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Evaluation of I-Kelahiran, A Health Informatics System in Sabah State Health Department – A Structural Equation Modeling

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Abstract
I-Kelahiran (Inovasi-Kelahiran) is a health informatics system that manages birth and immunisation data, developed and implemented in Sabah to address birth discrepancy, delayed reporting of high-risk pregnancy, and immunization coverage. This study aimed to evaluate the conceptual framework and the factors that determine the information system success of I-Kelahiran among the nurses in the Sabah State Health Department. It was a cross-sectional web-based study, conducted in 21 hospitals and 292 health clinics. A total of 1.200 nurses participated, with a mean age of 31.96 years (SD=7.76) and the majority of them were community nurses. About 93.8% of them had good computer literacy. Individual Impact (p=0.011) and Organizational Impact (p=0.0019) were seen to have significant association towards the nurse's place of work, and computer literacy had a significant association towards organizational impact (p=0.046). A structural equation modeling indicated that only perceived ease of use & importance of system are good predictors in outcome evaluation of I-Kelahiran while Individual Impact & Effectiveness are good domains to measure the overall outcome of I-Kelahiran (Chi-Square/df=2.850, Comparative Fit Index [CFI]= 0.991, Tucker-Lewis Index [TLI]= 0.989, Root Mean Square Error of Approximation [RMSEA]= 0.939). Future study is needed to study the complex external factors that lead to this information success model in Malaysia.

Keywords: Health information systems; Hospital information system; Structural Equation Modeling

Introduction

Sabah is one of the states of Malaysia, located on the Northern Borneo. It has a diverse ethnicity with an estimation of 42 ethnic groups with over 200 sub-ethnic groups with their own language. Based on the 2015 census, the state's population is 3.900.000 [1]. According to the national data, the reduction in the maternal mortality rate has been progressing well from 44 maternal deaths per 100,000 live births in 1991 to 29 deaths in 2019 [2].

Nevertheless, it has been a significant challenge over the years to improve maternal health care and achieving 100% immunization coverage for the Sabah State Health Department & Ministry of Health. In June 2012, I-Kelahiran (Inovasi Kelahiran) was implemented as part of the effort by the Sabah State Health Department to intervene in the issues of birth discrepancy, delayed reporting of high-risk pregnancy and immunization coverage within the state. It is a computerized birthing system that creates an online storehouse of information for tracking and reporting, with the purpose of reducing duplication, cost and time, and eliminates delays and confusion associated with the

collection or utilization of health information in health institutions, clinics, and hospitals around Sabah. It is hope that with the introduction of a health informatics tool such as I-Kelahiran in Sabah, State Health Department can improve data management between health facilities, inform high-risk cases via various online alert mechanism, improved post-natal tracings, solving birth data discrepancies and achieving 100% immunization coverage, in view of Sabah's vast geographical terrain and long distant to healthcare centers. The implementation of this system is believed to enhance performance and productivity, which leads to better administration of health care management.

Today, various healthcare information systems are used in hospitals and community clinics to assist healthcare professionals in their daily routine with patients. Healthcare information technology has shown to improve quality by increasing adherence to clinical guidelines, enhancing disease surveillance and outbreak management, and decreasing medical negligence and medication errors [3]. The question arises when everyone claims that a newly introduced system is successful. How effective and efficient is it? This has always been a haunting question for most stakeholders and policymakers even though Information and Communications Technology (ICT) is said to be a fundamental tool in healthcare delivery and public health internationally today [4].

There are many ways of assessing the health informatics system, particularly in a complex environment such as hospitals, ranging from using standardized certification system to questionnaire-based survey [5,6]. Many researchers argue that end-users satisfaction is the main variable that contributes to an organizational impact while others say that the ultimate domain would be how cost-effective is a newly implemented system since not all satisfied users are actually happy to use a system and when a system is compulsory or with standard instruction from higher management [7,8]. Delone and McLean [9] proposed a complete assessment of the health information system that should include not only the user satisfaction but the importance of the system, system quality (desirable characteristics of an information system, e.g. ease of use, system flexibility, system reliability, and ease of learning) and information quality (desirable characteristics of the system outputs-management reports) generated by the system. This study aimed to evaluate and study the factors that contribute to the success of a newly implemented Health Informatics System called I-Kelahiran in Sabah State Health Department using the Delone and McLean's model.

Material and Method

A cross-sectional study conducted in Sabah State Health Department was conducted. The Sabah State Health Department has 24 operating hospitals statewide, six Specialist Hospital and 18 District Hospital [10]. Twenty-one hospitals, 4 specialist hospitals and 17 district hospitals, with access to I-Kelahiran were selected. The three main specialist hospitals excluded from the study are Queen Elizabeth Hospital, Queen Elizabeth (II) Hospital and Bukit Padang Hospital in Sabah because do not provide maternal and child health services. The public health division consists of 11 main district health offices with 292 health clinics within the state, whereby all these clinics provide maternal and child health services within the Sabah State Health Department. The level of health care personnel that are involved in this study were matrons, sisters, staff nurses, and community nurses and accounts to approximately 1303 trained staff who are registered and accessed I-Kelahiran system. The nurses have also completed the I-Kelahiran training module as well.

The software design, application, and implementation of I-Kelahiran was done with the support of Hospital Likas and Sabah State Health Department. The existing server in Sabah State Health Department was used. The system was built based on PHP5, MYSQL, CSS JAVASCRIPT, APACHE, AWS WEBSERVER and Heidi 6 Mysql Administrator. The user interface of the system can be accessed at the following URL: http://ikelahiran.jknsabah.gov.my. The end-users are also able to access I-Kelahiran with web browsers via IE7, IE8, FIREFOX, and CHROME Browser that permits javascript and jquery, CSS minimum 1.0, and XML. The platform can be accessed by various networks for an instant, MOHNET, 1GovNET, Streamyx, as well as personal broadbands and even android and safari's Apple mobile devices.

The inclusion criteria for the selection of respondents include those who are currently working under the Department of Obstetrics and Gynecology of Sabah Health Department (matron, sister, staff nurse, and community nurses) why use the I-Kelahiran system. No sampling was done since all the 1.303 respondents who met the inclusion criteria were invited to participate in this study.

The survey instrument consists of two main sections: (1) Socio-demographic attributes of the respondents (e.g. age, education level, computer literacy); (2) Modified questions based on seven domains: System quality, 8 questions [11]; Information Quality, 10 questions [11]; User Satisfaction, 4 questions [12]; Usefulness, 6 questions [13]; System Importance, 5 questions [14]; Individual and Organizational Impact, 18 questions [9, 15-17]. All of the above questions have been used by Seddon and his team in their study [14]. The seventh domain – Effectiveness measured using 7 questions was added to strengthen the evaluation of I-Kelahiran. The response scale for all items was a seven-point packed Likert scale. Higher scores indicated more positive perceptions on I-Kelahiran. All questionnaires were administered in English. The independent variables used were socio-demographic and working profiles (age, service grade, qualification, years of experience in nursing and computer literacy prior to use of I-Kelahiran), system quality (adaptability, availability, reliability, response time and usability), Information Quality (timeliness, accuracy, relevance, format of information generated, completeness, ease of understanding and personalization), perceived usefulness (job effectiveness and productivity), Importance of system, and User satisfaction. The dependent variables used were Effectiveness, Individual impact, and Organization impact.

This study was conducted using a web-based self-administered questionnaire. The questionnaire was designed via an open-source platform that was monitored by the Sabah State Health Department's ICT team in terms of security and firewall. A hyperlink to the web-based questionnaire was sent to all participants via email. In order to overcome user confidentiality, the questionnaires were linked directly to the online web, and the end-users feedback was sent directly to an independent physical server located at the Sabah State Health Department and not to their respective supervisor for data collection and analysis purposes. A Personal Home Page (PHP) based script was uploaded to Sabah State Health Department under the state's firewall security system. The data was kept in a physical server in a binary log format. After the verification process, the questionnaires were then uploaded into the system for all users to view. The data was then saved in a local physical server in order to be extracted into Microsoft excel for data cleaning and data mining purpose before exporting it to Statistical Package for Social Science (SPSS), and Analysis of a Moment Structures (AMOS).

A pilot study of 100 respondents was done to test the reliability and construct validity of the questionnaire. The results from exploratory factor analysis using Principal Component Analysis (PCA) with a Varimax rotation reported the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy was 0.900 (greater than 0.6), and Bartlett's Test of Sphericity (BTS) was significant with $p<.0.01$, indicating the factorability of the correlation matrix was assumed. Based on the Scree plot and eigenvalues greater than 1, 35 items were initially loaded but only 28 items had good factor loading (>0.500) were loaded into four factors orthogonal solution. The solution accounted for 73.35% of the variance, with the first factor explaining. The newly grouped components were named based on the association of the items within the same component. Instead of the five components in the original adapted instrument, only four components were regrouped and adapted based on the findings of this study. They were named Information Quality, Importance of System, User Satisfaction, and Perceived Ease of Use. The factor loading was found ranging from 0.576 to 0.905. The solution accounted for 73.35% of the variance with the first factor explaining the greatest amount of variance (27.12%). The rotation converged in 7 iterations. The Cronbach's alpha coefficients for all items were ranging from 0.832 to 0.964, confirming the adequacy of these items. The three outcome variables also scored good Cronbach's alpha - Individual Impact (0.897), Organizational Impact (0.942), and Effectiveness (0.853).

Statistical Analysis

The data collected was coded and analyzed using IBM Statistical Package for Social Science (version 20) for Windows and Microsoft Office Excel 2010. This included descriptive and univariate analysis. Missing data & outliers were cleaned prior to the analysis to avoid major errors during the

data analysis process. Descriptive analysis was showed using frequency, means and standard deviations tables. For advance statistics, it was done using SPSS AMOS (Analysis of a moment structures) to answer the research questions. The software helps in describing the confirmatory factor analysis, measurement model & structural equation modeling and its model fitting criteria.

In order to ensure that there is no significant variance among different variables, discriminant validity was tested. Discriminant validity indicates to differentiate between one construct and another in the same model by comparing Average Variance Extracted (AVE) and the squared correlation between two constructs. According to Fomell and Larcker [18] the discriminant validity shows the level of square root of AVE should be greater than the correlations involving the constructs.

To evaluate model fitting, a set of fit indices were used based on recommended criteria: a comparative fit index (CFI) and Tucker–Lewis index (TLI) ≥0.90, which showed an acceptable fit of the model; the root mean square error of approximation (RMSEA), where values ≤0.05 can be regarded as an appropriate fit and values between 0.05 and 0.08 as an acceptable fit [19].

The data was treated as interval-level continuous as recommended by Rhemtulla et al. [20], with seven or more scale points, data can be safely treated as interval-level continuous data as long as the data are non-kurtosis and non-skewed.

The Measurement Model (MM) included four latent constructs and each construct had several indicators/items pertinent to its scale. This model revision was carried out by examining standardized factor loadings, standardized residuals, and modification indices (MI) as suggested by Jöreskog and Sörbom [19] and Hair et al. [21].

Ethical approval for this study was obtained from the Ethical Committee of University Malaysia Sarawak, Sabah State Health Department, and the National Medical Research Register (NMRR-14-610-21560), Ministry of Health. All the respondents were briefed via email, and web-based consent was obtained.

Results

Socio-Demographic Characteristics of Respondents

A total of 1,200 respondents participated in this study, with a mean age of 31.96 years (SD=7.761).

Details on socio-demographic and working profile of the respondents are presented in Table 1.

The results of mean score for all components of evaluation including both independent and dependent variables are presented in Table 2.

Table 2. Mean score for all components of evaluation (n=1,200)

Domain	Mean (SD)
Information quality	3.19 (1.20)
Importance of system	4.84 (1.26)
User satisfaction	4.65 (1.56)
Perceived Ease of Use	3.72 (1.34)
Individual Impact	4.18 (1.58)
Organizational Impact	4.25 (1.61)
Effectiveness	4.28 (1.64)
SD = standard deviation	

Table 3 shows the results of initial test models with modification indices and number of items under each variable.

Table 4 and 5 shows the correlation between the independent and dependent variables.

Table 1. Socio-demographic and working profile of the respondents (n=1,200)

Characteristic	n (%)
Age (year)	
30 and below	473 (39.4)
31-40	503 (41.9)
Above 40	224 (38.7)
Nursing grade	
Community Nurse	786 (65.5)
Staff nurse	274 (22.8)
Sister	117 (9.8)
Matrons	23 (1.9)
Nursing experience	
< 5 years	338 (28.2)
5-10 years	373 (31.0)
11-15 years	223 (18.6)
16-20 years	134 (1.2)
>20 years	132 (11.0)
Level of qualification	
Certificate in Nursing	838 (69.8)
Diploma in nursing	311 (25.9)
Degree	47 (3.9)
PhD	4 (0.3)
Computer literacy	1126 (93.8)
Place of work	
Hospital	404 (33.7)
Public Health facilities	796 (66.3)

Table 3. Initial test model for independent and dependent variables

No.	IQ*	IS	US	PU	II	OI*	Ef
Original item	1-10	1-11	1,2,3,4	1,2,3	1-7	1-12	1-7
Final items	1,5,6,9	3,7,9	1,2,3,4	1,2,3	3,4,5	4,6,8	1,5,6,7
Fit indices	**Fit statistics**						
χ^2	0.254 p=0.881	4.537 p=0.033	1.117 p=0.291	0.107 p=0.744	5.990 p=0.014	0.196 p=0.658	5.341 p=0.069
df	2	1	1	1	1	1	2
Normed χ^2	0.127	4.537	1.117	0.107	5.993	0.196	2.671
GFI	1.000	0.997	0.999	1.000	0.997	1.000	0.998
AGFI	0.999	0.985	0.996	1.000	0.980	0.999	0.989
NFI	1.000	0.998	0.999	1.000	0.998	1.000	0.999
TLI	1.002	0.996	1.000	1.003	0.994	1.001	0.998
CFI	1.000	0.999	1.000	1.000	0.928	1.000	0.999
RMSEA	0.000	0.054	0.010	0.000	0.065	0.000	0.037
90% CI_{lowe}	0.000	0.041	0.009	0.000	0.023	0.000	0.000
90% CI_{upper}	0.068	0.069	0.034	0.053	0.118	0.067	0.077

IQ = Information Quality*; IS = Importance of system; US = User satisfactions; PU = Perceived ease of use; II = Individual impact; OI = Organizational impact; Ef = Effectiveness

*Excluded as it did not meet the assumption.

χ^2 = Chi-Squared; df = degrees of freedom

GFI= Goodness of Fit; AGFI=Adjusted Goodness of Fit; NFI= Normed Fit Index; TLI= Tucker Lewis Index; CFI= Comparative Fit Index; RMSEA= Root Mean Square Error of Approximation

Table 4. Correlation between Information Quality, Importance of System, User Satisfaction and Perceived Ease of Use

	Information Quality	Importance of System	User Satisfactions	Perceived ease of Use
Information Quality	1	*p<0.001*	*p<0.001*	*p=0.500*
Importance of System	0.884	1	*p<0.001*	*p=0.006*
User Satisfactions	0.731	0.666	1	*p=0.066*
Perceived ease of Use	-0.024	-0.082	-0.033	1

Table 5. Correlation between Individual Impact, Organizational Impact & Effectiveness

	Individual Impact	Organizational Impact	Effectiveness
Individual Impact	1	*p<0.001*	*p<0.001*
Organizational Impact	0.853	1	*p<0.001*
Effectiveness	0.766	0.892	1

For independent variables (Information Quality, Importance of System, User Satisfaction, and Perceived Ease of Use), the Chi-squared/df was 6.913 and the Comparative Fit Index (CFI) = 0.973, Tucker Lewis Index (TLI) of 0.964, Root Mean Square Residual (RMSEA) was 0.70. However, the correlation between Information Quality and Importance of System was seen to be very high (r=0.93) that could possibly contribute to multi-collinearity. In view of that, the construct Information Quality was dropped. A slightly better value was seen after Information Quality was dropped with Chi-squared/df was 6.323 and the CFI = 0.984, TLI of 0.975, RMSEA was 0.067.

In order to ensure that there is no significant variance among different variables, discriminant validity was tested. Discriminant validity indicates to differentiate between one construct and another in the same model by comparing Average Variance Extracted (AVE) and the squared correlation between two constructs. The R-square value between Information Quality and Importance of System is more than the AVE values for Information Quality and Importance of System. Hence, there is a lack of discriminant validity between Information Quality and Importance of System. The pairwise R-square values are less than the respective AVEs. Hence, there is sufficient discriminant validity between the constructs.

For dependent variables, the measurement model analysis reported the Chi-squared/df was 4.598 and the CFI = 0.992, TLI of 0.988. RMSEA was 0.055. However, the correlation between Organizational Impact and Effectiveness was seen to be very high (0.94) and R squared value was also seen to be high that could possibly contribute to multi-collinearity. As a result, the construct Organizational Impact was dropped which resulted in a slightly better value was seen with Chi-squared/df was 4.572 and the CFI = 0.995, TLI of 0.991. RMSEA was 0.055. The results also indicated the R-square between Organizational Impact and Effectiveness is more than the AVE values. Hence, there is a lack of discriminant validity between Organizational Impact and Effectiveness.

The final path diagram structural model is shown in Figure 1 and the regression weights are presented in Table 6. The p-values were less than 0.001. Hence, all the relationships in the model were significant with good model fitting (a Chi-squared/df was 2.850, CFI = 0.991, TLI of 0.989 and RMSEA was 0.039 with 90% CI of 0.208). Importance of System and Perceived Ease of Use (PEOU) explains 18% of the variation in the overall outcome while Individual Impact and Effectiveness are seen as good indicators of the overall outcome.

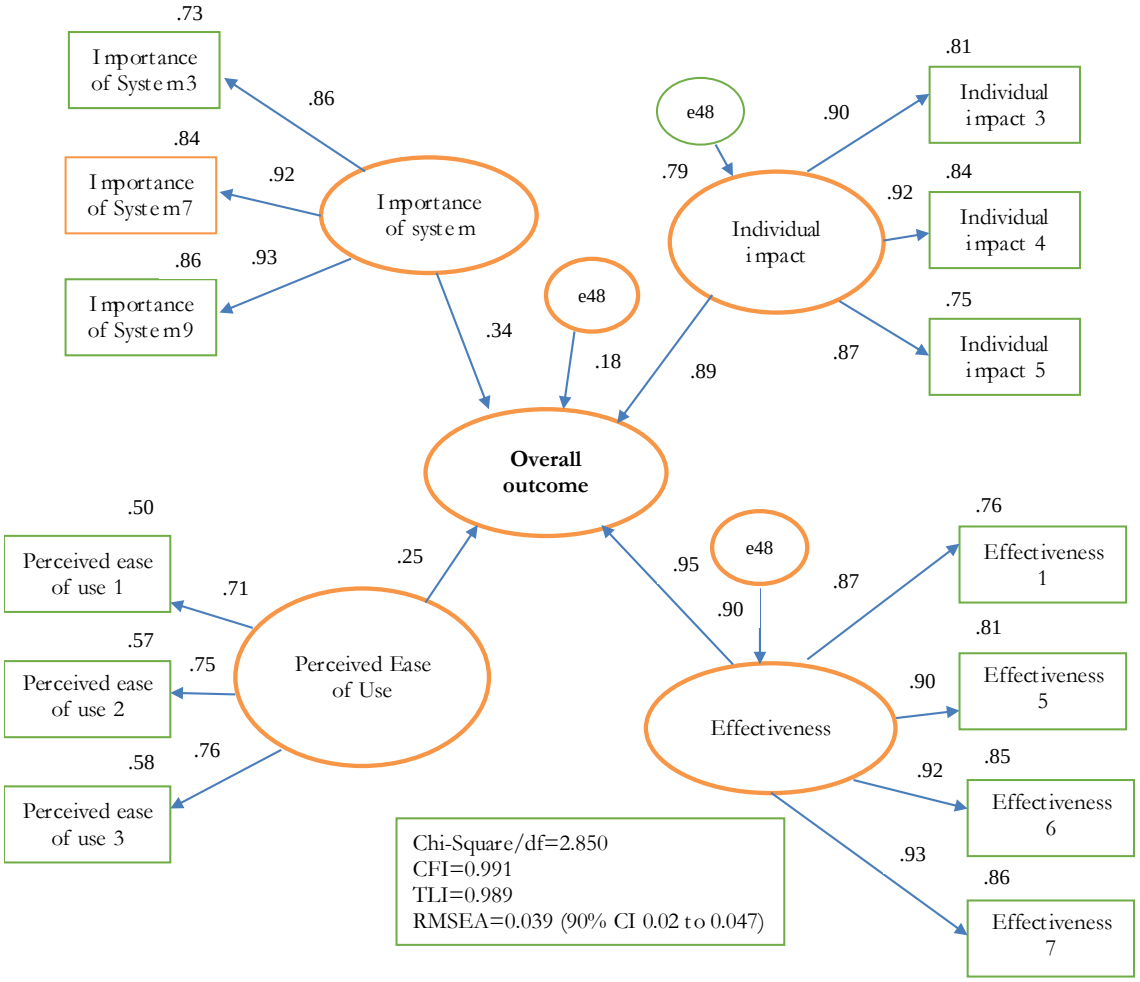

Figure 1. Final Structural Equation Modelling

Table 6. Regression Weights for The Final Model

			Unstd. estimate	S.E.	C.R.	Std. Estimate
Overall_Outcome	<---	Importance of System***	0.262	0.025	10.606	0.341
Overall_Outcome	<---	Perceived Ease of Use***	-0.226	0.030	-7.437	-0.254
Individual Importance	<---	Overall_Outcome	1.000			0.889
Effectiveness	<---	Overall_Outcome***	0.999	0.056	17.742	0.950
*** $p < 0.001$						

Discussion

The structural equation modelling was used to test the theoretical based modified model of the DeLone and McLean [9] to determine whether Information Quality, Importance of System, User Satisfaction and Perceived Ease of Use were good predictors for the overall outcome of a newly implemented health informatics system. The model fit was good with a Chi-Square of 2.850, CFI 0.991, TLI 0.989 and RMSEA of 0.039. Even though DeLone and McLean [9] suggested that there are 5 determinants that contribute to the success of an information system, our study found only 2 main determinants that contribute to an outcome & impact of a Health Informatics System in the Sabah State Health Department. The initial four determinants were Information Quality, Importance of System, User Satisfaction, and Perceived Ease of Use. However, out of the four determinants, user

satisfaction and information quality were discarded in the final model due to poor overall model fitting & highly correlated domains, as explained during the measurement model. Only Importance Of System and Perceived Ease Of Use was seen to be good predictors to the overall outcome of a newly implemented health informatics system. Importance Of System had the strongest loading factor as all items in the domain were (>0.85) as compared to Perceived Ease Of Use (>0.71) (refer to Figure 1). The finding of this research was consistent with the theory by DeLone and McLean [9], Seddon and Kiew [22] that importance of system measures the success that contributes to the outcome and impact of an organization. It is also said that other domains of perception such as User Satisfaction and Information Quality might overshadow this important component. Therefore, by including and measuring the importance of a system with other variables, we will be able to control other confounding factors in order to measure how successful the outcome of a health informatics system will be.

Perceived Ease of Use also fits well in the final model as explained in the initial measurement model as well. This could be due to the extensive research done in regards to this domain and studies by Hamid et al. [23] have also indicated that Perceived Ease of Use is a crucial domain and has an impact on the overall intention to use of an information system.

The final structural model tells us that 18% of the variation in the overall outcome of a health informatics system is explained by the Importance of system and Perceived Ease of Use. The Importance of System gave rise to a direct causal relationship of 34% to the overall outcome of an implemented health informatics system while Perceived Ease of Use contributes to about 25% towards the outcome of a newly implemented system. Seddon & Kiew [22] mentioned that different user interprets a system differently and it is crucial to gather those different opinions in order to draw a more substantial argument. Both this component, Importance of System & Perceived Ease of Use were seen as an important measure of overall outcome among healthcare personnel as it determines the success rate of the newly implemented system. He et al. [24] also mentioned that the Perceived Ease of Use and Importance of System reflects a healthcare personnel's view on how the system could increase their job effectiveness in daily healthcare setting irrespective if the information system is mandatory or not. This explains why both this domain had a proper model fitting and strongly influences the overall outcome of a health information system.

In this study as well, the final structural model also showed that Individual Impact & Effectiveness is a good outcome variable while Organizational Impact was discarded due to high R squared value that suggests multi-collinearity in relation to Individual Impact and Effectiveness as explained in the measurement model stage. It is said that Individual impact is the result of an information system towards the behavior of the recipient as well as the individual productivity of the end-user while effectiveness is about one reaching its desired objective in using the system. If one believes that the information of the newly implemented system has no value and does not reach his or her desired objective, they will not value the system as important and this phenomenon was also described by Wahdain and Ahmad [25].

When an individual feel that the system is effortless both physically or mentally, they will tend to use the system more frequently as it has a great individual impact on them, especially if they believe the system is effective that can help to achieve their daily goals. In this case, I-Kelahiran was seen to be able to help the respondents to organize the birth data, trace high-risk pregnancies and even track immunization schedule.

In nursing professionals especially, Holden et al. [26] said that nurses might have poor perceptions of a system as well since their clinical work might exceed the time for them to use a system. Hence only if end-users feel that a system could increase their job effectiveness, facilitate and automate their daily working process, the newly implemented system is seen as successful. This could be the reason why Individual Impact; the effect of the system towards the nurses and the Effectiveness domain; reaching the desired objective of a newly implemented system, was seen as a good outcome variable in order to measure the success of I-Kelahiran, a health informatics program in Sabah State Health Department

It was recognized that our study had few limitations. Firstly, the study was conducted in Sabah on a specific system. Therefore, findings may not be applicable or extended to other states in Malaysia or other systems. Secondly, the study was unable to evaluate and compare the pre and post effect of

I-Kelahiran as there was inadequate documentation prior to the implementation of this health informatics system in Sabah. Thirdly, there could be possibly being respondent bias in this study because it was based on the perception of the respondents. However, it is reasonable to suggest that the findings of this study could provide basic knowledge on evaluating a health informatics system in the Ministry of Health, Malaysia.

Conclusion

The finding in this study clearly indicates that the importance of system and perceived ease of use are strong predictors towards the individual impact and effectiveness of a newly implemented system. These findings serve as a basis to help in the implementation of a similar health information system in other health facilities in Malaysia. Policymakers will be able to utilize this model as a tool to identify the factors that contribute to the success or the failure of a newly implemented health informatics system. Currently, I-Kelahiran has been implemented in several states in Malaysia. Therefore, policymakers should pay more attention to user interface, user-friendly platform and individual benefit that could automate the healthcare personnel daily work as this is seen as a core quality that a health informatics system should have since this will finally affect the intention and the frequency to use the newly implemented system.

In a nutshell, evaluation of any Health Informatics program should be done progressively. We should not stop at the implementation phase as different phases of process evaluation of an Information System might give us a different result both on the human aspect as well as the software component due to the reason that human creates the machine for another human to use, and this could contribute to a complex degree of uncertainties that needs to be evaluated in-depth as well.

Conflict of Interest

There is no conflict of interest relevant to this manuscript.

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Competing Interest

No competing interest is declared by the authors.

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