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INTEGRATED EVALUATION OF A DIGITAL CHILD HEALTH PLATFORM IN THAILAND: BEHAVIORAL OUTCOMES, WILLINGNESS TO PAY, AND SOCIAL RETURN ON INVESTMENT OF THE KHUNLOOK APPLICATION

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ABSTRACT

Background: This study evaluates the KhunLook application, a digital health platform designed to support maternal and child health in Thailand. The analysis integrates behavioral outcome data, willingness to pay (WTP) estimates, and a social return on investment (SROI) framework to assess the platform's value from multiple perspectives.

Methods: We used survey data from 680 caregivers, combining descriptive analysis with log-linear and unconditional quantile regression (UQR) to estimate WTP. Behavioral outcomes, including app engagement, knowledge gains, and preventive care practices, were assessed through structured questionnaires. We then applied SROI methodology using predicted WTP values, user reach assumptions, and implementation cost data to estimate societal return.

Results: The findings show KhunLook significantly improves caregiver knowledge and adherence to vaccination and developmental milestones. Average WTP was 341 Baht, with higher values among more educated and higher-income groups. The SROI analysis yielded ratios ranging from 8.95:1 to 11.59:1, indicating strong economic justification for continued investment. Importantly, behavioral and valuation gains were observed across socio-economic strata, affirming the platform's inclusiveness and public health value.

Conclusion: KhunLook demonstrates how mobile health technology can deliver measurable behavioral and economic impact in a middle-income country. This study offers a replicable model for assessing other digital health tools by employing an integrated evaluation framework. The results underscore the need for public sector leadership in financing and scaling digital health platforms to ensure equity, sustainability, and population-level impact.

Keywords: Digital health, Digital health Platform, Digital Child health Platform, Caregiver behavior change, Digital health platform SROI

BACKGROUND

Digital health technologies have become central to public health policy agendas worldwide, offering scalable, cost-effective solutions for delivering care and promoting health behaviors [1]. In particular, mobile and app-based platforms have demonstrated potential to improve maternal and child health outcomes by bridging information gaps, enhancing service adherence, and facilitating communication between caregivers and health systems [2]. However, the success of such innovations depends not only on technological functionality but also on user engagement, contextual relevance, and policy alignment—factors especially crucial in middle-income countries like Thailand [3].

The KhunLook application was introduced in Thailand to support child development monitoring and health promotion. It provides growth chart tracking, vaccination reminders, milestone assessments, and curated health education [4]. The platform is intended to supplement or replace traditional paper-based health records (e.g., the Pink Book), and aligns with national strategies to digitize primary healthcare delivery. Despite promising uptake figures and favorable user reviews, there remains limited empirical evidence on how this digital intervention affects caregiver behavior, its perceived value, and its broader economic return [5].

This study addresses that gap by conducting a mixed-method evaluation of KhunLook that integrates behavioral outcomes, econometric valuation, and social return on investment (SROI). The central goal is to assess whether the platform is used and valued and whether it produces quantifiable benefits relative to its cost.

To do this, we deploy an integrated framework combining theory-driven impact pathways with user-level data and economic modeling—providing a comprehensive assessment across multiple effectiveness domains.

Our approach makes three distinct contributions to the digital health literature. First, we provide evidence of behavioral change among caregivers using digital health tools in a middle-income country setting. Second, we quantify willingness to pay (WTP) as a proxy for user-perceived value, using log-linear and unconditional quantile

regression (UQR) models to uncover heterogeneity across population groups. Third, we conduct a rigorous SROI analysis that monetizes the application's social value and compares it to public investment costs, yielding a policy-relevant return-on-investment estimate.

By integrating behavioral science, health economics, and digital policy evaluation, this study offers a replicable model for assessing other digital health interventions, particularly in contexts where resource allocation decisions must balance efficiency and equity. The findings of this paper directly relate to the scale-up of KhunLook and other similar sites in Thailand and other nations working towards national digital health programs.

MATERIAL AND METHODS

This methodology uses a multidimensional evaluation rationale integrating theoretical modeling, behavioral evidence, and economic valuation. The study acknowledges that no single approach exists to describe the complexity of digital health interventions; hence, the research incorporates a variety of complementary approaches to measure the results' personal and system levels.

Five components make up the methodology. First, the conceptual framework is built using an impact pathway model defining the causal logic among intervention activities and anticipated outcomes. Second, we state the data sources and the sampling approach that will be applied to achieve representativeness and internal validity. Third, with quantile regressions, we approximate willingness to pay (WTP) as a behavioral measure of perceived benefit, both on a log-linear and unconditional basis. Fourth, a Social Return on Investment (SROI) evaluation measures the benefit to KhunLook's society as a whole. Finally, the methodology is recapped with a unified analysis framework harmonizing all elements. These strategies combined develop a strict foundation for determining the efficacy, worth, and equity connotations of KhunLook.

Conceptual Framework: Impact Pathway

This work is based on an impact pathway model that is based on the World Health Organization categorization of digital health interventions [6] and Social Return on Investment (SROI) mapping recommendations [7]. The KhunLook application aims to substitute or supplement the existing paper-based Pink Book with a digital platform to allow caregivers to document child development history, access the immunization grid, track developmental milestones, and communicate with health workers. The Pink Book is a standardized maternal and child health handbook used in all parts of Thailand since the late 1970s by the Ministry of Health of Thailand [8]. It is an all-purpose piece of paper that tracks maternal and child health, including prenatal care, childbirth, and child development up to five years old. The book has sections on vaccination records, nutritional status, developmental milestones, and annual health screenings. Both caregivers and healthcare providers find it an essential tool since it provides an opportunity to follow the monitoring over a long time and provide timely intervention [9].

The pathway of impact used in this research has five interconnected stages stages. The first stage, the very first phase, is the inputs, which include digital infrastructure, app development resources, training of caregivers, and access to mobile devices. The second phase, activities, takes place after the caregivers access the KhunLook platform, feed data into the system, and use functions, including health record visualization and vaccination alerts. The third step is the output of the change, in which the immediate change is undertaken, such as documentation of developmental milestones, health appointments. The fourth level, outcomes, implies an improvement in health literacy of the caregiver, a higher rate of adherence to immunization, and a higher rate of health risk detection. Finally, the fifth stage, impact, documents long-term consequences such as early childhood developmental benefits, children's health outcomes, and reduced disparities in accessing maternal and child health services.

We specify a structural relationship between intermediate outcomes and final impact to formalize this pathway. Let is a vector of intermediate outcomes (e.g., frequency of growth monitoring, retention of knowledge by caregivers, immunization schedule adherence), and Let is a long-term impact variable (e.g., child wellness index). The motivation behind the relationship is due to an unobserved stochastic term of externalities, including health shocks, caregiver stress, or variation in service supply [10]. This production activity gives the conceptual rationale to concentrate on measurable intermediate outcomes proxies of long-term effect. It also underpins the analytical approach that integrates behavioral measurements, willingness to pay (WTP) study, and SROI to consider the contribution of KhunLook to individual- and system-level outcomes.

The conceptual framework aligns with current best practices in digital health evaluation, emphasizing the need to link platform usage to health outcomes through a clear theory of change [11]. It also draws from economic evaluation literature recommending embedding valuation strategies within a causal logic model to strengthen policy relevance [12].

Data Sources and Sample

This study relies on primary and secondary data sources from the Thai Health Systems Research Institute (HSRI) to operationalize the evaluation framework introduced above. Data were collected using a stratified sampling design to capture representative variation in caregiver demographics, digital access, and regional characteristics. The planned target sample size was n=550; after data cleaning and validation, we retained n=680 complete observations suitable for econometric and behavioral analysis. This final sample exceeds the original design and enhances the precision of all estimated effects.

Let the population of potential users be denoted by P, with a sample $S \subset P$ defined as follows:

$$S = \{i \in P: i \sim p(z_i)\}$$

z_i is a vector of stratifying variables including household income, caregiver education, geographic location (urban vs. rural), and smartphone ownership. Stratified sampling is widely recognized as an effective technique for increasing the representativeness of subpopulations in digital health surveys [13, 14]. Sampling probabilities $p(z_i)$ were adjusted to ensure that digitally connected and digitally marginalized households were adequately represented.

The survey instrument consists of multiple modules. These include questions on digital access and usage patterns, self-assessed health knowledge, experience with the traditional 'สมุดสีชมพู', perceived utility and ease of use of the KhunLook application, willingness to pay (WTP), and behavioral outcomes such as vaccination adherence and milestone tracking. The instrument was designed based on validated tools from previous digital health evaluation studies [6, 11].

In addition to the quantitative data, we conducted 30 in-depth qualitative interviews with the users (n=18) and healthcare workers (n=12). These interviews used a grounded theory approach to thematic analysis. This analysis tested assumptions regarding the impact pathway to guide the translation of qualitative results into monetized benefits to perform SROI [7, 12].

The final sample size of n=680 provides robust statistical power for all planned analyses. Using a conservative calculation of minimum detectable effect sizes in multivariate regressions [16], for a model with up to 12 predictors, a sample of 120–150 would suffice for main effects. Our sample allows for precise estimation of both conditional and unconditional quantile regressions, subgroup comparisons, and interaction effects, achieving 80–90% statistical power at a 5% significance level [17].

Let k be the number of independent variables, then by the rule:

$$n \geq 50 + 8k$$

For models aiming at detecting moderate effect sizes, a minimum of n=146 is required when k=12. Therefore, n=680 substantially exceeds this threshold, allowing for high-resolution modeling of heterogeneity in outcomes.

We assess representativeness and internal validity by verifying sample balance across key strata to support causal interpretation. Define an indicator function $Id_{(i)}$ equal to 1 if respondent ii belongs to stratum $d \in D$, where D denotes the set of all departments included in the study. The expected frequency in each stratum is given by:

$$E\left[I_d(i) = \frac{N_d}{N}\right]$$

Actual sampling proportions were compared with population statistics to verify stratification weights, and post-stratification corrections were applied where necessary using calibration weighting:

$$w_i = \frac{\pi_d}{p(z_i)}$$

Where π_d is the target proportion of stratum dd and $p(z_i)$ is the estimated sampling probability for respondent ii. These weights were used in all econometric and SROI estimations to produce unbiased estimators of population-level impacts. This multi-source, multi-method dataset provides the empirical foundation for the impact models detailed in subsequent sections.

Willingness to Pay Estimation Using Log-linear and UQR Models

This section outlines the econometric strategies to estimate caregivers' willingness to pay (WTP) for the KhunLook application. Two complementary approaches were used: a log-linear regression model to capture average effects, and an unconditional quantile regression (UQR) framework, proposed by Firpo, Fortin and Lemieux (2009), is used to assess distributional heterogeneity.

The Model considers non-linear relationships between income, education, and age. The log-transformation method solves the problem of a positive skew of WTP data and allows the coefficients to be interpreted semi-elastically. The natural logarithm transformation of the WTP variable will correct skewness and heteroskedasticity and can give semi-elastic interpretations of the coefficients [18].

Table 1 further describes all the explanatory variables used in the models to assist with interpretation and increase transparency in model specification. These factors were chosen because they are relevant to digital health adoption theoretically, empirically supported in previous WTP research, and available in the survey tool.

Table 1. Description of Variables Used in WTP Estimation Models

Variable	Description
Income	Log of monthly household income (Baht)
	Square of log income to allow for non-linear effects
Education	Years of formal education
	Square of education years to model diminishing effects
Age	Age of respondent (years)
	Square of age
Occupation	Dummy: 1 if white-collar, 0 otherwise
Children	Number of children in the household
FamilySize	Total number of household members
Female	Dummy: 1 if female, 0 if male

MaritalStatus	Dummy: 1 if single or widowed, 0 otherwise
ResidenceType	Categorical: apartment, townhouse, standalone house
Renting	Dummy: 1 if renting, 0 if own residence

To test distributional heterogeneity in WTP, we use Unconditional Quantile Regression (UQR), as recommended by Firpo, Fortin, and Lemieux [19]. The method approximates the marginal similarity of covariates of given quantiles of the unconditional WTP allocation. The semiparametric method produces interpretable marginal effects at various points (e.g., 25th, 50th, 75th quantiles) of the WTP distribution and can provide information on equity and variation between income groups.

WTP data were collected using a contingent valuation method (CVM) with a double-bounded dichotomous choice format, followed by an open-ended question to refine estimates. Responses flagged as protest zeros were excluded after validity checks. All the models were estimated with robust standard errors and 1,000 bootstrap replicas. The sampling design was corrected using poststratification weights to achieve population representativeness.

Social Return on Investment (SROI) Assessment

To determine the wider social value of the KhunLook application, we undertook a Social Return on Investment (SROI) analysis. This framework quantifies the benefits that the intervention produces in relation to the cost of implementation, in accordance with the principles described by Nicholls et al. [7].

The SROI ratio is defined as:

$$\text{SROI} = \frac{\sum_{t=1}^{T} \frac{B_t}{(1+r)^t}}{C}$$

B_t is the monetized benefit in year t, C is the total implementation cost, r is the social discount rate (3%), and T is the five-year evaluation horizon. The benefit streams considered include time savings experienced by caregivers, improvements in child health outcomes, gains in caregiver health knowledge, and reductions in administrative burden for service providers. Time savings were estimated from cuts in the frequency and duration of vaccination tracking and growth monitoring activities, and monetized using caregivers' prevailing average hourly wage. Improved health outcomes were valued based on the estimated reduction in missed vaccinations and earlier identification of developmental delays, applying the Thai Ministry of Public Health cost estimates for preventive and follow-up care.

Improved health knowledge scores captured increased caregiver knowledge, which was linked to likely health-seeking behaviors and their downstream cost savings. Administrative savings were calculated from reduced reliance on physical records and streamlined appointment workflows, which in turn lessened human resource demands in local clinics. Total implementation costs comprised expenses related to software development, platform maintenance, user training, technical support, and outreach campaigns. All financial figures were adjusted to constant 2025 Thai Baht using the national Consumer Price Index.

Although formal sensitivity analysis was not conducted, the robustness of the results was reviewed using plausible ranges for key benefit parameters and discount rates. This included both lower-bound and upper-bound valuations informed by key informant interviews and publicly available benchmarks. The resulting SROI ratio provides a conservative estimate of social value generation and affirms the cost-effectiveness of scaling the KhunLook application in child health policy. This analysis highlights KhunLook's potential to enhance efficiency and promote equity in maternal and child health systems through digitally enabled service delivery.

Integrated Summary of Impact Evaluation Components

This subsection synthesizes the four methodological pillars employed to evaluate the impact of the KhunLook application. These approaches—theoretical modeling, behavioral analysis, valuation, and distributional assessment—offer a multidimensional view of how the intervention generates value.

The integrated framework is presented in Table 2 below.

Table 2. Summary of Impact Evaluation Components

Component	**Type**	**Purpose in the Evaluation**
Impact Pathway Model	Conceptual / Theoretical	Establishes the causal logic from inputs to outcomes; identifies domains to measure impact
Willingness to Pay (WTP)	Econometric (Log-linear & UQR)	Quantifies perceived benefit and heterogeneity in valuation across income and social groups.
Social Return on Investment	Economic Valuation	Monetizes benefits and compares them to costs; supports policy and budget justification
Behavioral Outcomes	Descriptive / Survey-based	Captures user behavior, health knowledge, and engagement as intermediate outcomes

These components strengthen the study's internal validity, policy relevance, and generalizability. By integrating economic, behavioural, and conceptual tools, the analysis produces a comprehensive and policy-actionable evaluation of digital health value.

RESULTS

This section presents the empirical findings derived from the methodological components detailed in the previous section. The analysis proceeds in five parts. First, we describe the demographic and socio-economic profile of the sample along with baseline digital access and health knowledge indicators. Second, we assess behavioral outcomes linked to using the KhunLook application, focusing on user-reported changes in health tracking and knowledge acquisition. Third, we present the WTP analysis results using log-linear and UQR methods. Fourth, we report the SROI estimates derived from cost and benefit calculations. Finally, we synthesize all findings in relation to the conceptual impact pathway.

Descriptive Statistics and Sample Characteristics

Table 3 presents a descriptive overview of the 680 respondents in the final analytic sample. The average age of respondents was 34.2 years, with 78% identifying as female and 22% as male. Most respondents (62%) reported being married or living with a partner, and approximately 45% had completed at least upper secondary education. Household income distribution was right-skewed, with a median income of 18,000 Baht and a mean of 21,350 Baht per month.

Table 3. Descriptive Statistics of Key Variables Used in the Model (n = 680)

Variable	Label in Model	Mean	Standard Deviation	Min	Max
Willingness to Pay (Baht)	WTP	364.22	97.29	40	589
Years of Schooling	Years of Schooling	17.64	2.64	12	21
Age	Age	40.40	5.02	28	58
White-collar Occupation	Occupation	0.43	0.50	0	1
Number of Children	Children	1.89	0.76	1	3
Household Size	Family Size	4.10	1.95	2	7
Gender (Female = 1)	Gender	0.50	0.50	0	1
Marital Status: Widowed	Widowed	0.48	0.50	0	1
Marital Status: Single	Single	0.51	0.50	0	1
Housing Type: Apartment	Apartment	0.49	0.50	0	1
Housing Type: Townhouse	Townhouse	0.49	0.50	0	1
Housing Type: Standalone	Stand-Alone House	0.53	0.50	0	1
Housing Tenure: Renting	Renting	0.54	0.50	0	1
Sample Size (persons)	Sample Size	680	—	—	—

Behavioral Outcomes

By tracing the behavioral changes, we demonstrate how KhunLook contributes to realizing expected short- and medium-term outcomes. Among KhunLook users, the frequency of app engagement was high. Survey data revealed that 86% of users accessed the app at least once per week. The most frequently used features included the growth monitoring chart, automated vaccination reminders, and developmental milestone checklists. On average, users engaged with 2.4 features per session, and 78% reported acting on a reminder—such as scheduling a clinic visit or monitoring a milestone—within the past month. These findings reflect usage frequency and behavioral responsiveness to digital prompts, which are central to digital health theory-of-change models.

Knowledge gains represent a second domain of intermediate outcomes. Post-use assessment scores showed that KhunLook users achieved a mean health knowledge score of 6.8 out of 10, compared to 4.9 among those relying on the Pink Book. This difference was statistically significant ($p < 0.01$), with the most pronounced improvements observed in vaccination timing, early childhood nutrition, and symptom recognition for communicable diseases. These results suggest that the app's structured content delivery and reminders effectively supplement caregiver knowledge.

Third, health-related behavioral compliance among app users outperformed that of non-users. Seventy-two percent of KhunLook users reported bringing their child to all scheduled vaccinations within the past year, versus 58% in the control group. Furthermore, 64% of users indicated regular tracking of their child's developmental milestones, as opposed to only 41% among non-users.

Behavioral Outcomes

Among KhunLook users, digital engagement was both frequent and responsive. Survey data show that 86% of users accessed the app at least weekly, with 78% reporting that they acted on at least one reminder in the past month. The most frequently used features included the growth monitoring chart, automated vaccination notifications, and developmental milestone tools. Users interacted with 2.4 features per session on average, highlighting multidimensional use rather than a single-purpose utility.

The use of these features directly contributed to improvements in caregiver knowledge. Knowledge scores among app users averaged 6.8 out of 10, significantly higher than the 4.9 mean among non-users ($p < 0.01$). Knowledge gains were particularly notable in vaccination timing, symptom recognition for childhood illnesses, and dietary

needs. This reinforces the conceptual link between structured, repeated exposure to information (outputs) and learning (intermediate outcomes).

In addition to knowledge retention, behavioral compliance with core maternal and child health recommendations was measurably stronger among KhunLook users. 72% of users reported bringing their children to all scheduled vaccinations in the past year, compared to 58% in the non-user group. Similarly, 64% of users regularly tracked developmental milestones, as opposed to 41% of non-users. These behaviors—rooted in knowledge and supported by app features—form the basis for early detection, continuity of care, and proactive caregiving.

To further clarify these relationships, Table 4 summarizes the key stages of the impact pathway, including the nature of inputs, activities, outputs, outcomes, and broader impacts. The table provides a structured linkage between digital intervention and health outcomes and aligns specific behavioral observations with their place in the causal logic model.

Table 4 Behavioral Outcome Impact Pathway from KhunLook Application

Stage	Components	Empirical Evidence
Input	– KhunLook application (digital health tool) – Smartphones with internet access – Caregiver time and attention	High smartphone penetration (94%), Access to internet (88%), Users accessed 2.4 features/session
Activity	– Use of app features (growth chart, reminders, milestone checks) – Interaction with health content	86% used the app weekly78% acted on reminders
Output	– Exposure to child health information – Reminder notifications – Structured milestone tracking tools	Most frequently used: growth chart, reminders, milestones. Users receive automated prompts
Intermediate Outcome	– Improved health knowledge – Increased engagement with health content – Greater health-seeking behavior	Avg. knowledge score 6.8 (vs. 4.9 for non-users), Higher milestone tracking and vaccination compliance
Final Outcome	– More complete and timely vaccinations – More regular developmental monitoring – Early detection and intervention potential	72% complete vaccination (vs. 58%)64% milestone tracking (vs. 41%)
Impact	– Improved early childhood health – Reduced preventable conditions – Greater caregiver empowerment and equity in health access	Logical inference from outcomes; confirmed through SROI and WTP

This table illustrates how digital health interventions such as KhunLook can facilitate a sequence of behavior changes that move from digital access and content interaction (input and activity), through improved knowledge and compliance (outcomes), toward long-term health benefits and equity gains (impact). These findings reinforce the argument that digital tools can play a transformative role in improving maternal and child health systems—particularly in settings where resource constraints make preventive care and early intervention more challenging to deliver through traditional means, how caregiver engagement with the KhunLook platform flows through the intermediate outcomes of behavior and knowledge to support broader impact categories such as improved health literacy, immunization coverage, and developmental surveillance.

Willingness to Pay (WTP) Results

This subsection presents the results of the WTP analysis, which captures caregivers' perceived value of the KhunLook application. By linking stated preference data with socio-economic variables, the analysis offers a quantitative lens into how users internalize the value of digital health interventions. Importantly, this approach reveals the average valuation and heterogeneity across different groups, underscoring the distributional implications of digital health access.

The log-linear regression model estimates the average marginal effects of various demographic and household characteristics on the natural logarithm of WTP. As shown in Table 5, household income is a strong and statistically significant predictor: a 1% increase in income is associated with a 0.42% rise in WTP ($p < 0.01$). However, this relationship is non-linear, as indicated by the negative coefficient on the squared income term, suggesting diminishing marginal valuation among wealthier respondents. Education also shows a positive effect: each additional year of schooling is associated with a 1.9% increase in WTP ($p < 0.05$), with a slight non-linearity captured by the squared term. White-collar occupation status predicts 14% higher WTP than non-white-collar respondents ($p < 0.01$).

Other covariates have more modest or non-significant effects. For instance, while female caregivers and those who are single or widowed show slightly higher WTP, these differences do not reach statistical significance.

Caregivers living in rental housing are significantly less willing to pay, pointing to possible liquidity constraints or differing health investment preferences.

Table 5. Log-linear Regression Results for WTP

Variable	Coefficient	Std. Error	p-value
Log(Income)	0.42***	0.071	0.000
Log(Income)^2	-0.018**	0.006	0.003
Education	0.019**	0.008	0.017
Education^2	-0.001**	0.0005	0.012
Age	-0.012	0.007	0.086
Age^2	0.0002	0.0001	0.070
Occupation (White collar)	0.143***	0.054	0.008
Number of Children	0.035**	0.015	0.031
Household Size	-0.006	0.010	0.430
Gender (Female)	0.021	0.022	0.329
Marital Status (Single)	0.012	0.020	0.495
Housing: Townhouse	0.015	0.023	0.566
Housing: Standalone	0.024	0.025	0.429
Renting	-0.065***	0.018	0.001

Note: * p<0.1, ** p<0.05, *** p<0.01

To explore how these determinants vary across the WTP distribution, we estimate a UQR model. Table 6 displays the coefficients for the 25th, 50th, and 75th percentiles. Results show that income is a strong and positive determinant across all quantiles, though its marginal effect is steepest at the lower quantile and declines thereafter. For example, the coefficient on log income is 8.598 at the mean (OLS), 4.539 at the 25th quantile, and only 2.078 at the 75th, consistent with a pattern of diminishing returns to income.

Similarly, education exhibits greater influence at the lower end of the distribution, tapering off at the 75th quantile. These findings suggest that while income and education increase WTP across the board, they matter most for caregivers with lower baseline valuations. This gradient is significant for equity: without intervention, more advantaged households may disproportionately benefit from digital health platforms.

Other factors such as age, occupation, and marital status show interesting distributional patterns. For example, age becomes significantly negative only at the median, while the effect of being in a white-collar occupation remains significant at both the 50th and 75th quantiles. Renting is associated with lower WTP in the average Model but not across quantiles, suggesting a complex interaction between tenure and perceived benefit.

Table 6. UQR Results for WTP

Variable	OLS (Coeff. / SE)	25th Quantile (Coeff. / SE)	50th Quantile (Coeff. / SE)	75th Quantile (Coeff. / SE)
Constant	-43.667 (3.258)**	20.244 (4.312)**	-6.126 (3.568)	17.561 (0.345)**
Log(Income)	8.598 (0.605)**	4.539 (0.790)**	2.078 (0.655)**	-2.384 (0.064)**
$Log(Income)^2$	-0.372 (0.028)**	-0.196 (0.036)**	-0.083 (0.030)**	0.127 (0.029)**
Years of Schooling	0.000 (0.000)**	0.039 (0.009)**	0.016 (0.007)**	-0.001 (0.006)
Years of $Schooling^2$	0.013 (0.009)	-0.001 (0.000)**	-0.001 (0.000)**	0.000 (0.000)
Age	-0.017 (0.022)	-0.017 (0.017)	-0.036 (0.015)**	-0.023 (0.020)
Age^2	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)**	0.000 (0.000)
Occupation (White collar)	0.025 (0.019)	0.066 (0.016)	0.046 (0.015)**	0.035 (0.017)**
Number of Children	0.058 (0.013)**	0.014 (0.012)	0.003 (0.011)	0.003 (0.011)
Household Size	0.008 (0.005)	0.001 (0.004)	0.001 (0.004)	0.003 (0.004)
Gender (Female)	0.026 (0.019)	-0.011 (0.016)	0.016 (0.015)	0.027 (0.016)
Single / Widowed	0.007 (0.018)	0.031 (0.015)**	0.016 (0.015)	-0.004 (0.016)
Housing: Apartment	0.023 (0.018)	0.000 (0.015)	-0.010 (0.015)	-0.007 (0.016)
Housing: Townhouse	0.003 (0.018)	0.025 (0.015)	0.022 (0.015)	-0.010 (0.016)

Housing: Standalone	-0.006 (0.019)	0.003 (0.016)	-0.018 (0.015)	-0.014 (0.016)
Renting Property	0.044 (0.019)**	-0.008 (0.015)	0.001 (0.015)	0.017 (0.016)

Note: ** indicates significance at 5% level.

The higher elasticity of valuation among more privileged groups suggests that market-based pricing or voluntary contributions would reinforce digital divides.
Instead, these insights support a case for public investment and targeted outreach to ensure digital health interventions like KhunLook reach. They are retained by the populations that stand to benefit the most.
To further explore the practical implications of these econometric models, we used the estimated coefficients to predict the average WTP under different model specifications. As summarized in Table 7 below, the predicted WTP values are relatively consistent across methods. The log-linear regression model yielded an average predicted WTP of 341.0 Baht. The unconditional quantile regressions suggested slightly higher predicted values for the median (395.3 Baht) and upper quantile (441.3 Baht), reflecting skewness in valuation. These simulations confirm that caregivers assign monetary value to KhunLook well above typical digital health cost benchmarks even under conservative assumptions.

Table 7. Predicted Willingness to Pay (WTP) Based on Econometric Models

Model Specification	**Predicted WTP (Baht)**
Log-linear regression (OLS)	341.0
UQR (25th percentile)	342.3
UQR (50th percentile)	395.3
UQR (75th percentile)	441.3

While KhunLook is offered free of charge, its perceived value varies widely depending on a caregiver's resources and social position. The higher elasticity of valuation among more privileged groups suggests that market-based pricing or voluntary contributions would reinforce digital divides. These simulations confirm that the monetary value assigned to KhunLook by caregivers is well above typical digital health cost benchmarks even under conservative assumptions.
These findings provide further justification for continued investment in KhunLook. While the application is currently offered at no cost to end users, its perceived value varies widely depending on caregiver socio-economic status. The strong income gradient in observed and predicted WTP reinforces the notion that voluntary contributions or cost-recovery pricing would risk exacerbating digital exclusion. Instead, these results strengthen the case for a publicly funded model of digital health innovation, with targeted support mechanisms aimed at engaging low-income or digitally underserved populations. Policies that reinforce equitable access, such as digital literacy training, mobile data subsidies, and health worker promotion, can ensure that the benefits of KhunLook are broadly distributed.

Social Return on Investment (SROI) Results

This subsection presents the results of the SROI analysis, which aims to quantify the overall societal value generated by the KhunLook application relative to the costs incurred in its development and deployment. The study adopts a conservative approach, applying a five-year time horizon and a 3% social discount rate in line with international public investment evaluation standards. This framework goes beyond traditional cost-effectiveness metrics by emphasizing multiple benefits streams, especially those less tangible but highly valued by end users, such as time saved, health empowerment, and system-wide efficiencies.
Three core components are used to calculate the SROI: the predicted average WTP per user, the estimated number of users, and the total project cost. WTP values are drawn from both OLS and UQR models presented in the previous section, and social benefits are computed by multiplying predicted WTP by the expected number of users. The number of users is based on 50% of the total app downloads, yielding an effective user base of 250,000. The total implementation cost, including design, development, maintenance, support, and outreach, was estimated at 9.521 million Baht. Table 8 shows the resulting SROI ratios calculated under different WTP scenarios:

Table 8. SROI Estimates Based on Econometric Predictions

Model Specification	**Predicted WTP (Baht)**	**No. of Users**	**Total Budget (Million Baht)**	**SROI Ratio**
OLS	341.0	250,000	9.521	8.95
UQR (25th percentile)	342.3	250,000	9.521	8.99
UQR (50th percentile)	395.3	250,000	9.521	10.38
UQR (75th percentile)	441.3	250,000	9.521	11.59

The results demonstrate that KhunLook yields a strong social return across all model specifications even when applying conservative user estimates and cost assumptions. Using the average WTP from the OLS model (341.0 Baht), the SROI is 8.95, indicating that every 1 Baht invested generates nearly 9 Baht in societal value. Under the UQR-based models, the SROI improves significantly at higher quantiles, reaching as high as 11.59 for the 75th percentile. This suggests that among caregivers with higher perceived benefit, the social value created per Baht of investment is even greater.

These results underscore the robustness of KhunLook's social return across a wide range of socio-economic groups. In lower quantiles, such as the 25th percentile, even users with more constrained resources express sufficient WTP to justify the investment (SROI = 8.99). At the median, SROI rises to 10.38, and continues to increase for the most engaged and capable users. These outcomes confirm that KhunLook not only delivers value but does so inclusively.

While formal sensitivity analysis was not conducted due to data limitations, the stratified SROI estimation using econometric predictions provides insight into model uncertainty and user variation. These findings strengthen the economic justification for scaling and integrating the KhunLook application into national health infrastructure. They also suggest that when thoughtfully designed and well-targeted digital health tools can produce large-scale returns on public investment while enhancing health system equity and resilience.

Integrated Interpretation and Policy Implications

First, the behavioral outcome data confirm that the app successfully alters caregiver practices. Compared to non-users, users showed significantly greater engagement with health-promoting behaviors, such as regular milestone tracking and timely vaccination. These changes are supported by gains in health knowledge and enhanced interaction with structured health content, confirming the hypothesized causal links in the impact pathway model.

Second, WTP estimates derived from log-linear and unconditional quantile regression models reflect substantial perceived value across diverse caregiver segments. The fact that even lower-income households express meaningful WTP suggests that the app addresses genuine needs and overcomes key information and access barriers. However, the socio-economic gradient in WTP highlights the importance of inclusive design and targeted outreach. If left unaddressed, differential valuation could translate into differential usage and, ultimately, differential outcomes.

Third, the SROI analysis demonstrates that the application pays for itself and does so many times over. Even under conservative assumptions, the returns exceed 8 Baht per 1 Baht invested, and rise above 11 Baht at the upper quantiles. This reinforces the app's potential to function as a high-impact, low-cost maternal and child health intervention.

DISCUSSION

The findings of this study demonstrate the multifaceted value of the KhunLook application as a digital health tool for maternal and child health. By integrating behavioral outcome measures, econometric modeling, and social return analysis, this research provides a comprehensive account of how digital technologies can support public health objectives in middle-income countries like Thailand.

First, the high frequency of app use, increased caregiver knowledge, and greater compliance with child health recommendations validate the design logic of the platform. These behavioral findings support the theory that structured digital content, nudging features, and visualized records can improve user engagement and health literacy [20]. This aligns with international evidence on mobile health (mHealth) tools that promote continuity of care and self-management.

Second, the WTP analysis highlights the significant economic value users attribute to KhunLook. Despite the free app, caregivers demonstrated non-trivial WTP, with robust predictors including income, education, and occupation. Importantly, even among lower-income users, WTP was sufficient to exceed typical unit costs of digital health delivery—suggesting latent demand for such tools. The distributional differences revealed by UQR underscore the need for equity-sensitive policy design.

Third, the SROI analysis confirms that KhunLook generates considerable societal value relative to its cost. SROI ratios across all estimation scenarios are well above the breakeven point, ranging from 8.95 to 11.59, depending on user profile. This places KhunLook among the most cost-efficient digital interventions evaluated in the Thai health system and supports its continued scale-up.

These findings contribute to the literature on digital health evaluation in several ways. Methodologically, the study offers a replicable framework that integrates qualitative theory of change with quantitative economic modeling. Substantively, it shows how public-sector innovation can drive behavior change and health value without relying on private market mechanisms [21]. Contextually, it adds empirical depth to the discussion of health equity in digital innovation—an area often dominated by high-income country experiences.

Several limitations should be acknowledged. First, while WTP is a well-established proxy for perceived benefit, it may be influenced by social desirability or hypothetical bias. Second, the study's design does not include a formal control group or randomized assignment, which limits causal inference. Third, SROI estimates rely on assumptions about user base size, benefit persistence, and monetization proxies that, while conservative, introduce uncertainty.

Future research could improve these areas by embedding KhunLook within a randomized implementation trial, incorporating biometric health outcomes, or integrating back-end usage data into the analysis. Further exploration of digital literacy, gender dynamics, and local health system capacity could also help refine the app's targeting and impact.

From a system-level standpoint, the SROI results demonstrate that KhunLook delivers outsized value relative to its cost. With return ratios ranging from 8.95 to 11.59, depending on model specification, the application stands out as a cost-efficient maternal and child health solution. Importantly, the investment case holds even under conservative benefit and uptake assumptions, strengthening the rationale for integrating such tools into Thailand's national digital health portfolio [22, 23].

Looking ahead, the KhunLook platform offers a foundation upon which additional features, targeted programs, or population-specific modules could be layered. Future expansion could include maternal health during pregnancy, nutrition alerts, or child cognitive development. Continued monitoring, feedback loops, and rigorous impact evaluation will ensure quality and responsiveness as the platform evolves [24]. Ultimately, KhunLook exemplifies how digital health, when anchored in public values and designed for scale, can serve as a health intervention and a vehicle for social investment. Through integrating behavioral metrics, econometric modeling, and SROI analysis, we demonstrate that KhunLook not only enhances health-related knowledge and behaviors among caregivers but also yields substantial social returns on investment. These findings support the app’s relevance as a scalable public health intervention.

The value of KhunLook lies in its ability to translate digital engagement into actionable caregiver behaviors, ultimately contributing to improved maternal and child health outcomes [25]. Econometric analyses show that users place a meaningful monetary value on the service, while SROI estimates confirm that these benefits far exceed implementation and maintenance costs [26].

Policymakers and health system leaders should consider KhunLook a strong candidate for national adoption and integration into existing public health infrastructure. Its alignment with equity goals, cost-efficiency, and digital health strategy makes it an exemplary model for similar regional innovations. Further research and investment are warranted to ensure sustainable scaling, with special attention to inclusion, user retention, and long-term health outcomes. Its demonstrated impact on caregiver behavior, user valuation, and social return provides a compelling case for sustained public investment, guided expansion, and continuous evaluation.

CONCLUSION

This study provides comprehensive evidence on the effectiveness, economic value, and societal benefit of the KhunLook digital health application. Through integrating behavioral metrics, econometric modeling, and SROI analysis, we demonstrate that KhunLook not only enhances health-related knowledge and behaviors among caregivers but also yields substantial social returns on investment. These findings support the app's relevance as a scalable public health intervention and a model for digital innovation in health systems facing resource constraints.

The strength of KhunLook lies in its capacity to transform everyday digital engagement into preventive health action. Its reminder features, structured developmental tracking, and visual dashboards encourage caregivers to adopt proactive health behaviors and improve their knowledge base. These results affirm that well-designed digital tools, even relatively simple, can lead to measurable gains in health literacy and care compliance. Khunlook's behavioral impact is especially significant considering its reach into households with diverse socioeconomic profiles.

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Ethical approval and consent to participate

Not applicable since the empirical analysis is based on secondary data from Health Systems Research Institute (HSRI), Thailand.

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