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An economic assessment of the information system for the surveillance of liver fluke and cholangiocarcinoma of the Fluke Free Thailand Project (Isan cohort)

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Abstract

This study aimed to assess the economic impact of the information system for the surveillance of liver fluke and cholangiocarcinoma of the Fluke Free Thailand Project (Isan cohort) implemented by Khon Kaen University with an allied network. The economic benefit of the Isan cohort was estimated using willingness to pay (WTP), obtained from the contingent valuation method (CVM). WTP was estimated using a Tobit model and maximum likelihood method. Future benefits were forecasted via a triple exponential smoothing method. Investment worthiness was also analyzed using a cost-benefit analysis covering a 10-year investment period, fiscal years 2017-2026, with four financial measures. The estimated result of the users' WTP for accessing the Isan cohort was 54.64 Baht per access. The average value of the benefits was 27.2 million Baht per year. The payback period (PBP) of the project was within 0.94 years. This project was commercially worthwhile as the net present value was 1.53 million Baht (NPV > 0), the benefit-cost ratio was 6.92 (BCR > 1), and the internal rate of return (IRR) was 110.66% higher than the discount rate (8.00%). The Isan cohort project, therefore, should be invested in further. However, investment, operation, and maintenance of the project are high costs that should be supported by the Thai government, as the benefits of the project would provide an economic and social impact on the entire country. Conversely, the project would not be feasible if users utilized the software less than 50,669 times a year.

Keywords: Big data, Cost-benefit analysis, Impact assessment, Investment worthiness, Willingness to pay

1. Introduction

Thailand currently contains the greatest number of patients with cholangiocarcinoma (CCA) in the world. The Northeast (Isan) region is the area with the highest density of patients [1] with a rate of up to 96 per 100,000 men and 38 per 100,000 women [2]. The Cholangiocarcinoma Screening and Care Program (CASCAP) under the Faculty of Medicine, Khon Kaen University is aware of this problem and the severity of the impact. Therefore, the program cooperated with the allied network for the implementation of the Thailand Grand Challenges: Fluke Free Thailand Project, supported by the National Research Council of Thailand (NRCT) to control and eliminate liver fluke and CCA in Thailand. Through the use of a holistic approach covering primary, secondary, and tertiary prevention; the Fluke Free Thailand Project is a large integrated project consisting of 11 interrelated research projects under Khon Kaen University with expert researchers from several faculties. Encompassing the Faculty of Medicine, Faculty of Public Health, Faculty of Veterinary Medicine, Faculty of Agriculture, Faculty of Education, and the Faculty of Humanities and Social Sciences; research implementation has required the cooperation of several agencies; such as the Ministry of Public Health, Ministry of Education, Ministry of Agriculture and Cooperatives, and the Ministry of the Interior.

The implementation of the project requires data collection and analysis from several stakeholders through the use of a prospective cohort study [3] consisting of data collection, data analysis, long-term follow-up, and 'big data' management. Therefore, to achieve efficient data management of the Fluke Free Thailand Project, the information system, called “Isan cohort” (previously referred to as CASCAP Tools) [4], was developed to integrate and link the data of all minor research projects; namely, risk population registration, data recording, monitoring, evaluating, and reporting to the Ministry of Public Health of Thailand and the general public. This was implemented under a minor project called the “Information System for the Surveillance of Liver Fluke and Cholangiocarcinoma in Northeastern Thailand: Isan cohort” administered by researchers from the Faculty of Public Health, Khon Kaen University, Khon Kaen, Thailand. The Isan cohort represents the first and sole source of information of liver fluke and CCA in the world, which system administrators and users can utilize on the internet in real time [5]. Currently, the Isan cohort represents a key type of software used by a number of stakeholders of the Ministry of Public Health; including Don Mot Daeng Hospital, Ubon Ratchathani province [6], and Chun Hospital, Phayao province [7]. A minor system, for example, in the Isan cohort for CCA risk screening called the teleconsultation ultrasonography [8] was initiated by the registration of the risk groups from district health promotion hospitals. Ultrasound images were provided for such groups, then sent to a cloud server. Diagnostic results were verified and confirmed by an expert radiologist through the Isan cohort at each step. The system reduced the shortage of radiologists, documentation procedures, and travel costs of patients for radiological examinations.

The aforementioned data indicate the usefulness of the Isan cohort in the development of the Thai public health system. The project, however, had high implementation costs. Therefore, an assessment of its economic impact, particularly an estimation of investment worthiness, would be required for decision-making policymakers to manage the limited R&D budget for the highest benefits. In the field of economics, there are four key tools for estimating investment worthiness; cost-minimization analysis (CMA), cost-effectiveness analysis (CEA), cost-utility analysis (CUA), and cost-benefit analysis (CBA) [9]. Each method, while similar in cost estimation, differs in benefits measurement. The CMA concept is suitable for the evaluation of non-profit projects, as their results, measured simply, focus only on cost estimation, in which only the lowest cost projects should be implemented. However, this method assumes that each project will generate equal economic benefits. CEA, in turn, assumes that each project has equal costs, and selects the project with the highest efficiency. CUA measures the qualitative opinion of each individual with different standards, which may be difficult to interpret; for example, satisfaction levels and quality of life. In contrast, CBA can estimate the monetary costs and returns, allowing each project to be compared without any assumptions at all. However, despite the apparent usefulness of CBA in the administration of policy regulations, very few users utilize this method for evaluating public health projects [10]. This may be due to the difficulty involved in surveying the monetary benefits of service users, which can be both expensive and time-consuming [11]. Because most public health services within the government sector offer free (or low-cost) services, the Isan cohort software may be unable to directly estimate the true monetary economic benefits.

Therefore, our research, herein, incorporates CBA, as well as the Isan cohort based on the concept of the willingness to pay (WTP) to determine their respective economic impacts. In economics, WTP has been widely used to measure the monetary benefits of consumers [12-15], yet remains limited in the estimation of a project’s worthiness for information systems in public health services in Thailand. A single research effort utilizing CBA was conducted in 2002 by the National Electronics and Computer Technology Center (NECTEC) of Thailand [16], which evaluated the return of an R&D information system within the Outpatient Department (OPD), Nopparat Rajathanee Hospital, under the Ministry of Public Health. The results revealed that the information system created user benefits amounting to 40.89 million Baht, with a cost of 9.45 million Baht. However, their assessment was based on a completed project and did not forecast future costs or benefits. To date, there exists no research on the assessment of the economic impacts of the Isan cohort. Our research, therefore, evaluated and forecasted the economic impacts of the Isan cohort in which to assist in the decision-making support of policymakers, future budget allocation guidelines, and investment worthiness of public health and medical information systems.

2. Materials and methods

We intend to assess the economic impacts of the Isan cohort project for over ten years (fiscal years 2017-2026). We implemented the Fluke-Free Thailand Project beginning with the fiscal year 2017 (Oct 1, 2016, to Sep 30, 2017) and continued through the fiscal year 2018 (Oct 1, 2017, to Sep 30, 2018). We intend to forecast the anticipated net benefits via the software system through the fiscal year 2026.

2.1 Data collection

Cost data of the Isan cohort project were collected from annual expenses of the “Information System for the Surveillance of Liver Fluke and Cholangiocarcinoma in Northeastern Thailand: Isan cohort” research project, which was a minor project within the Fluke-Free Thailand Project. Benefit data focusing on WTP were collected from both the users of the Isan cohort software, consisting of public health officers of both government and private sectors joining the Fluke-Free Thailand Project; and general users who were interested in utilizing the software. The population, which determined the sample size for the first fiscal year, consisted of 4, 151 participants. The sample size, with 95% reliability [17], consisted of 365 cases. The instrument for data collection was an online questionnaire conducted over two months, from Nov 6, 2018, to Jan 6, 2019.

To avoid the low response rate of an online survey, we e-mailed the questionnaire (non-randomly) to all users/participants of the Isan cohort software in the fiscal year 2017 to 2018 and received responses from 398 respondents (a response rate of 9.59%). All questionnaires were useable (a useable rate of 100%), which was larger than the calculated sample size.

2.2 Data analyses

For the assessment of the economic impact of R&D within the Isan cohort software system, project life was set at 10 years. Data analyses were divided into three steps: the first step estimated the software's benefits from the WTP; the second step anticipated future expected costs and benefits forecasted through prediction methods, and the last step evaluated the project's economical worthiness via CBA.

2.2.1 The evaluation of the software's benefits

The benefits evaluation of the Isan cohort employed the estimation of the WTP from the software users. The CVM was used to create a survey questionnaire, as was appropriate for estimating the benefits by measuring the WTP from the project or policy [18]. The survey questions of the WTP were set as open-ended questions, to provide an opportunity for the software users to unconditionally demonstrate their maximum WTP. Because the mean of the WTP was given as a value of attitude, they could not be immediately added to the value of the benefits. As a consequence, an open-ended CVM format was tested for the reliability of statistical properties using the WTP function with an econometric method. In this study, the statistical significance of the factors affecting WTP was tested using a multiple regression model.

According to the WTP of the 398 participants, the user's minimum WTP on the Isan cohort was 0 Baht per use, with a maximum WTP of 3,000 Baht, and a mean WTP of 51.16 Baht per use. When the users were divided into groups based on their WTP level (Table 1), we found 39.2% unwilling to pay, as they felt that the Isan cohort software service, as a public service, should be free of charge. A much smaller percentage of users (3.52%) were willing to pay 500 Baht or more per use.

Table 1 Willingness to pay (WTP) of the Isan cohort users.

WTP (Baht per time)	Isan cohort users	
	Frequency	Percentage (%)
0	156	39.20
1 - 9	90	22.61
10 - 19	44	11.06
20 - 49	37	9.30
50 - 99	25	6.28
100 - 499	32	8.04
500 and over	14	3.52
Total	398	100

Because the values of the user's WTP, a dependent variable in this research, were zero in many cases (156 out of a total of 398 observations), the ordinary least squares (OLS) estimation would have included numerous biases and inconsistencies. Tobit or the censored regression models [19] were used frequently as alternative methods. WTP data observed in this study contained zero and continuous values, with occurrences of data censoring. However, WTP data collected directly from the users of the Isan cohort software further demonstrated the direct value of the software. Respondent's zero WTP reflected a real or genuine zero. The Tobit model has often been employed as an alternative method for use with censored data in literature on contingent valuation methods in health economics [20], and is deemed appropriate when an *all-zero* realization represents an economic decision; for example, a *real zero* preference for a health care program under evaluation [21].

Therefore, this study employed the Tobit model for estimating WTP. LIMDEP econometric software was used for processing data, utilizing the maximum likelihood estimation (MLE), displayed in Equation 1.

$$WTP_i^* = \beta_0 + \sum_{j=1}^{n} \beta_j X_{ji} + \varepsilon_i \,, \qquad (1)$$
$$WTP_i = 0 \text{ if } WTP_i^* \leq 0,$$
$$WTP_i = WTP_i^* \text{ if } WTP_i^* > 0.$$

Where, for the i software user (i = 1, 2, 3, …, 398): WTP_i is the value of the user's WTP on the Isan cohort; β_0 is the constant; X_{ji} are the independent variables (j = 1, 2, 3,..., 14), demonstrated in Table 2; β_j are the coefficients of the independent variables (X_{ji}), and ε_i is the error term.

Table 2 Descriptions of the variables used in the users' WTP equation.

Variable	Parameter	Description
WTP	-	Willingness to pay for using the software (per time, Baht).
Gender	β_1	1 = Male, 0 = Female.
Age	β_2	Age of software users (years).
Workplace 1	β_3	1 = Primary care unit, e.g., district health promotion hospitals. 0 = Secondary care unit or tertiary care unit.
Workplace 2	β_4	1 = Medical care agencies, e.g., hospitals, district health promotion hospitals, and community-public health centers. 0 = Public health administrative agencies, i.e., provincial public health offices, district health offices, disease control offices, and universities.
Position 1	β_5	1 = Job positions related to medical care, i.e., physicians and nurses, 0 = Others.
Position 2	β_6	1 = Executives/board, i.e., hospital directors, hospital specialized directors, hospital deputy-directors, nursing deputy-directors, and chiefs of public health centers, 0 = Others.
Position 3	β_7	1 = Job positions related to medical care support, i.e., statistics, administrative affairs, accounting, finance, computer, researchers, typists, public health academicians, 0 = Others.
Objective 1	β_8	1 = Use Isan cohort for data completion and records, 0 = Others.
Objective 2	β_9	1 = Use Isan cohort for verification and follow-up, 0 = Others.
Objective 3	β_{10}	1 = For using the overall data obtained from the data processing by the software system, 0 = Others.
Objective 4	β_{11}	1 = For verification and follow-up, and for using the overall data obtained from the data processing by the software system, 0 = Others.
Problem 1	β_{12}	Problems caused by the software, e.g., how to use, stability, processing speed (Score: 1 = smallest, 2 = small, 3 = moderate, 4 = high, and 5 = highest).
Problem 2	β_{13}	Problems of the quality of the data, e.g., correctness, reliability, utilization, and novelty (Same scoring criteria as Problem 1).
Problem 3	β_{14}	Problems caused by the management of software administrators, e.g., unable to contact the administrators and the administrators cannot solve problems (Same scoring criteria as Problem 1).

The expected mean value of the WTP was calculated as per Equation 2 [22-24].

$$E(WTP) = \Phi\left(\frac{\beta\bar{X}}{\sigma}\right)(\beta\bar{X} + \sigma\lambda)$$
$$\lambda = \frac{\emptyset(\frac{\beta\bar{X}}{\sigma})}{\Phi(\frac{\beta\bar{X}}{\sigma})} \qquad (2)$$

Where, $E(WTP)$ is the expected mean value of the WTP (Baht), $\Phi(\cdot)$ is the standard normal cumulative distribution function (CDF), $\emptyset(\cdot)$ is the standard normal probability density function (pdf.), β is the coefficient vector of the independent variables, $\bar{X}$ is the mean values of the vector of the independent variables, and σ is the standard error of the error term.

2.2.2 Forecasting the future investment worthiness of the software

Forecasting the future expected benefits of the Isan cohort was the next step in estimating the monetary benefits of the software. Data of the monetary benefits during the fiscal years 2017-2018 was used as the database to forecast the expected benefits for the next eight years (2019-2026) by utilizing a time series forecasting model. This study used a triple exponential smoothing method, or Holt-Winters method, developed by Holt [25] and Winters [26] in the form of an additive seasonal model. This was undertaken because when comparing the results forecasted by different methods, it was found that the results obtained from this method included the smallest error in which the mean absolute percentage error (MAPE) of the model was minimal. The additive seasonal model used in this research is displayed in Equation 3 [27].

$$F_{t+m} = L_t + b_t m + S_{t-s+m} \quad (3)$$

Where,

F_t = Time forecasting (t).
L_t = Component of the data level [= $\alpha(Y + S_{t-s}) + (1-\alpha)(L_{t-1} + b_{t-1})$].
b_t = Component of the trend [= $\gamma(L_t - L_{t-1}) + (1-\gamma)b_{t-1}$].
S_t = Component of seasonality [= $\delta(Y_t - L_t) + (1-\delta)S_{t-s}$].
α = Smoothing constant between the data and forecasting value, $0 \leq \alpha \leq 1$.
γ = Smoothing constant between the actual trend and estimated trend, $0 \leq \gamma \leq 1$.
δ = Smoothing constant between the actual season and estimated season, $0 \leq \delta \leq 1$.
s = Seasons in one year (based on monthly data, s = 12).
m = Future forecasting period (m = 96; to forecast the upcoming data in the next 96 months).

Our research used MAPE based on the interpretation of Lewis [28] to forecast and measure accuracy. To clarify: MAPE < 10% implied high forecasting accuracy; MAPE = 10-20% implied good forecasting; MAPE = 20-50% implied fair forecasting, and MAPE > 50% implied no forecasting accuracy.

The estimations of the future costs of the project were calculated by increasing the yearly values according to the average growth of the Thai inflation rates over the past 10 years (2007-2016). This was calculated by finding β from the equation, $Y = \alpha e^{\beta t}$, where Y is the inflation rate, α is the constant, β is the average yearly growth rate, and t is time (t = 1, 2, ...,10). The average projected growth rate was estimated at 1.70% per year.

2.2.3 Investment worthiness analysis

The final step of data analysis was to estimate the worthiness of the investment in the software system by conducting a CBA based on decision-making criteria and the consideration of the future monetary value. As such, four financial measures were calculated: payback period (PBP); net present value (NPV); benefit-cost ratio (BCR); and internal rate of return (IRR).

The payback period (PBP) was the criteria used to determine the number of years that the perceived return would be worth the fund's initial investment. This method proved easy to calculate and decide upon, as policymakers would consider projects with short PBPs due to their lower risk. Additionally, funds repaid could be utilized for future investment in other projects. The formula for calculating the PBP is shown in Equation 4.

$$PBP = \frac{Initial\ Investment}{Net\ Benefit\ per\ year} \quad (4)$$

The net present value (NPV) represents the difference between the present values of the total benefits of the project subtracted by the present value of the project's total cost. The decision to invest in a project utilizing NPV was based upon three projected outcomes: an NPV > 0 indicates investment worthiness, as the benefits obtained from the project are greater than its expenses; an NPV < 0 indicates investment unworthiness, as the benefits obtained from the project are lower than its expenses; however, if the NPV = 0, this indicates a break-even point, at which the project's benefits are thought to be equal to the expenses. In the present study, the NPV was calculated through Equation 5; in which B_t = project benefits in year t, C_t = project expenses in year t, and r = the discount rate. The discount rate for government project investment in Thailand [29] was estimated the rate of 8.00%**.** t = the project period (1, 2, … , n), and n = the project life (n = 10).

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t} \quad (5)$$

The benefit-cost ratio (BCR) determines the ratio between the present value of the return and the present value of all expenses throughout the life of the project. Again, the investment's decision-making principle through BCR was based on three possible results. If the BCR > 1, the sum of the present return is higher than the sum of the present value of its expenses; thus, this project should be invested in. If the BCR < 1, the sum of the present return is lower than the sum of the present value of its expenses; consequently, this project should not be invested in. However, if the BCR = 1, the sum of the present return is equal to the sum of the present value of its expenses. The formula for calculating the BCR is given in Equation 6.

$$BCR = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}} \quad (6)$$

The IRR is the internal rate of return from the investment fund that would generate benefits worth the invested expenses. The return obtained is expressed as a percentage, where the discount rate would be calculated to make the NPV = 0. The decision to invest is based on a comparison of the IRR with the discount rate or market interest rate (*r*). If the IRR > *r*, this indicates a higher rate of return than the discount rate; thus, the project is worth investing in. If the IRR < *r*, the project's rate of return is lower than the discount rate, indicating that it is not worth investing in. However, if the IRR = r, equal rates of return and discount rate would not provide a definitive course of action. The formula for calculating the IRR is given in Equation 7.

$$NPV = 0 = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+IRR)^t} \quad (7)$$

3. Results and discussion

3. 1 The evaluation of benefits and costs for the fiscal years 2017-2018

3.1.1 Estimation of software benefits

The Tobit model estimation tested the problem of multicollinearity through the use of correlation coefficients. Our results presented correlation coefficients of all 14 independent variables below 0.80, which indicated no multicollinearity problems within the model, as displayed in Table 3. When considering the factors influencing the users' WTP in year *t*, we found that the positions of physicians and nurses (position 1) were negatively related to WTP, with a statistical significance of 0.10. This may indicate that physicians or nurses, as system users, were less willing to pay for the system than users in other positions; based on such factors as their excessive workloads and major medical care responsibilities.

Job positions related to medical care support (position 3) were positively related to WTP, with a statistical significance of 0.10; indicating a greater willingness to pay, as the software could efficiently reduce documentation and managerial functions, which were their direct responsibility.

As for problems caused by the management of software administrators (problem 3), a negative relationship existed with WTP, with a statistical significance of 0.05; indicating that problems caused by the management of software administrators were affected by the reduction in the users' WTP. Medical care respondents greater than 40 years of age were found to be more likely to have problems caused by the management of software administrators. To increase the WTP, we suggest that software administrators provide additional training with this user group, as well as provide immediate assistance when necessary.

Other independent variables; such as gender, Workplace 1, Workplace 2, Position 2, Objective 1, Objective 2, Objective 3, Objective 4, Problem 1, and Problem 2 had no significant relationship with WTP.

Table 3 The results of the Tobit model coefficient estimation.

Variable	Coefficient	Std. error	T-ratio	*P*-value	Mean of X
Constant	60.4973	111.772193	0.541	0.5883	
Gender	-22.8776	35.4466012	-0.645	0.5187	0.3542714
Age	0.00105	0.13476058	0.008	0.9938	25.153266
Workplace 1	50.0757	68.3092383	0.733	0.4635	0.8718593
Workplace 2	-24.145	90.9607009	-0.265	0.7907	0.0678392
Position 1	-71.9942*	38.9278522	-1.849	0.0644	0.2763819
Position 2	-90.6344	86.2543824	-1.051	0.2934	0.0376884
Position 3	139.401*	73.3587573	1.900	0.0574	0.0502513
Objective 1	-51.0102	74.8307618	-0.682	0.4954	0.9472362
Objective 2	14.2503	36.8595927	0.387	0.6990	0.6256281
Objective 3	15.884	35.2139769	0.451	0.6519	0.4949749
Objective 4	15.7897	38.8498307	0.406	0.6844	0.3015075
Problem 1	2.22837	29.0802750	0.077	0.9389	2.4728643
Problem 2	15.2768	27.4888524	0.556	0.5784	2.2160804
Problem 3	-60.6507**	27.7752973	-2.184	0.0290	2.3139698
Sigma	289.352	13.4596102	21.498	0.0000	
Log-likelihood	-1815.414				

***, **, and * represent levels of significance at 1%, 5%, and 10%; respectively.

The statistics of all significant variables in Table 3 were calculated to find the mean of the users' WTP within the Isan cohort per use, through the following Equation 8.

$$E\ (WTP) = \Phi(\frac{\bar{X}}{\sigma}\beta)\bar{X}\beta + \sigma\phi(-\frac{\bar{X}}{\sigma}\beta)$$
$$= (-153.2367005 \text{ x } 0.298199583) + (289.352 \text{ x } 0.346743809) \quad (8)$$
$$= 54.64$$

Hence, the mean of WTP of 54.64 Baht per use may be estimated into monthly and yearly benefits (Table 4). The maximum benefit values of the Isan cohort, based on the number of times the software was used, were 2.3 million Baht in June for the fiscal year 2017, and 2.7 million Baht in July for fiscal year 2018; whereas the minimum recorded values were 1.2 million Baht in January for the fiscal year 2017, and 1.2 million Baht in January for the fiscal year 2018. In the fiscal year 2017, the Isan cohort system was used a total of 420,626 times, which generated a benefit of (420,626 × 54.64) 22.9 million Baht. In the fiscal year 2018, the software system was used for a total of 435,375 times, generating a benefit of (435,375 × 54.64) 23.7 million Baht.

Table 4 Received benefits from the Isan cohort in the fiscal years 2017-2018.

Month	Number of users (person)		Amount of usage (time)		Benefit (Baht)	
	2017*	2018**	2017	2018	2017	2018
Oct.	787	643	33,841	27,649	1,849,072	1,510,741
Nov.	576	647	24,768	27,821	1,353,324	1,520,139
Dec.	689	547	29,627	23,521	1,618,819	1,285,187
Jan.	524	531	22,532	22,833	1,231,148	1,247,595
Feb.	701	663	30,143	28,509	1,647,014	1,557,732
Mar.	900	826	38,700	35,518	2,114,568	1,940,704
Apr.	758	822	32,594	35,346	1,780,936	1,931,305
May	997	1057	42,871	45,451	2,342,471	2,483,443
Jun.	1,004	1145	43,172	49,235	2,358,918	2,690,200
Jul.	928	1178	39,904	50,654	2,180,355	2,767,735
Aug.	969	1114	41,667	47,902	2,276,685	2,617,365
Sep.	949	952	40,807	40,936	2,229,694	2,236,743
Total			420,626	435,375	22,983,005	23,788,890

*Fiscal year 2017 = October 2016 to September 2017.
**Fiscal year 2018 = October 2017 to September 2018.

3.1.2 Cost of the Isan cohort project

Table 5 displays the R&D costs of the Isan cohort project for the fiscal year 2017. The amount of money used for the development and administration of the software system service was 20.9 million Baht, consisting of fixed costs of 20.2 million BahtB and variable costs (system operations and maintenance) of 687,500 Baht. However, the R&D project of the Isan cohort did not receive any further budget from the fiscal year 2018 onward.

Table 5 Cost of the Isan cohort in the fiscal year 2017 (unit: Baht).

Item	Amount	Total
Fixed costs		
Data software management system	19,000,000	
Data management	1,000,000	
Training on the data software management system	260,000	20,260,000
Variable costs		
Remuneration	58,850	
Operating expenses	542,455	
Materials	54,416	
Utilities	31,779	687,500
Total		20,947,500

3.2 Investment worthiness analysis for ten fiscal years (2017-2026)

3.2.1 Results of the project's benefits and costs forecast

The future expected benefits of the Isan cohort for the fiscal years 2019-2026 were forecasted from monthly benefits (24 months) expressed in Table 4. The results of fiscal years 2019-2026 (96 months) found that MAPE = 5.99% (MAPE < 10%), which indicates high forecasting accuracy. The triple exponential smoothing method for fiscal years 2019-2026 (Table 6) revealed that the expected benefits for the eight fiscal years would tend to increase each year. The estimate of future benefits over ten years would, therefore, amounted to 27.2 million Baht.

When considering the costs of the project for the fiscal year 2017, the fixed costs (which occurred within the first year) totaled 20.2 million Baht; while the variable (yearly operating) costs totaled 687,500 Baht, and were expected to increase yearly with inflation. Hence, over the project's 10-year lifespan, the Isan cohort had a projected average variable cost of 742,550 Baht per year, and a median total cost of 2.7 million Baht per year.

Table 6 Results of the forecasted benefits, costs, and net benefits of the Isan cohort for the fiscal years 2017 to 2026 (unit: Baht).

Fiscal year	Benefits*	Costs**			Net benefits
		Fixed costs	Variable costs	Total costs	
2017	22,983,005	20,260,000	687,500	20,947,500	2,035,505
2018	23,788,890	-	699,188	699,188	23,089,702
2019	25,416,164	-	711,074	711,074	24,705,090
2020	26,222,059	-	723,162	723,162	25,498,897
2021	27,027,954	-	735,456	735,456	26,292,498
2022	27,833,849	-	747,958	747,958	27,085,891
2023	28,639,744	-	760,674	760,674	27,879,070
2024	29,445,639	-	773,605	773,605	28,672,034
2025	30,251,534	-	786,756	786,756	29,464,778
2026	31,057,429	-	800,131	800,131	30,257,298
Average	27,266,627	-	742,550	2,768,550	24,498,076

*Benefits in the fiscal years 2017-2018 represent actual values, whereas in fiscal years 2019 to 2026 the figure are predicted values.
**Costs in the fiscal year 2017 represent actual values, whereas in fiscal years 2018-2026, the costs were estimated.

The implementation of the Isan cohort in the fiscal year 2017 was deemed worthy of investment with a total net benefit of 2 million Baht; which was further estimated over the long-term at 24.4 million Baht per year. Additionally, we calculated that the average yearly cost divided by the single-use cost (54.64 Baht) resulted in projected usage of 50,669 times per year.

3.2.2 Evaluation of investment worthiness

Four financial measurements were conducted to evaluate the *worthiness analysis* of the Isan cohort project over ten years (Table 7). The project's PBP was 0.94 years or 11.32 months; considered a very short payback period. The NPV was 153.3 million Baht (NPV > 0), the BCR was 6.92 (BCR > 1), and the IRR was 110.66% (higher than the discount rate or opportunity cost of 8.00%); all of which concluded that the Isan cohort project should be invested in.

Table 7 Results of the worthiness analysis of the Isan cohort project.

Year	Benefit	Cost	Net benefit	Present value of benefit*	Present value of cost*	NPV*
0	0	20,947,500	-20,947,500	0	20,947,500	-20,947,500
1	22,983,005	687,500	22,295,505	21,280,560	636,574	20,643,986
2	23,788,890	699,188	23,089,702	20,395,139	599,441	19,795,698
3	25,416,164	711,074	24,705,090	20,176,170	564,473	19,611,697
4	26,222,059	723,162	25,498,897	19,273,996	531,546	18,742,451
5	27,027,954	735,456	26,292,498	18,394,771	500,539	17,894,232
6	27,833,849	747,958	27,085,891	17,540,046	471,340	17,068,706
7	28,639,744	760,674	27,879,070	16,711,016	443,846	16,267,170
8	29,445,639	773,605	28,672,034	15,908,563	417,955	15,490,608
9	30,251,534	786,756	29,464,778	15,133,299	393,574	14,739,725
10	31,057,429	800,131	30,257,298	14,385,599	370,615	14,014,983
Total	272,666,267	28,373,004	244,293,263	179,199,159	25,877,404	153,321,755
PBP (Years)			0.94			
NPV (Baht)						153,321,755
BCR						6.92
IRR (%)						110.66

* Calculations based on the discount rate of 8.00%.

4. Conclusion

This study assessed the economic impacts of the R&D information system for the surveillance of liver fluke and cholangiocarcinoma of the Fluke Free Thailand Project (Isan cohort). The Isan cohort project has been regarded as the ‘big data’ of Thai public healthcare. The estimation of a users’ willingness to pay (WTP) determined that each access to the Isan cohort software cost 54.64 Baht, which may be further adjusted to an average yearly economic benefit of 27.2 Baht. Three factors that influenced the WTP were job positions related to physicians or nurses (negative relationship), job positions related to medical care support (positive relationship), and problems caused by the management of software administrators (negative relationship). We concluded that the project should develop into a system with a more attractive template for physicians and nurses with greater perceived usefulness and a more friendly application design. And, that the problems created by the management of the software administrators must also be resolved. We determined that respondents over 40 years of age, in medical care positions (physicians or nurses) were more likely to experience problems caused by the management of the software administrators. We surmised that additional training and more efficient assistance within this target group by software administrators should increase WTP.

The examination of investment worthiness over the project’s 10-year period found that the Isan cohort had the average total annual cost of 2.7 million Baht. Therefore, the project’s breakeven point of investment worthiness would be a usage of at least 50,669 times per year. The results of the CBA indicated that the Isan cohort would pay back the investment funds within the first year, as the PBP was 0.94 years (PBP < 1). The project was also deemed worthy of long-term investment, as the NPV was 153.3 million Baht (NPV > 0), the BCR was 6.92 (BCR > 1), and the IRR was 110.66% (with a higher rate of return than the discount rate of 8.00%). Overall, the Isan cohort project should be invested in further; however, investments in operation and maintenance of the project are also significant costs which should be supported by various Thai government sectors; such as, the Health Systems Research Institute, the National Research Council of Thailand, and Khon Kaen University, as the economic benefits of the project will extend throughout the country.

We also wish to recognize the limitations of the data collection method within the study, which utilized an online survey in determining the WTP. The questionnaire design was restricted through the use of open-ended questions. We, therefore, suggest that further study involve face-to-face data collection with a more suitable double bounded CVM or CM method.

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6. Ethic approval

Data collection was approved by the Khon Kaen University Ethics Committee for Human Research under reference number HE601290, 23 February 2018.

7. References

[1] Suwannatrai AT, Thinkhamrop K, Clements AC, Kelly M, Suwannatrai K, Thinkhamrop B, et al. Bayesian spatial analysis of cholangiocarcinoma in northeast Thailand. Sci Rep. 2019;9:14263.
[2] Charbel H, Kawas FH. Cholangiocarcinoma: epidemiology, risk factors, pathogenesis, and diagnosis. Curr Gastroenterol Rep. 2011;13:182-187.
[3] Khuntikeo N, Chamadol N, Yongvanit P, Loilome W, Namwat N, Sithithaworn P, et al. Cohort profile: cholangiocarcinoma screening and care program (CASCAP). BMC Cancer 2015;15:459.
[4] Cholangiocarcinoma Screening and care program. Isan cohort [Internet]. 2020 [cited 2020 Jun 25]. Available from: https://cloud.cascap.in.th/site/index?id=9.
[5] Khuntikeo N, Chamadol N, Youngvanit P, Sithithaworn P, Thinkhamrop B, Loilome W. Health system development for screening, early diagnosis and management of cholangiocarcinoma in northeast, Thailand. [Final report]. Khon Kaen: Health Systems Research Institute, the National Research Council of Thailand, and Khon Kaen University;2018.
[6] Vannakaew N. Analysis type of ultrasound of liver and biliary system from CASCAP project in Don Mod Daeng district, Ubon Ratchathani province in the year 2014-2015. JUR. 2017;15(2):5-18.
[7] Kantha K, Koetsuk L, Suwannasak C. Analysis type of liver and biliary system in Chun district, Phayao province. JDPCHS. 2009;6(2) Suppl 1:1-11.
[8] Chamadol N, Laopaiboon V, Srinakarin J, Loilome W, Yongvanit P, Thinkhamrop B, et al. Teleconsultation ultrasonography: a new weapon to combat cholangiocarcinoma. ESMO Open. 2017 ;22;2(3): e000231. PMID:29209530.
[9] Leelahanaj T. Economic evaluation of healthcare interventions. J Psychiatr Assoc Thailand. 2003;48:57-65.
[10] Tantivess S, Teerawattananon Y, Mills A. Strengthening cost-effectiveness analysis in Thailand through the establishment of the health intervention and technology assessment program. Pharmacoeconomics 2009;27:931-945.
[11] OECD. E-government for better government [Internet]. Paris: OECD Publishing; 2005 [cited 2020 Jun 25]. Available from: https://doi.org/10.1787/9789264018341-en.
[12] Hsu JL, Shiue CW. Consumers' willingness to pay for non-pirated software. J Bus Ethics. 2008;81:715-732.
[13] Han B, Windsor J. User's willingness to pay on social network sites. J Comput Inf Syst. 2011;51:31-40.
[14] Makkonen M, Halttunen V, Frank L. The effects of gender, age, and income on the willingness to pay for music downloads. In: Pucihar A, Gričar J, Lechner U, Wigand DL and Clarke R, editors. The 24th Bled e-Conference e-Future: creating solutions for the individual, organizations and society;2011 June 12-15; Bled, Slovenia. Georgia:AIS Electronic Library; 2011. p. 102-111.
[15] Han B, Windsor J. An investigation on the user's willingness to pay on hedonic social network sites. In: Joshi KD, Yoo Y, editors. The 18th Americas Conference on Information Systems (AMCIS 2012 Proceeding); 2012 August 9-12: Washington D.C, United States. California: AIS Electronic Library; 2012. p.1-8.
[16] Terdudomtham T, Khanti W, Techakanont K. Return on investment of information technology in Government. Final report. Bangkok: National Electronics and Computer Technology Center, Thammasat University; 2004.
[17] Yamane T. Statistics: an introductory analysis. 3rd ed. New York: Harper and Row;1973.
[18] Mitchell RC, Carson RT, Using surveys to value public goods: the contingent valuation method. 3rd ed. Washington, D.C.: Resources for the Future;1993.
[19] Tobin J. Estimation of relationships for limited dependent variables. Econometrica.1958;26:24-36.
[20] Donaldson C, Shackley P, Abdalla M, Miedzybrodzka Z. Willingness to pay for antenatal carrier screening for cystic fibrosis. Health Econ.1995;4:439-452.
[21] Havet N, Morelle M, Remonnay R, Carrere M. Econometric treatment of few protest responses in willingness-to-pay studies: an application in health care. J Demogr Econ. 2012;78:53-74.

[22] Greene WH. Econometric analysis. 7th ed. Harlow: Pearson Education Limited;2012.
[23] Whitehead JC. Combining willingness to pay and behavior data with limited information. Resour Energy Econ. 2005;27:143-155.
[24] Whitehead JC. Improving willingness to pay estimates for quality improvements through joint estimation with quality perceptions. South Econ J. 2006;73:100-111.
[25] Holt CC. Forecasting seasonals and trends by exponentially weighted moving averages. Int J Forecast. 2004;20:5-10.
[26] Winters PR. Forecasting sales by exponentially weighted moving averages. Manage Sci. 1960;6:324-342.
[27] Hyndman RJ, Athanasopoulos G. Forecasting: principles and practice. 2nd ed. Melbourne: OTexts publishing; 2018.
[28] Lewis CD. Industrial and business forecasting methods. London: Butterworth Scientific;1982.
[29] Digital Government Development Agency. The study report of the worthiness analysis in the operation of electronic government in 2016 [Internet]. 2016 [cited 2020 Jun 25]. Available from: https://www.dga.or. th /upload/download/file_8ef98c13818b20ce486afaed2c7a30e2.pdf.