation.

Contribution and Insights: The research methodology, combining stakeholder survey, AHP analysis, and QFD, contributed valuable insights for developers, engineers, and stakeholders in optimizing smart parking systems in Bangkok to meet user needs effectively. The findings provided guidance for system development and optimization.

Limitations: It is important to acknowledge limitations such as potential biases in participant selection and the reliance on self-reported data. These limitations should be considered when interpreting the results and generalizing the findings.

Research Design

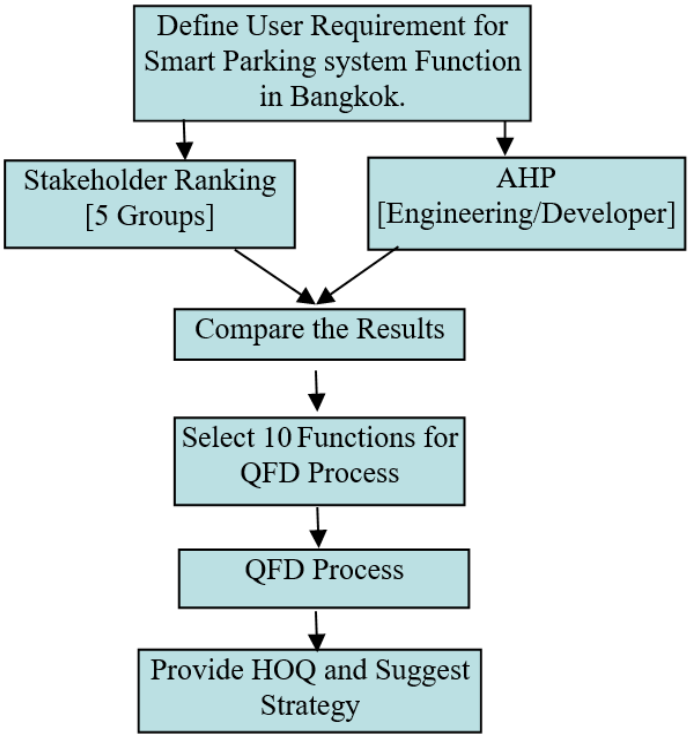


Figure 1: Research Design

Results of Stakeholder Ranking

From the survey, a total of 304 respondents participated, and they were categorized into five stakeholder groups or stakeholders with multiple interests as follows:

- General Customers: 81 individuals, accounting for 26.6%.
- Business/Organization Customers: 59 individuals, accounting for 19.4%.
- Urban Planning and Transportation Professionals: 51 individuals, accounting for 16.8%.
- Technology Enthusiasts/Supporters: 68 individuals, accounting for 22.4%.
- Decision Makers: 55 individuals, accounting for 18.1%.

It should be noted that some respondents belong to multiple stakeholder groups, indicating multiple interests. The detailed breakdown is shown in Figure 2. Number of Survey Respondents by Stakeholder Groups [Figure2].

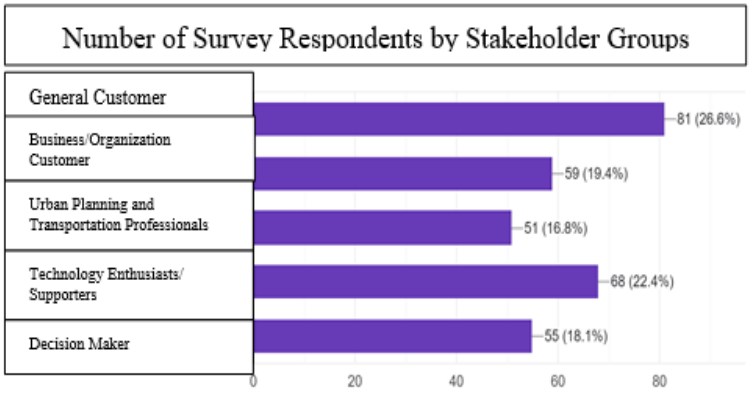


Figure 2: Survey Respondents by Stakeholder Groups

In the present study, the respondents were asked to rank the importance of various functions (G1-G5) and sub-functions within each group of the Smart Parking System, specifically in relation to its significance for Bangkok. The rankings were assigned on a scale of 1 to 5, with rank 1 denoting the highest level of importance and rank 5 representing the lowest level of importance. These rankings, as depicted in Figures 3-8 [Figure3-Figure8], provide valuable insights into the perceived importance of different aspects of the Smart Parking System for Bangkok city.

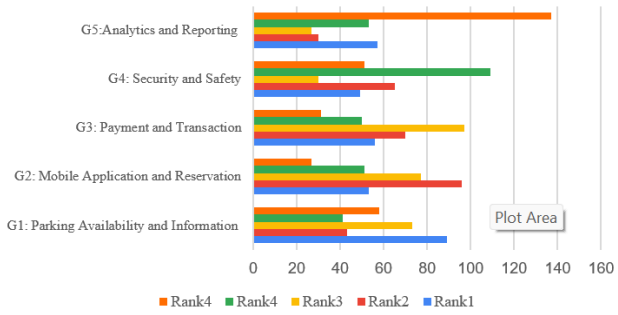


Figure 3: Ranking result of Group function

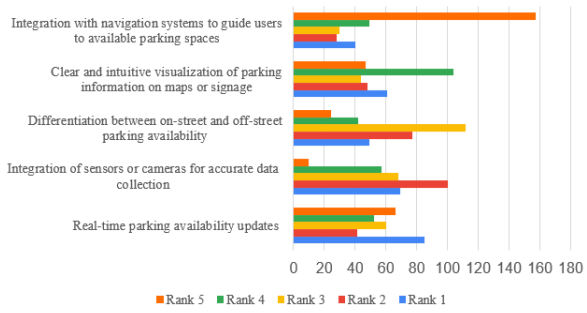


Figure 4: Ranking result of G1

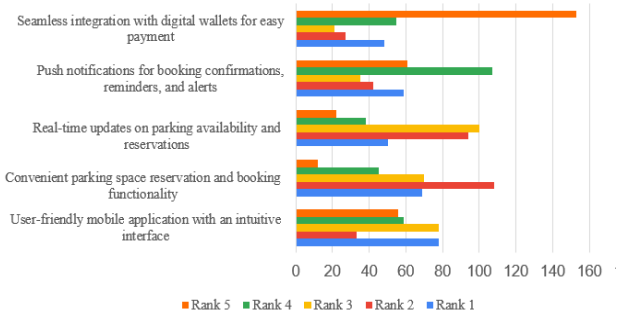


Figure 5: Ranking result of G2

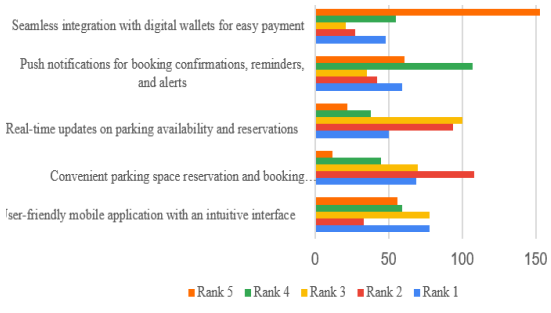


Figure 6: Ranking result of G3

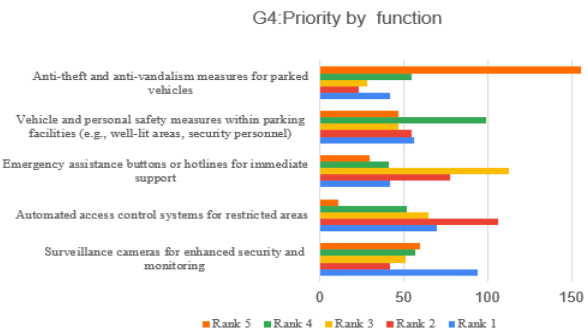


Figure 7: Ranking result of G4

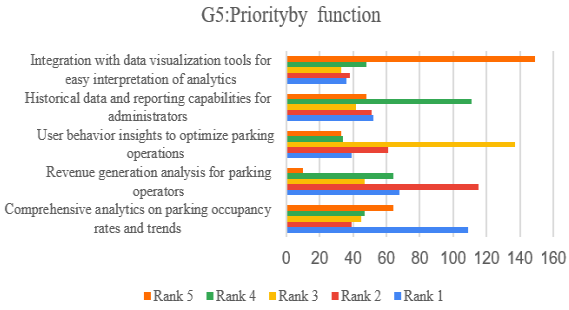


Figure 8: Ranking result of G5

Based on the survey data and ranking of importance within each group, as depicted in Figure 3, The importance order of the groups was determined based on the survey data and the ranking of importance within each group. Table 1 displays the number of customers who ranked each group from 1 to 5.

Table 1: Number of customers ranking each group

Group	nRank1	nRank2	nRank3	nRank4	nRank5
G1	89	43	73	41	58
G2	53	96	77	51	27
G3	56	70	97	50	31
G4	49	65	30	109	51
G5	57	30	27	53	137

To calculate the weighted average and determine the importance order of each group, the ranks were multiplied by their respective weights and then averaged. The weights assigned were 5 for Rank 1, 4 for Rank 2, 3 for Rank 3, 2 for Rank 4, and 1 for Rank 5. The weighted average was calculated using the following formula [12]:

$$Weighted\ Average = \frac{\sum wx}{\sum w}$$

w = the weight for each data point.

x = the value of each data point.

$$\text{weighted average} = \frac{[(nRank1 \times 5) + (nRank2 \times 4) + (nRank3 \times 3) + (nRank4 \times 2) + (nRank5 \times 1)]}{(5 + 4 + 3 + 2 + 1)}$$

The results for each group are presented as follows:

G1: Parking Availability and Information. The weighted average was calculated to be 65.07

G2: Mobile Application and Reservation. The weighted average was calculated to be 67.27

G3: Payment and Transaction. The weighted average was calculated to be 65.47

G4: Security and Safety. The weighted average for was calculated to be 57.6

G5: Analytics and Reporting. The weighted average for G5 was calculated to be 48.6

Based on the weighted averages, the groups were ranked in descending order of importance: G2, G3, G1, G4 and G5

In assessing the function levels of each group, G1-G5, based on the weighted average, the results are as follows:

Table 2: Group 1 - Parking Availability and Information

Function (Group weighted 65.07)	Importance Level
Integration of sensors or cameras for accurate data collection (71.53)	Most Important
Differentiation between on-street and off-street parking availability (62.60)	Rank 2
Real-time parking availability updates (66.47)	Rank 3
Clear and intuitive visualization of parking information on maps or signage (58.93)	Rank 4
Integration with navigation systems to guide users to available parking spaces (43.80)	Least Important

Table 3: Group 2 - Mobile Application and Reservation

Function (Group weighted 67.27)	Importance Level
Convenient parking space reservation and booking functionality (72.60)	Most Important
Real-time updates on parking availability and reservations (62.00)	Rank 2
User-friendly mobile application with an intuitive interface (68.27)	Rank 3
Push notifications for booking confirmations, reminders, and alerts (56.20)	Rank 4
Seamless integration with digital wallets for easy payment (44.93)	Least Important

Table 4: Group 3 - Payment and Transaction

Function (Group weighted 65.47)	Importance Level
Cashless payment options to reduce reliance on cash (69.53)	Most Important
Secure payment processing to protect user data and privacy (65.07)	Rank 2
Integration with multiple payment methods (e.g., mobile wallets, credit/debit cards) (62.47)	Rank 3
Automated payment calculations based on parking duration and rates (60.47)	Rank 4
Receipt generation and transaction history for reference and reimbursement (46.47)	Least Important

Table 5: Group 4 - Security and Safety

Function (Group weighted 57.6)	Importance Level
Automated access control systems for restricted areas (72.27)	Most Important
Emergency assistance buttons or hotlines for immediate support (64.87)	Rank 2
Surveillance cameras for enhanced security and monitoring (64.33)	Rank 3
Vehicle and personal safety measures within parking facilities (59.07)	Rank 4
Anti-theft and anti-vandalism measures for parked vehicles (43.47)	Least Important

Table 6: Group 5 - Analytics and Reporting

Function (Group weighted 48.6)	Importance Level
Revenue generation analysis for parking operators (71.93)	Most Important
Comprehensive analytics on parking occupancy rates and trends (66.27)	Rank 2
User behavior insights to optimize parking operations (63.40)	Rank 3
Historical data and reporting capabilities for administrators (57.33)	Rank 4
Integration with data visualization tools for easy interpretation of analytics (45.07)	Least Important

The importance of different functions within each group of the parking system was assessed through a stakeholder ranking survey. In Group 1, "Parking Availability and Information," integrating sensors or cameras for accurate data collection was ranked as the most important function. Group 2, "Mobile Application and Reservation," highlighted the significance of convenient parking space reservation and a user-friendly mobile application. In Group 3, "Payment and Transaction," offering cashless payment options and secure payment processing were ranked highly. Group 4, "Security and Safety," prioritized automated access control systems and emergency assistance buttons. Lastly, Group 5, "Analytics and Reporting," emphasized revenue generation analysis and comprehensive analytics on parking occupancy rates.

These results provide insights into the priorities and preferences of the surveyed stakeholders regarding the functions within each group of the parking system [Table 7]. This information can be valuable for decision-making and resource allocation when developing and implementing a parking system that aligns with stakeholder needs and expectations.

Table 7: Ranking and total weight for each function

Rank	Function Name	Function Weigh	Group Weight	Total Weight
1	Convenient parking space reservation and booking functionality	72.6	67.3	4,883.80
2	Integration of sensors or cameras for accurate data collection	71.5	65.1	4,654.46
3	User-friendly mobile application with an intuitive interface	68.3	67.3	4,592.52
4	Cashless payment options to reduce reliance on cash	69.5	65.5	4,552.13
5	Real-time parking availability updates	66.5	65.1	4,325.20
6	Secure payment processing to protect user data and privacy	65.1	65.5	4,260.13
7	Real-time updates on parking availability and reservations	62	67.3	4,170.74
8	Automated access control systems for restricted areas	72.3	57.6	4,162.75
9	Integration with multiple payment methods	62.5	65.5	4,089.91
10	Differentiation between on-street and off-street parking availability	62.6	65.1	4,073.38
11	Automated payment calculations based on parking duration and rates	60.5	65.5	3,958.97
12	Clear and intuitive visualization of parking information on maps or signage	58.9	65.1	3,834.58
13	Push notifications for booking confirmations, reminders, and alerts	56.2	67.3	3,780.57
14	Emergency assistance buttons or hotlines for immediate support	64.9	57.6	3,736.51
15	Surveillance cameras for enhanced security and monitoring	64.3	57.6	3,705.41
16	Revenue generation analysis for parking operators	71.9	48.6	3,495.80
17	Vehicle and personal safety measures within parking facilities	59.1	57.6	3,402.43
18	Comprehensive analytics on parking occupancy rates and trends	66.3	48.6	3,220.72
19	User behavior insights to optimize parking operations	63.4	48.6	3,081.24
20	Receipt generation and transaction history for reference and reimbursement	46.5	65.5	3,042.39
21	Seamless integration with digital wallets for easy payment	44.9	67.3	3,022.44
22	Integration with navigation systems to guide users to available parking spaces	43.8	65.1	2,850.07
23	Historical data and reporting capabilities for administrators	57.3	48.6	2,786.24
24	Anti-theft and anti-vandalism measures for parked vehicles	43.5	57.6	2,503.87
25	Integration with data visualization tools for easy interpretation of analytics	45.1	48.6	2,190.40

Results of AHP

In the AHP (Analytic Hierarchy Process) section, the researchers conducted interviews with engineers and developers involved in the development of Smart Parking systems from service providers. The interviewees provided importance ratings.

Goal: The objective of this Analytic Hierarchy Process (AHP) analysis is to prioritize the functions of a smart parking system in Bangkok, Thailand, based on their relative importance from an engineering or developer perspective.

Criteria: C1-Technological Feasibility: This criterion assesses the feasibility of implementing and maintaining each function within the smart parking system.

C2-User Experience: This criterion evaluates the impact of each function on enhancing the overall user experience.

C3-Operational Efficiency: This criterion considers the contribution of each function towards optimizing parking operations and efficiency.

C4-Security and Safety: This criterion analyzes the role of each function in ensuring the security and safety of parking facilities and users.

C5-Financial Viability: This criterion evaluates the potential economic benefits and cost-effectiveness of implementing each function.

Alternatives: The original list of 25 functions can be grouped into five broader categories [Table 8], each representing a specific aspect of the smart parking system:

Table 8: Group of Smart Parking system functions.

Group 1: Parking Availability and Information	**Group 2: Mobile Application and Reservation**
F11: Real-time parking availability updates	F21: User-friendly mobile application with an intuitive interface
F12: Integration of sensors or cameras for accurate data collection	F22: Convenient parking space reservation and booking functionality
F13: Differentiation between on-street and off-street parking availability	F23: Real-time updates on parking availability and reservations
F14: Clear and intuitive visualization of parking information on maps or signage	F24: Push notifications for booking confirmations, reminders, and alerts
F15: Integration with navigation systems to guide users to available parking spaces	F25: Seamless integration with digital wallets for easy payment
Group 3: Payment and Transaction	**Group 4: Security and Safety**
F31: Integration with multiple payment methods	F41: Surveillance cameras for enhanced security and monitoring
F32: Cashless payment options to reduce reliance on cash	F42: Automated access control systems for restricted areas
F33: Secure payment processing to protect user data and privacy	F43: Emergency assistance buttons or hotlines for immediate support
F34: Automated payment calculations based on parking duration and rates	F44: Vehicle and personal safety measures within parking facilities
F35: Receipt generation and transaction history for reference and reimbursement	F45: Anti-theft and anti-vandalism measures for parked vehicles
Group 5: Analytics and Report	
F51: Comprehensive analytics on parking occupancy rates and trends	F54: Historical data and reporting capabilities for administrators
F52: Revenue generation analysis for parking operators	F55: Integration with data visualization tools for easy interpretation of analytics
F53: User behavior insights to optimize parking operations	

By grouping the functions, we have reduced the number of alternatives, allowing for a more manageable AHP analysis.

Pairwise Comparison Matrix

The pairwise importance comparisons between the respective functional groups are represented in Table 9. The numbers in the cells indicate the ratio of importance based on the Analytic Hierarchy Process (AHP) scale, commonly used in decision-making. The scale ranges from 1 to 9, with interpretations as follows:

1: Equally important

3: Moderately important

5: Strongly important

7: Very strongly important

9: Extremely important

2, 4, 6, and 8: Intermediate values indicating the importance between the adjacent judgments.

Table 9: Pairwise Comparison Matrix for Criteria

Criteria	C1	C2	C3	C4	C5
C1.Technological Feasibility	1	4	2	3	2
C2.User Experience	1/4	1	1/3	1/4	1/3
C3.Operational Efficiency	1/2	3	1	1/2	1/2
C4.Security and Safety	1/3	4	2	1	2
C5.Financial Viability	1/2	3	2	1/2	1

In the context of the Pairwise Comparison Matrix function for each group function in Table 10-15

Table 10: Pairwise Comparison Matrix C1

Group	G1	G2	G3	G4	G5
G1	1	1/5	3	1/3	1/2
G2	5	1	4	1/3	1/2
G3	1/3	1/4	1	1/5	1/4
G4	3	3	5	1	2
G5	2	2	4	1/2	1

Table 11: Pairwise Comparison Matrix C2

Group	G1	G2	G3	G4	G5
G1	1	1/4	1/3	1/4	1/5
G2	4	1	3	1/3	1/3
G3	3	1/3	1	1/2	1/2
G4	4	3	2	1	2
G5	5	3	2	1/2	1

Table 12: Pairwise Comparison Matrix C3

Group	G1	G2	G3	G4	G5
G1	1	1/4	1/4	1/3	1/5
G2	4	1	3	1/2	1/3
G3	4	1/3	1	1/2	1/3
G4	3	2	2	1	1/3
G5	4	3	2	3	1

Table 13: Pairwise Comparison Matrix C4

Group	G1	G2	G3	G4	G5
G1	1	1/4	1/5	1/4	1/5
G2	4	1	3	1/2	1/3
G3	5	1/3	1	1/2	1/3
G4	4	2	2	1	2
G5	5	3	3	1/2	1

Table 14: Pairwise Comparison Matrix C5

Group	G1	G2	G3	G4	G5
G1	1	1/4	1/5	1/4	1/5
G2	4	1	1/3	1/2	1/3
G3	5	3	1	3	2
G4	4	2	1/3	1	1/2
G5	5	3	1/2	2	1

Calculation of the Analytic Hierarchy Process (AHP) outcomes for the provided matrix necessitated a sequence of computations to ensure accurate results. Initially, the matrix was normalized through the division of each element within a column by the sum of that respective column. Subsequently, the column-wise average of the normalized matrix was calculated to obtain the priority vector, which represents the relative significance of the criteria. To ensure the reliability of the results, a consistency check was performed. [13]

The process was facilitated by utilizing specialized software, such as Super Decisions, which played a crucial role in streamlining the AHP analysis [14]. Super Decisions provided a platform for data input, automated the necessary calculations, and generated the final results. The software's capabilities extended to obtaining the normalized and idealized values for each criterion, enabling insights into their respective relative importance and prioritization within the evaluated context.

The utilization of Super Decisions and the adherence to the aforementioned methodology enhanced the efficiency and accuracy of the AHP analysis, contributing to a robust framework for decision-making and criterion evaluation within the given research context.

The Priority Evaluation and Consistency value

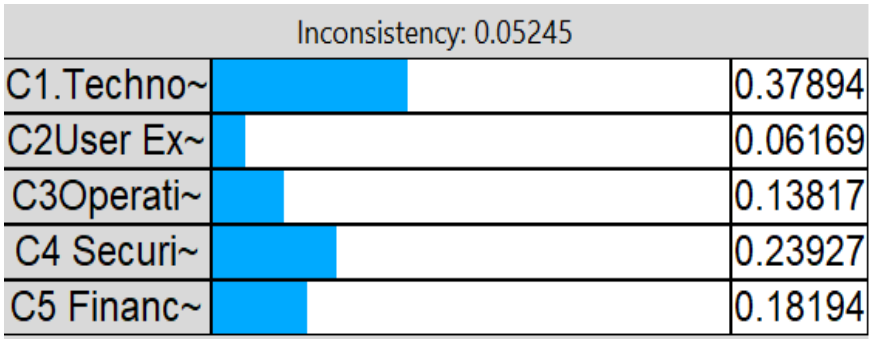


Figure 9: Comparisons in "Criteria" cluster result

Comparisons within the "Criteria" cluster were conducted, and the results are illustrated in Figure 9 [Figure9]. The analysis yielded an inconsistency measure of 0.05245, indicating a reasonably consistent set of judgments. This suggests that the pairwise comparisons made during the Analytic Hierarchy Process (AHP) analysis were coherent.

The interpretation of the criteria comparisons within the cluster is as follows:

C1 - Technological Feasibility: This criterion holds a normalized value of 0.37894, indicating a moderate level of importance. It attains the highest idealized value of 1.00000, signifying its top-ranking position among the evaluated criteria.

C2 - User Experience: With a normalized value of 0.06169, this criterion demonstrates relatively less significance compared to the others. Its idealized value of 0.16280 reflects a lower prioritization within the analyzed context.

C3 - Operational Efficiency: This criterion possesses a normalized value of 0.13817, suggesting a moderate level of importance. It achieves an idealized value of 0.36462.

C4 - Security and Safety: Having a normalized value of 0.23927, this criterion carries notable importance. Its idealized value of 0.63142 indicates a relatively high rank among the evaluated criteria.

C5 - Financial Viability: With a normalized value of 0.18194, this criterion showcases a moderate level of importance. It obtains an idealized value of 0.48013.

These results offer insights into the relative importance and prioritization of each criterion within the analyzed context. Technological Feasibility (C1) emerges as the most crucial criterion, followed by Security and Safety (C4) and Operational Efficiency (C3). User Experience (C2) and Financial Viability (C5) hold relatively lower levels of importance in comparison.

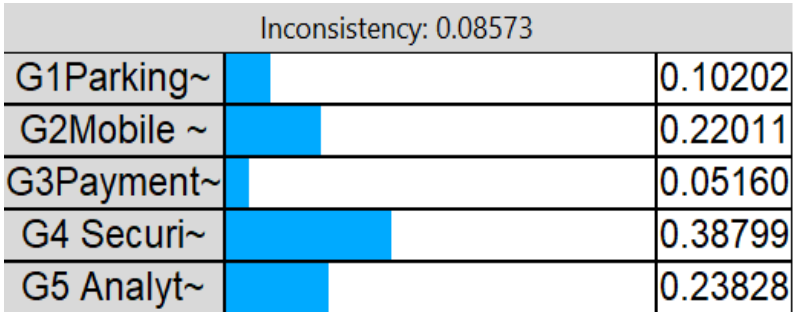


Figure 10: Comparisons in the "C1" node result

The comparisons within the "C1. Technological Feasibility" node are presented in Figure 10. The analysis yielded an inconsistency measure of 0.08573, indicating a reasonably consistent set of judgments. This suggests that the pairwise comparisons made during the Analytic Hierarchy Process (AHP) analysis were coherent.

The interpretation of the comparisons within the "C1. Technological Feasibility" node is as follows: G1 - Parking Availability and Information: This criterion has a normalized value of 0.10202, indicating a relatively lower level of importance. In terms of prioritization, it holds an idealized value of 0.26296.

G2 - Mobile Application and Reservation: With a normalized value of 0.22011, this criterion demonstrates a moderate level of importance. Its idealized value is 0.56732.

G3 - Payment and Transaction: This criterion possesses a normalized value of 0.05160, suggesting a relatively lower level of importance. It achieves an idealized value of 0.13299.

G4 - Security and Safety: Having a normalized value of 0.38799, this criterion carries a notable level of importance. Its idealized value of 1.00000 indicates its highest rank among the evaluated criteria.

G5 - Analytics and Reporting: With a normalized value of 0.23828, this criterion showcases a moderate level of importance. It obtains an idealized value of 0.61415.

These results offer insights into the relative importance and prioritization of each criterion within the "C1. Technological Feasibility" node. Security and Safety (G4) is considered the most important criterion, followed by Mobile Application and Reservation (G2) and Analytics and Reporting (G5). Parking Availability and Information (G1) and Payment and Transaction (G3) hold relatively lower levels of importance in comparison.

Inconsistency: 0.08474	
G1Parking~	0.05317
G2Mobile ~	0.18196
G3Payment~	0.12349
G4 Securi~	0.35869
G5 Analyt~	0.28269

Figure 11: Comparisons in the "C2" node result

Inconsistency: 0.07690	
G1Parking~	0.05366
G2Mobile ~	0.18981
G3Payment~	0.12089
G4 Securi~	0.21255
G5 Analyt~	0.42308

Figure 12: Comparisons in the "C3" node result

Inconsistency: 0.09879	
G1Parking~	0.04864
G2Mobile ~	0.19034
G3Payment~	0.12868
G4 Securi~	0.32553
G5 Analyt~	0.30681

Figure 13: Comparisons in the "C4" node result

Inconsistency: 0.04183	
G1Parking~	0.04886
G2Mobile ~	0.11953
G3Payment~	0.39330
G4 Securi~	0.16741
G5 Analyt~	0.27090

Figure 14: Comparisons in the "C5" node result

Comparisons within the "C2. User Experience" Node [Figure11]

The comparisons conducted within the "C2. User Experience" node indicate that Security and Safety (G4) is the most important criterion, followed by Mobile Application and Reservation (G2) and Analytics and Reporting (G5) in terms of priority. Parking Availability and Information (G1) and Payment and Transaction (G3) hold relatively lower levels of importance compared to the other criteria.

Comparisons within the "C3. Operational Efficiency" Node [Figure12]

Based on the comparisons made within the "C3. Operational Efficiency" node, Analytics and Reporting (G5) emerges as the most important criterion. It is followed by Mobile Application and Reservation (G2), Security and Safety (G4), Payment and Transaction (G3), and Parking Availability and Information (G1) in terms of priority.

Comparisons within the "C4. Security and Safety" Node [Figure13]

Considering the comparisons within the "C4. Security and Safety" node, Mobile Application and Reservation (G2) holds the highest importance. It is followed by Analytics and Reporting (G5), Payment and Transaction (G3), Security and Safety (G4), and Parking Availability and Information (G1) in terms of priority.

Comparisons within the "C5. Financial Viability" Node [Figure14]

Referring to the comparisons made within the "C5. Financial Viability" node, Payment and Transaction (G3) emerges as the most important criterion. It is followed by Analytics and Reporting (G5), Security and Safety (G4), Mobile Application and Reservation (G2), and Parking Availability and Information (G1) in terms of priority.

Priority Analysis of Group Functions in Smart Parking System

Name	Graphic	Ideals	Normals	Raw
G1Parking Availability and Information		0.226773	0.064460	0.034450
G2Mobile Application and Reservation		0.599680	0.170457	0.091101
G3Payment and Transaction		0.738536	0.209927	0.112195
G4 Security and Safety		0.953079	0.270910	0.144788
G5 Analytics and Reporting		1.000000	0.284247	0.151916

Figure 15: Priority Analysis of Group Function in Smart Parking System

The analysis of the Smart Parking System group functions' priorities, as depicted in Figure 15 [Figure15], reveals valuable insights into the relative importance and prioritization of each criterion. The table includes the ideal values, normalized values, and raw values for each criterion, enabling a comprehensive understanding of their significance.

The "Ideals" column showcases the ideal values associated with each criterion, reflecting the most desirable outcomes that could be achieved. Notably, the criterion "Analytics and Reporting" (G5) stands out with the highest ideal value of 1.000000, emphasizing its utmost importance. Additionally, "Security and Safety" (G4) follows closely with an ideal value of 0.953079. Conversely, the remaining criteria, namely "Payment and Transaction" (G3), "Mobile Application and Reservation" (G2), and "Parking Availability and Information" (G1), exhibit progressively lower ideal values, indicating comparatively lesser significance.

The "Normals" column presents the normalized values obtained through the Analytic Hierarchy Process (AHP) analysis, which provides a measure of the relative importance of each criterion in relation to the others. Higher normalized values signify greater importance. Consequently, the criterion "Analytics and Reporting" (G5) retains its top priority, as evidenced by its normalized value of 0.284247. "Security and Safety" (G4) also maintains a significant position with a normalized value of 0.270910. Conversely, "Parking Availability and Information" (G1), "Mobile Application and Reservation" (G2), and "Payment and Transaction" (G3) exhibit progressively lower normalized values, indicating their relatively lower levels of importance within the context.

The "Raw" column represents the raw values assigned to each criterion during the AHP analysis, serving as the foundation for calculating the normalized values. These raw values facilitate a quantitative basis for comparison and decision-making processes

Overall, from an engineering or specialist perspective, the AHP analysis of group function priorities in the Smart Parking System highlights the critical significance of "Analytics and Reporting" (G5) and "Security and Safety" (G4). These findings provide valuable guidance for decision-makers, enabling them to prioritize actions and allocate resources effectively based on the relative importance of each criterion within the Smart Parking System context.

Smart Parking System Priority Compare and Discussion

The comparison between the stakeholder ranking and AHP analysis provides valuable insights into the prioritization and relative importance of group functions within the Smart Parking System. These results contribute to a comprehensive understanding of the key considerations for developing an effective smart parking system in Bangkok.

The stakeholder ranking results reveal that stakeholders place high importance on the Mobile Application and Reservation (G2) group, followed closely by the Payment and Transaction (G3) and Parking Availability and Information (G1) groups. This indicates that stakeholders prioritize user-friendly mobile applications, convenient payment options, and accurate parking availability information. On the other hand, the Security and Safety (G4) and Analytics and Reporting (G5) groups were ranked lower in importance, suggesting a lesser emphasis on security measures and data analytics functionalities.

In contrast, the AHP analysis conducted from an engineering perspective emphasizes the criticality of the Analytics and Reporting (G5) and Security and Safety (G4) groups. This analysis highlights the importance of leveraging data analytics for optimized parking operations and ensuring robust security and safety measures within the smart parking system. The engineering considerations prioritize the utilization of data for decision-making and the integration of security features to protect users and their vehicles.

When comparing the stakeholder ranking and AHP analysis, it is evident that there is some alignment between the two approaches. Both perspectives recognize the significance of the Mobile Application and Reservation (G2) group, indicating its importance in meeting stakeholder expectations and engineering requirements. Additionally, the Payment and Transaction (G3) group receives considerable attention in both analyses, emphasizing the need for convenient and secure payment options within the system.

To effectively proceed with the development of the smart parking system, it is recommended to integrate the insights from both perspectives and consider the following points:

Customer-Centric Design: Incorporate the priorities identified in the stakeholder ranking to ensure that the system meets user expectations and provides a seamless parking experience. Pay attention to user-friendly interfaces, convenient reservation and payment processes, and accurate availability information.

Engineering Excellence: Address the engineering considerations highlighted in the AHP analysis by emphasizing the Analytics and Reporting (G5) and Security and Safety (G4) groups. Leverage data analytics to optimize parking operations and enhance decision-making. Implement robust security measures to protect users and their vehicles within the parking facilities.

Collaborative Approach: Foster collaboration between stakeholders and engineering experts to ensure a balanced approach. Facilitate discussions and seek input from both parties to strike a harmonious balance between customer requirements and technical feasibility.

Iterative Development Process: Adopt an iterative approach that allows for continuous improvement and incorporates feedback from stakeholders and technical experts. This iterative process ensures that the smart parking system remains adaptable to evolving needs and takes advantage of technological advancements.

User Experience Optimization: Prioritize user experience design by creating intuitive interfaces, conducting usability tests, and gathering feedback from users. Continuously refine the user interface and system functionality based on user input to enhance satisfaction and usability.

Comprehensive Security Strategy: Develop a comprehensive security strategy that includes measures such as access control systems, surveillance cameras, and anti-theft mechanisms. Conduct regular security audits and stay updated on emerging security threats to ensure the system's integrity.

By considering these points and integrating the stakeholder ranking and AHP analysis insights, the Quality Function Deployment (QFD) process can be effectively applied in the next phase of development [13]. This will enable the translation of customer requirements into specific design specifications, ultimately leading to the creation of a smart parking system that meets stakeholder expectations while incorporating essential engineering functionalities.

Results of QFD

In order to effectively address the customer requirements and align them with the technical requirements, we utilized the Quality Function Deployment (QFD) methodology. The QFD analysis allows us to translate customer needs into specific engineering characteristics

and prioritize them based on their importance. This section outlines the key steps involved in the QFD process. [15][16].

Step 1: Identify Customer Requirements and Technical Requirements

Customer Requirements:

CR1: Technological Feasibility,

CR2: User Experience

CR3: Operational Efficiency

CR4: Security and Safety

CR5: Financial Viability

Technical Requirements: Table 15 presents the chosen priority functions from the stakeholder ranking survey, as mentioned in Table 7, in the form of Technical Requirement:

Table 15: Technical Requirements

TR1	Convenient parking space reservation and booking functionality
TR2	Integration of sensors or cameras for accurate data collection
TR3	User-friendly mobile application with an intuitive interface
TR4	Cashless payment options to reduce reliance on cash
TR5	Real-time parking availability updates
TR6	Secure payment processing to protect user data and privacy
TR7	Real-time updates on parking availability and reservations
TR8	Automated access control systems for restricted areas
TR9	Integration with multiple payment methods
TR10	Differentiation between on-street and off-street parking availability

These priority functions represent the key technical requirements identified by customers in the stakeholder ranking survey. Addressing these requirements will enable the development and implementation of an effective parking management system that meets stakeholder expectations.

Step 2: Determine the Importance weights

To assign appropriate importance weights to the customer requirements, customer feedback is collected through surveys. The importance weights range from 1 to 5, with 5 denoting the highest level of importance.

Customer Requirement Importance Weights:

CR1: Technological Feasibility	Weights: 4
CR2: User Experience	Weights: 5
CR3: Operational Efficiency	Weights: 4
CR4: Security and Safety	Weights: 4
CR5: Financial Viability	Weights: 3

Step 3: **Identify Correlations and Relationships**

Identify and assess the correlations and relationships between customer requirements and technical requirements. Assign ratings based on the strength of the relationship using a rating scale of 9 for strong, 3 for moderate, and 1 for weak.

The correlations and relationships between customer requirements (CR) and technical requirements (TR) are presented in Table 16.

Table 16: The correlation between CR and TR

	TR1	TR2	TR3	TR4	TR5	TR6	TR7	TR8	TR9	TR10
CR1	9	9	9	3	3	3	3	3	1	1
CR2	9	3	3	9	9	3	3	3	9	9
CR3	3	9	9	1	3	9	9	9	3	1
CR4	3	9	3	1	1	3	3	3	1	1
CR5	1	3	3	9	1	3	3	1	9	1

Step 4: Calculate the QFD Matrix

Using the importance weights and correlation values, the QFD matrix was calculated by multiplying the correlation values by the importance weights. The results are presented in Table 17.

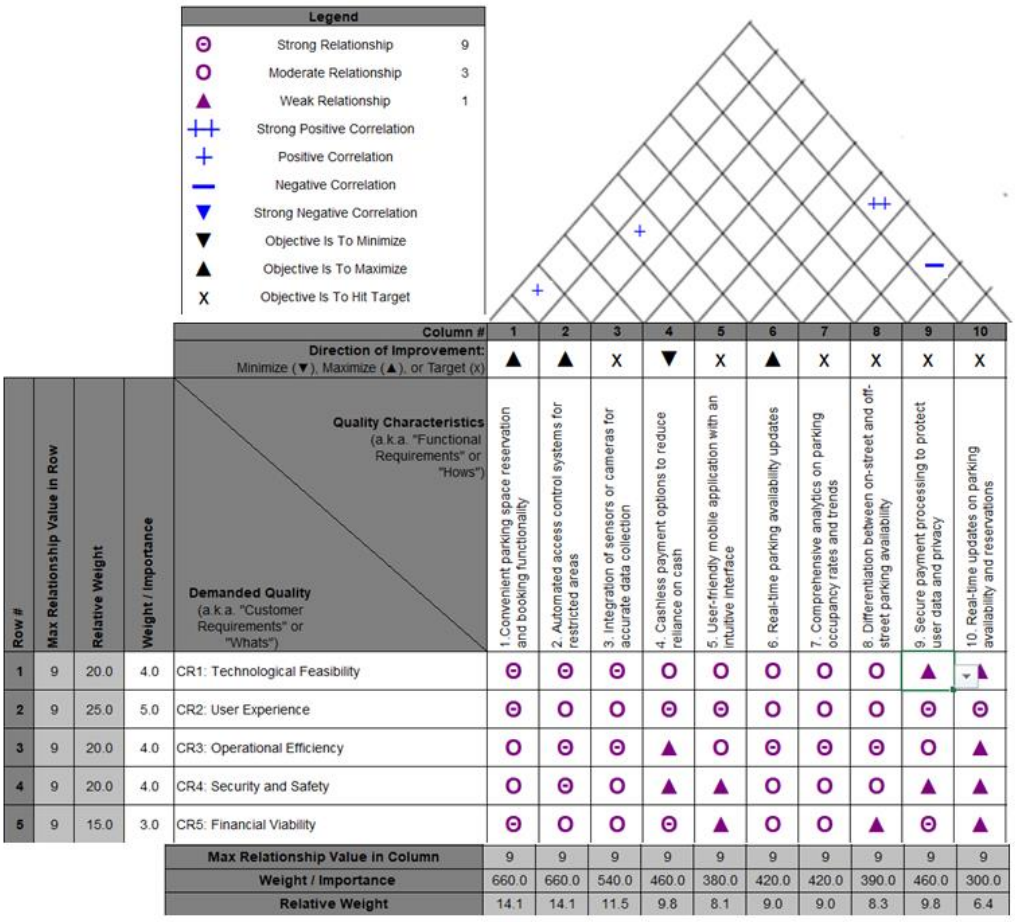
Table 17: QFD matrix

	TR1	TR2	TR3	TR4	TR5	TR6	TR7	TR8	TR9	TR10
CR1(4)	36	36	36	12	12	12	12	12	4	4
CR2(5)	45	15	15	45	45	15	15	15	45	45
CR3(4)	12	36	36	4	12	36	36	36	12	4
CR4 (4)	12	36	12	4	4	12	12	12	4	4
CR5 (3)	3	9	9	18	3	9	9	3	18	3

In the QFD matrix, each cell represents the relationship between a customer requirement (CR) and a technical requirement (TR) based on the correlation values and importance weights. The values in the matrix are obtained by multiplying the correlation value by the corresponding importance weight.

Step 5: Creation of the House of Quality (HOQ)

The House of Quality (HOQ) provides a visual representation summarizing the relationships between customer requirements and technical requirements [11][15]. It offers a structured approach to prioritizing technical requirements based on their impact on meeting customer needs. The House of Quality (HOQ) incorporates technical considerations such as maximization, minimization, and target values, as well as relative weights and importance weights [11][15][16]. It is not only a matrix but a comprehensive framework that captures the interrelationships between customer requirements and technical specifications [11][15].



Legend		
⊖	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
—	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
X	Objective Is To Hit Target	

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") \ Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	1. Convenient parking space reservation and booking functionality	2. Automated access control systems for restricted areas	3. Integration of sensors or cameras for accurate data collection	4. Cashless payment options to reduce reliance on cash	5. User-friendly mobile application with an intuitive interface	6. Real-time parking availability updates	7. Comprehensive analytics on parking occupancy rates and trends	8. Differentiation between on-street and off-street parking availability	9. Secure payment processing to protect user data and privacy	10. Real-time updates on parking availability and reservations
				Column #	1	2	3	4	5	6	7	8	9	10
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▲	▲	x	▼	x	▲	x	x	x	x
1	9	20.0	4.0	CR1: Technological Feasibility	⊖	⊖	⊖	O	O	O	O	O	▲	▲
2	9	25.0	5.0	CR2: User Experience	⊖	O	O	⊖	⊖	O	O	O	⊖	⊖
3	9	20.0	4.0	CR3: Operational Efficiency	O	⊖	⊖	▲	O	⊖	⊖	⊖	O	▲
4	9	20.0	4.0	CR4: Security and Safety	O	⊖	O	▲	▲	O	O	O	▲	▲
5	9	15.0	3.0	CR5: Financial Viability	⊖	O	O	⊖	▲	O	O	▲	⊖	▲
				Max Relationship Value in Column	9	9	9	9	9	9	9	9	9	9
				Weight / Importance	660.0	660.0	540.0	460.0	380.0	420.0	420.0	390.0	460.0	300.0
				Relative Weight	14.1	14.1	11.5	9.8	8.1	9.0	9.0	8.3	9.8	6.4

Figure16: House of Quality For Smart parking system for Bangkok, Thailand.

Decision Making Strategy

The decision-making strategy outlined in this section leverages the House of Quality (HOQ), represented in Figure 16, to guide the prioritization of technical requirements (TRs) in the development of a parking management system. The objective of this strategy is to align technical requirements with customer requirements (CRs) effectively, optimizing the system's performance across various dimensions.

Maximizing Customer Satisfaction

The HOQ analysis reveals that among the technical requirements (TR1 to TR10), TR1, TR2, and TR3 exhibit stronger correlations with customer requirements CR1 to CR5 compared to other TRs. To achieve the goal of "Maximizing Customer Satisfaction," decision-makers should focus their attention on technical requirements that demonstrate high correlation values and importance weights. These requirements establish robust connections with customer needs and should take precedence in the development process. Prioritizing TR1, TR2, and TR3 can enhance customer satisfaction and elevate the overall customer experience.

Enhancing User Experience

For those aiming to "Enhance User Experience" (particularly aligning with CR2 in the HOQ), special emphasis should be placed on technical requirements that directly contribute to improving user interactions. Priority should be given to TR1, TR4, TR5, TR9, and TR10. However, when considering the engineering perspective, TR4 is the technical requirement that should be minimized, and TR9 and TR10 have already met their targets. Consequently, TR1 emerges as the optimal technical requirement for decision-making focus. Concentrating efforts on TR1 can streamline the reservation process and provide user-friendly interfaces, ensuring a seamless and convenient experience for users.

Optimizing Operational Efficiency and Security

In pursuit of "Optimizing Operational Efficiency and Security" (aligning with CR3 and CR4), technical requirements that enhance operational efficiency and security must be addressed. Prioritizing TR2, which exhibits strong relationships with both CR3 and CR4, is essential to enable efficient parking management and enhance security measures.

Consideration of Financial Viability

For decision-makers looking to address "Financial Viability" (associated with CR5), appropriate resources should be allocated to technical requirements that ensure financial sustainability. Emphasizing TR1, TR4, and TR9 is recommended. Furthermore, from an engineering standpoint, TR4 should be minimized, while TR9 has already reached its target. Therefore, TR1 stands out as the most suitable technical requirement for decision-making.

Managing Negative and Positive Relationships

It is crucial to consider relationships between technical requirements. In some instances, negative correlations may exist, as seen in the HOQ's upper section, where TR8 and TR10 have a negative correlation. Improving TR10 should be done cautiously, as it may lead to a reduction in TR8. Conversely, TR6 exhibits a strong positive relationship with TR10, meaning that improving TR6 will also support TR10.

Embrace Continuous Improvement

Recognize that the Quality Function Deployment (QFD) process is iterative and dynamic. Regularly review and update the QFD analysis to stay aligned with evolving customer needs, emerging technologies, and market trends. Monitor customer feedback and technological advancements to identify areas for improvement and innovation. Continuously strive to enhance the parking management system to meet and exceed customer expectations.

Conclusion

To sum it all up, our journey through this research has culminated in a thoughtful decision-making strategy, one that's not just a product of thorough analysis but a blueprint for crafting a truly exceptional parking management system. Drawing wisdom from our meticulous exploration of the House of Quality (HOQ) depicted in Figure 16, we've unveiled a systematic path for prioritizing the technical requirements (TRs) that underpin this cutting-edge system. What's truly powerful about this strategy is its ability to seamlessly blend these TRs with the specific desires of our customers (CRs), resulting in a system that excels in key dimensions.

Our findings have illuminated the undeniable importance of certain TRs:

TR1 - Convenient parking space reservation and booking functionality

TR2 - Integration of sensors or cameras for accurate data collection

TR3 - User-friendly mobile application with an intuitive interface

These TRs aren't just requirements; they're the lifeblood of "Maximizing Customer Satisfaction." Elevating these TRs to the forefront cements strong bonds with customer needs and, in turn, elevates the overall customer experience.

But our journey doesn't end there. For those on a mission to "Enhance User Experience," there's more to be done. Alongside TR1, let's shine a spotlight on TR4 - Cashless payment options to reduce reliance on cash, TR5 - Real-time parking availability updates, TR9 - Integration with multiple payment methods, and TR10 - Differentiation between on-street and off-street parking availability. With TR1 as our engineering cornerstone, these TRs streamline processes and promise a user-friendly interface, culminating in a parking experience that's both seamless and convenient.

For those looking to "Optimize Operational Efficiency and Security," look no further than TR2 - Integration of sensors or cameras for accurate data collection, especially given its robust ties to CR3 and CR4. This approach is the key to boosting parking management efficiency and fortifying security measures.

Now, when it comes to "Financial Viability," here's the deal: allocate your resources wisely, with a spotlight on TR1, TR4, and TR9. TR1, in particular, is the unsung hero here, though don't forget to minimize TR4, and keep in mind that TR9 has already hit the mark.

And let's not forget the intricacies of the relationships between these TRs. Whether it's the delicate dance between TR8 - Automated access control systems for restricted areas and TR10 - Differentiation between on-street and off-street parking availability, or the symbiotic relationship between TR6 - Secure payment processing to protect user data and privacy and TR10, understanding these dynamics is critical for making informed improvements.

Lastly, our strategy extols the virtues of continuous improvement. The world doesn't stand still, and neither should our system. Keep the Quality Function Deployment (QFD) process in your toolbox, and use it to adapt, evolve, and stay in tune with changing customer expectations and emerging tech.

In closing, this strategy is your compass, your guiding star. With it, you're not just crafting a parking management system; you're sculpting an experience that's customer-

centric, efficient, secure, and future-proof. So, let's embark on this journey, not just in Bangkok, Thailand but beyond, creating parking solutions that redefine convenience and elevate satisfaction.

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The use of Statistics to Compare the Co-operative Education Students Abilities of Rajabhat Rajanagarindra University

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Abstract

This research aimed to determine the Use statistics to compare the abilities of co-operative education students. From the sample group of 60 people, Rajabhat Rajanagarindra University. The tools used were questionnaires in terms of characteristics of students, educational institutions, and enterprises. The results showed that the factors affecting the ability to practice cooperative education of students and institutions were different significantly at the 0.01 level and the characteristics factors of educational institutions and different establishments significantly at the 0.05 level. The ability to practice co-operative education in the field of Industrial Management Engineering is different from the field of Electrical Engineering and the field of Automotive Mechanical Engineering. Significantly at the 0.05 level in the field of Electrical engineering towards the fields of Automotive Mechanical Engineering are different significantly at the 0.05 level.

Keywords: Statistics, Cooperative, Students, Educational Institutes

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