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Approach For Optimizing The Preventive Maintenance of Complex Repairable Systems Based On The Intensity Reduction Model (IRM): Case Study On an Air Compressor

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Abstract—Planning a preventive maintenance (PM) periodicity for complex repairable systems (CRS) is the main objective of any reliability modeling. Consequently, manufacturers often resort to the renewal process (RP) and nonhomogeneous Poisson process (NHPP) which are unable to take into account the dynamic reliability of the system and the influence of certain covariates on its proper functioning. In this paper, we consider the Intensity Reduction Model (IRM) for an approach to optimize the frequency of preventive maintenance (PM) of an air compressor that has been in operation for nearly three years in the LPG (liquefied petroleum gas) company of NAFTAL (subsidiary of the SONATRACH Group, Algeria). The objective of using this intensity reduction model (IRM) is to describe the future performance of the system according to the effectiveness of the maintenance actions in order to provide a decision support tool for the determination of the better periodicity of preventive maintenance over a fixed time horizon and on the basis of an economic criterion representing the average cost generated by each recommended PM interval. The estimation of the parameters and the validation of this model is done by the maximum likelihood estimation (MLE) which makes it possible to develop, on the MATLAB programming language, a simulation algorithm making it possible to reflect the frequency which has the average cost the most optimal.

Keywords— complex repairable systems (CRS), economic criterion, fixed time horizon, intensity reduction model (IRM), maximum likelihood estimation, optimize the frequency of preventive maintenance (PM).

Introduction

Preventive maintenance is a very important activity for complex systems that must ensure continuous production without any corrective maintenance action that could penalize the proper functioning of an industrial process and therefore affect the brand image of the company. However, the management of preventive maintenance (PM) uses several mathematical models which are traditionally expressed in the form of a block replacement policy or age-based replacement policy following a renewal process (PR) assuming that the repair is perfect (maximum) and that the system takes its state as new after each replacement (i.e. as-good-as-new) [1]–[5] . However, if the periods between failures are not stationary, the renewal process (RP) is not the appropriate model. Another maintenance policy based on minimal repair (NHPP) can be a solution for multicomponent systems where the repair is minimal and consists of restoring the system only to its state before the failure [6]–[10]. The inevitable change in failure intensity after each repair makes this model an approximation that is often difficult to interpret because replacing or repairing a small number of components does not necessarily improve the reliability of the entire complex system.

Based on imperfect repair models, a third replacement policy can be conditioned by a model describing the degree to which a repaired system can be restored to like-new condition. This type of model assumes that the system is imperfectly renewed and its state is expressed proportionally to the degree of repair efficiency as shown in Fig. 1 [11].
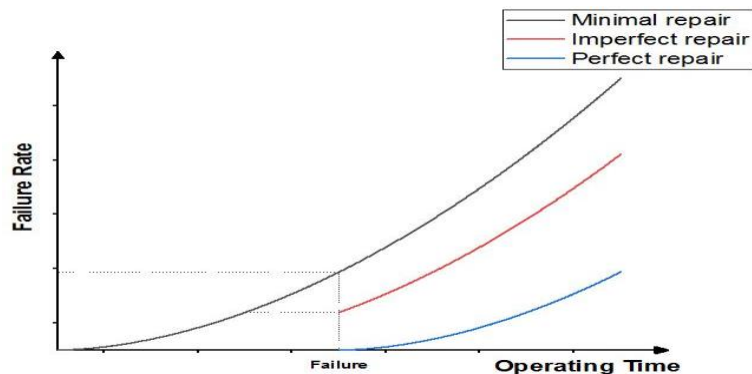

FIG. 1. EXAMPLE OF FAILURE RATE CHANGE FOR MINIMAL, IMPERFECT AND PERFECT

The imperfect repair process has been discussed by several works. Brown and Proschan [12]–[14] considering that the intervention is either a maximal repair with probability (p), or a minimal repair with probability (1-p). However, this assumption requires other models to partially reduce the intensity after each repair.

Imperfect repair according to the Kijima model [15] was expressed by virtually changing the age of the system after each corrective maintenance (CM) action by an additive or multiplicative age reduction factor. Kijima's model is not responsive to modeling the effectiveness of maintenance actions because repairing the failed component does not reduce the age of the system by the time other components are no less likely to fail [16] . The virtual age model also exhibits negative values of the failure intensity function if the additive form of the virtual age factor is used [17], [18]. Other imperfect repair models have been proposed in the literature such as quasi-RP, trend RP, etc., but they are not suitable to apply to complex repairable systems constituting a large number of components [19], [20].

Based on the Cox proportional intensity model (PIM) [21], an extension of NHPP which consists in correcting the basic intensity function at each corrective maintenance action to avoid the minimal repair hypothesis was considered. Then, other authors [22], [23] took advantage of these ideas to propose the intensity reduction model (IRM) avoiding the unnecessary complexity and the lack of the physical sense of the previous models. The proposed variant of IRM involves multiplicative scaling of the intensity function at each repair. This allows the variable of preventive maintenance (PM) of the system to be linked to the natural behavior of systems improving or deteriorating over time. Imperfect maintenance models have been addressed by several authors [24]–[27] whose objective is to program an optimal frequency of PMs based on the history of the system. The optimal frequency of PMs has often been argued by an economic criterion, particularly for systems that operate continuously [28]–[31].

In this study, we are interested in the intensity reduction model (IRM) to describe the dynamic behavior of an air compressor taking into account the degree of effectiveness of preventive maintenance actions. This model will be examined for two probability distributions representing the log-linear law and the power law by validating, according to the maximum likelihood estimation (MLE), the one that reflects the best quality of fit. Finally, a simulation algorithm will calculate over a fixed time horizon, and on the basis of an economic equation, the average cost for each proposed interval [32].

Model Specification

Nonhomogeneous Poisson Process (NHPP)

The nonhomogeneous Poisson process (NHPP) or minimal repair ensures that the system is restored to its state just before the failure and must satisfy the following conditions for $0<K<t$:

- $N(0) = 0$ System initialization at t = 0.

- $N(t) - N(K) \perp N(K)$ Independence of increments.

- $\{N(t) - N(K)\} \sim \mathrm{P_0}\left\{\int_K^t \lambda(u)d(u)\right\}$ Poisson failure pattern.

The nonhomogeneous Poisson process is characterized by conditionally independent increments and times between failures that occur with intensity λ(t) [33]:

$$\lambda(t) = \lim_{\Delta \to 0} \frac{\{n(t+\Delta) - n(t) \geq 1 | H(t)\}}{\Delta}$$

Where *H(t)* represents the process history up to time t, with t not included, and n(t) is the number of time intervals t.

The Intensity Reduction Model (IRM)

The Intensity Reduction Model (IRM) involves multiplicative scaling of intensity with each failure and repair. This model can be expressed as an NHPP with an intensity function:

$$\lambda(t) = \lambda_0(t)\prod_{i=1}^{N(t)} \rho_i$$

Where $\lambda_0(t)$ is the basic function which can take several reliability laws and ρ_i are constants representing the intensity of the multiplicative scaling factor. In our study we assume that these constants are equal, so $\rho_1 = \rho_2 = \ldots\ldots = \rho_{N(t)} = \rho$ for some unknown parameter. However, the most used basic failure intensity functions in the literature to model the complex repairable systems (CRS) are shown in Table I [34]–[36].

TABLE I.   DIFFERENT BASIC INTENSITY FUNCTIONS

Basic intensity functions	Expressions	Parameter characteristics	
Power law intensity	αt^{β}	$\alpha > 0$	$\beta \in R$
Log-linear intensity	$\alpha \beta^t$	$\alpha > 0$	$\beta > 0$

The IRM is a natural model of systems improving or deteriorating over time and provides a perfect description of their physical condition [37]. Based on the history of system failures, the estimation of model parameters is done by the maximum likelihood approach. Defining events as PM or CM actions and assuming that we observe actual event times t_k in the interval (0, T], with corresponding censoring indicator variables C_k, where:

$$c_k = \begin{cases} 0, \text{No failure at time } t_k \ (PM) \\ \\ 1, \text{Presence of failure at time } t_k \ (CM) \end{cases}$$

For k= 1, 2, ……n, where n represents the number of maintenance actions, the likelihood function for the IRM can be given as follows:

$$L\{\lambda(t); H(t)\} \propto \left\{ \prod_{k=1}^{n} \lambda(t_k)^{c_k} \right\} \exp\left\{ -\int_0^T \lambda(t)dt \right\}$$

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And so the log-likelihood function is:

$$LL\{\lambda(t); H(t)\} \doteq \sum_{k=1}^{n} c_k \log(\lambda(t)) - \int_0^T \lambda(t)dt$$

☐☐

Substituting the failure intensity function by (2), we find:

$$LL\{\lambda(t); H(t)\} \doteq \sum_{k=1}^{n} c_k \{\log(\lambda_0(t)) + N(t)\log(\rho)\}$$

$$- \sum_{k=0}^{n} \left\{ \rho^{N(t_k)} \int_{t_k}^{k+1} \lambda_0(t)dt \right\}$$

☐☐☐

With N(t) the number of preventive maintenance actions. Since this function does not accept an analytical solution, numerical approaches, such as the trust region approach, the Newton-Raphson method, etc., are necessary. In this article, we used the trust region approach to estimate the parameters of the models [38], [39]. The latter make it possible to avoid the use of complicated derivatives of (5). The maximum likelihood results are used to choose the best fitting model by referring to the likelihood ratio (LR) test. Asymptotically, this ratio test has a Chi-square distribution and is based on two hypotheses:

- The null hypothesis H_0: it assumes that there is no difference between the two models studied.
- The alternative hypothesis H_1: it assumes that the variable added to the basic model will be significant and may add more information.

The level of statistical significance is expressed by the p-value of the Chi-square distribution which varies between 0 and 1, of which a minimum p-value (p-value<0.05) makes it possible to reject the null hypothesis by keeping the alternative hypothesis. The formula for the likelihood ratio (LR) test can be given as follows [40]:

$$LR = -2\ln\left(\frac{L_2}{L_1}\right) \cong \chi^2(P_1 - P_2)$$

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Where L_1, L_2 are the likelihood functions and $P_1 > P_2$ are the number of model parameters. The goodness of fit of the models can also be judged by the value of the maximum likelihood, of which the high value reflects the best model.

PM Scheduling

The optimization of PM frequency is done based on the results of the best reliability model. The latter makes it possible to simulate failure times x based on the conditional probability density function $f(x|t, \lambda(t))$. Taking the log-linear model as an example, this function is given as follows:

$$f(x|t, \lambda(t)) = \lambda_0(t+x) \left(\prod_{j=1}^{N(t)} \rho_i \right)$$

$$\times \exp \left\{ - \left(\int_t^{t+x} \lambda_0(u)\, du \right) \left(\prod_{j=1}^{N(t)} \rho_i \right) \right\}$$

Replacing $\lambda_0(t)$ with the intensity function of the log linear law, we find for x>0:

$$f(x|t, \lambda(t)) = \left(\prod_{j=1}^{N(t)} \rho_i \right) \times \alpha \beta^{t+x}$$

$$\times \exp \left\{ - \frac{\left(\prod_{j=1}^{N(t)} \rho_i \right) \times \alpha}{\log(\beta)} \left(\beta^{t+x} - \beta^t \right) \right\} \qquad (8)$$

The inverse transform method makes it possible to obtain the failure time x by exploiting the cumulative distribution function corresponding to (8) which is given by:

$$F(u|t, \lambda(t)) = \int_0^x f(u|t, \lambda(t))\, du$$

$$= \left(\prod_{j=1}^{N(t)} \rho_i \right) \times \alpha \beta^t \exp \left(\frac{\left(\prod_{j=1}^{N(t)} \rho_i \right) \times \alpha}{\log(\beta)} \right)$$

$$. \int_0^x \beta^u \exp \left(- \frac{\left(\prod_{j=1}^{N(t)} \rho_i \right) \times \alpha}{\log(\beta)} \beta^{t+u} \right) du$$

After simplification, we find:

$$F(u|t, \lambda(t)) = 1 - \exp\left(-\frac{\left(\prod_{j=1}^{N(t)} \rho_i\right) \times \alpha}{\log(\beta)}\left(\beta^{t+x} - \beta^x\right)\right)$$

    □□□□

□□□

If we define U(0,1) a pseudo-random number *p=1–F(x|t, λ(t))*, the failure time x can be given as follows:

$$x = \log\left(1 - \frac{\log(\beta)}{\left(\prod_{j=1}^{N(t)} \rho_i\right) \times \alpha\beta^t}\log(p)\right) / \log(\beta)$$

□□

This allows us to generate random failure times. These are compared with the PM interval set at the start. If this time is less than the fixed PM interval, a failure is counted and the values of the variables are updated. The time to next failure is sampled again and continues until the time of the next failure exceeds the length of the selected PM interval. The simulation algorithm only stops when the cumulative time exceeds the predefined time horizon. The average number of failures is counted over k=1000 (or more) executions and the cost per unit time is estimated for this PM interval. The expected cost per unit time over k simulation runs is estimated as follows [28], [29], [41],[42]:

$$C(L) = \frac{\sum_{i=1}^{k} c_{pm}^i + v_i c_{cm}^i}{kL}$$

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Where:

C^i_{pm} and C^i_{cm} are average PM and CM cost values based on historical data.

v_i: The number of failures.

Modeling Application

In order to show the usefulness of the intensity reduction model (IRM), we considered an air compressor having a vital role in the production process of liquefied petroleum gas (LPG) within the NAFTAL company (SONATRACH). The modeling is done by considering the nonhomogeneous Poisson process (NHPP) and the intensity reduction model (IRM) with the log-linear law and the power law. Based on the actual failure history of the air compressor shown in Table II, these two models will be compared to choose the one that represents the best quality of fit. Events representing a preventive maintenance (PM) action are noted by an Asterisk in Table II.

TABLE II.   AIR COMPRESSOR FAILURE HISTORY

Event Number	System Age	Event Number	System Age	Event Number	System Age
1	16*	23	260*	45	520
2	31.5*	24	274*	46	525.5*
3	45*	25	290*	47	541*
4	60.5*	26	306*	48	556*
5	68.5	27	320*	49	571.5*
6	74.5*	28	324.5	50	585*
7	75	29	336*	51	593
8	91.5*	30	351.5*	52	599*
9	96	31	357.5	53	605
10	112*	32	366.5*	54	612.5
11	126*	33	376.5	55	620*
12	139.5*	34	388*	56	635.5*
13	154.5*	35	403.5*	57	651.5*
14	170*	36	417.5*	58	666*
15	186*	37	434.5*	59	669.5
16	191.5	38	449*	60	681.5*
17	199.5*	39	466*	61	697*
18	215.5*	40	474.5	62	712.5*
19	218	41	480*	63	718.5
20	229.5*	42	482	64	726.5*
21	239	43	495.5*	65	743*
22	244.5*	44	511.5*		

Assuming that the corrective maintenance actions (CM) are minimal, the estimation results by the maximum likelihood approach on the MATLAB programming language is presented in Table III.

TABLE III.   ESTIMATION OF MODEL PARAMETERS

Reliability model	basic intensity function	Estimated Log-Likelihood	Model parameters		
			$\hat{\alpha}$	$\hat{\beta}$	$\hat{\rho}$
NHPP	Power law	−81.04	0.009	0.158	/
	Log-linear	−81.15	0.02	1.01	/
IRM	Power law	−80.99	0.005	0.336	0.988
	Log-linear	−62.42	0.0175	1.23	0.042

It is noted that the log-linear law gave the greatest value of the log-likelihood for the intensity reduction model (IRM) which implies that it is the most appropriate law to model the behavior of the air compressor. The intensity reduction model also showed that preventive maintenance (PM) actions reduce the intensity of the failure with a degree of efficiency $\rho=0.042$. Since the value of the shape parameter β is greater than 1 ($\beta=1.23$), the air compressor follows a wear (or aging) behavior. Fig. 2 shows the evolution of the failure intensity function by the intensity reduction model (IRM).
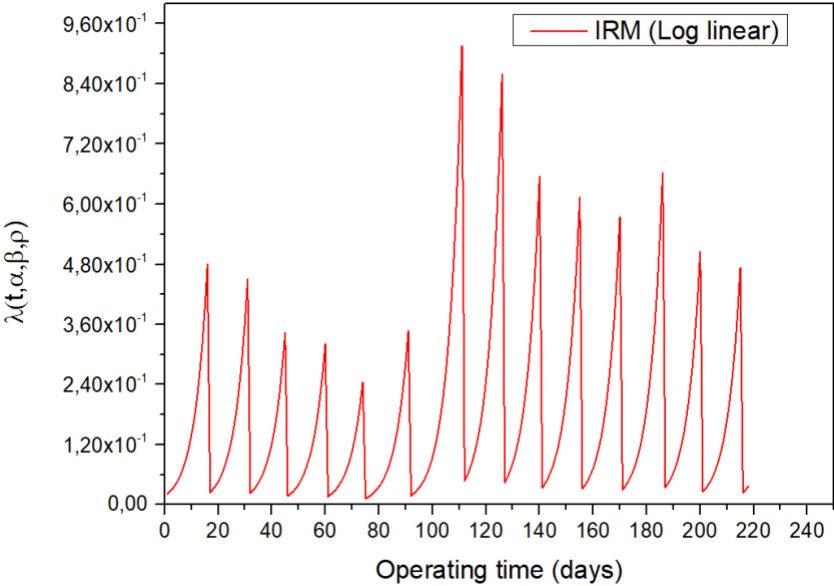
FIG. 2. BASIC LOG-LINEAR IRM FIT TO AIR COMPRESSOR.

It can be seen that the failure intensity function increases with time. However, the value of the multiplicative scaling factor ρ= 0.042 considerably reduces the intensity of the failure with each preventive maintenance action. The change in the behavior of the air compressor is not evident in the nonhomogeneous Poisson process (NHPP) as shown in Fig. 3.
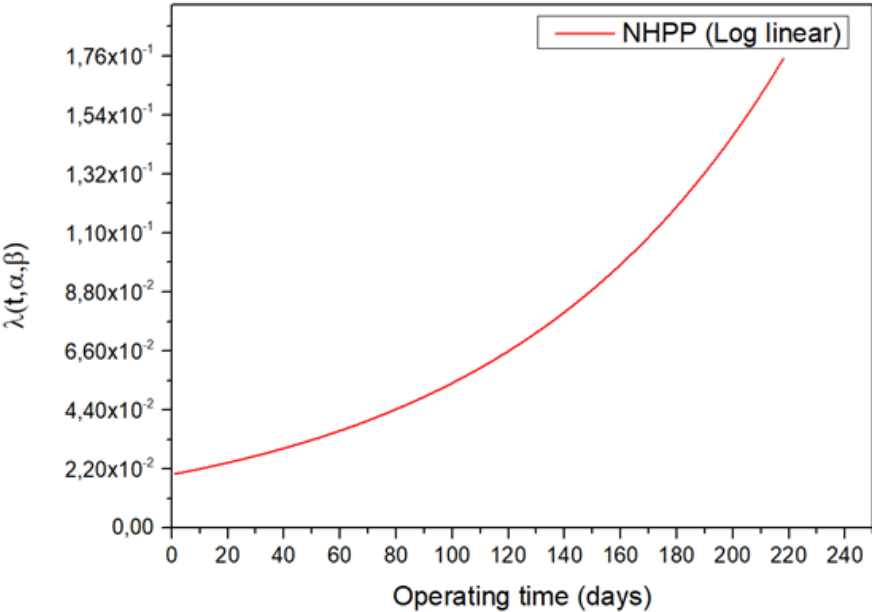
FIG. 3. BASIC LOG-LINEAR NHPP FIT TO AIR COMPRESSOR.

The quality of fit of the IRM for the log-linear law can also be evaluated by the likelihood ratio test (LR) $LR = -2 \times -(81.15 + 62.42) = 37.46$ which gave us a level of significance (p) less than 0.01 compared to the upper tail of a $\chi^2(2)$ distribution. This value shows that IRM provides more information on the behavior of the compressor.

Results and discussion

After constructing the appropriate reliability model of the air compressor and finding that preventive maintenance actions are effective ρ <1, one can proceed to optimize the frequency of preventive maintenance (PM). Since the optimization approach proposed in this study is based on the economic criterion, it is necessary to specify the cost generated by each maintenance action. Taking the number of gas cylinders lost per maintenance action as an optimization criterion, the preventive and corrective maintenance action generates respectively a loss of 400 and 1033 Gas cylinders according to the average time lost for each type of maintenance.

The air compressor is subject to a preventive maintenance (PM) frequency every 15 days. For this purpose, the simulation will be started with an interval of one (01) day, then, the progressive lengthening of the PM interval will allow us to choose the best frequency of the PMs of the air compressor. The unknown parameters of the reliability models used are replaced by their maximum likelihood estimators. Using the MATLAB programming language, a simulation algorithm examines the predictive reliability of the repairable system over a five-year horizon and for several PM scenarios by evaluating the total cost of each of the many repetitions. The average costs of the different simulated PM intervals are presented in Table IV.

TABLE IV.   PM PLANNING SIMULATION RESULTS

PM period (Days)	Average cost (Gas cylinders /MP × 5 year time horizon)	
	Imperfect repair (IRM)	*Minimal repair (NHPP)*
1	749610	889551
2	386780	529739
3	268180	413530
4	210900	359970
5	178820	328559
6	160030	311647
7	149410	299484
8	**145310**	294629
9	147130	291363
10	155640	290296
11	173510	**290104**
12	207330	292892
13	275520	294841
14	452230	299309
15	1634400	303376

It is clearly evident that the frequency of eight (08) days reflects the lowest average cost with 145310 Gas cylinders /PM over a period of five (05) years. This periodicity represents the lowest point of the economic curve shown in Fig. 4. It can be seen that the average cost according to the different periodicities examined decreases until the periodicity of eight (08) days where it begins to increase constantly for all the other periodicities. Monitoring this frequency will ensure a balance between preventive and corrective maintenance actions.
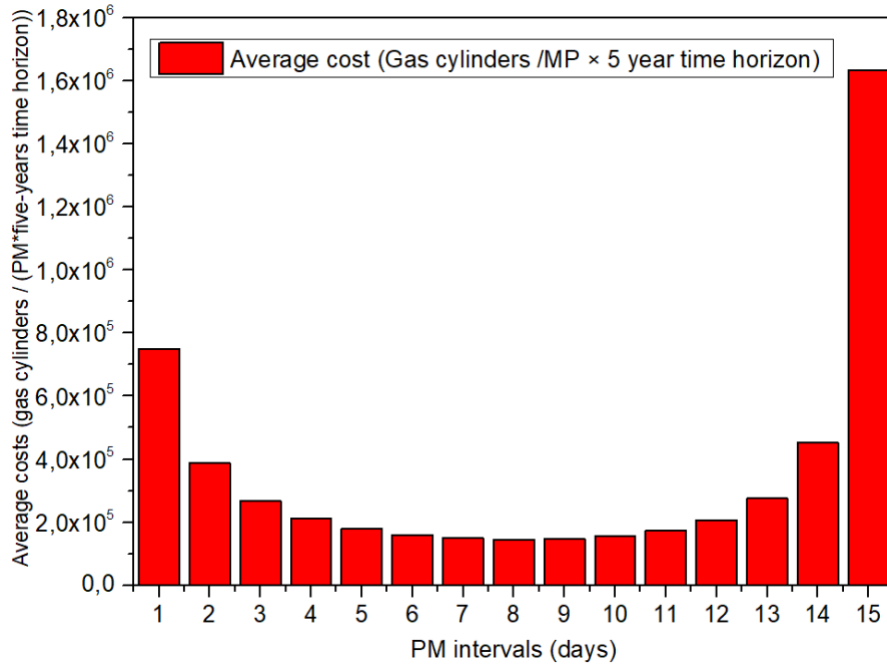
FIG. 4. COST CURVE FOR DIFFERENT MP INTERVALS (IRM).

Given that the NHPP is a particular case of the IRM where the multiplicative scale factor is equal to 1 (minimal repair), we tried to compare the results of optimization by the IRM model with those of the NHPP. We note, as shown in Table IV, that the average costs of the simulation with the NHPP are higher than that of the IRM. This can be interpreted by the fact that the simulation with the NHPP generates more corrective actions because of the zero effectiveness of preventive maintenance actions ($\rho=1$). However, Fig. 5 shows the same trend of the economic curve for the simulation with the NHPP with an optimal periodicity of 11 days. This model did not reflect the best fit quality and therefore we keep the results of the optimization by the intensity reduction model (IRM).
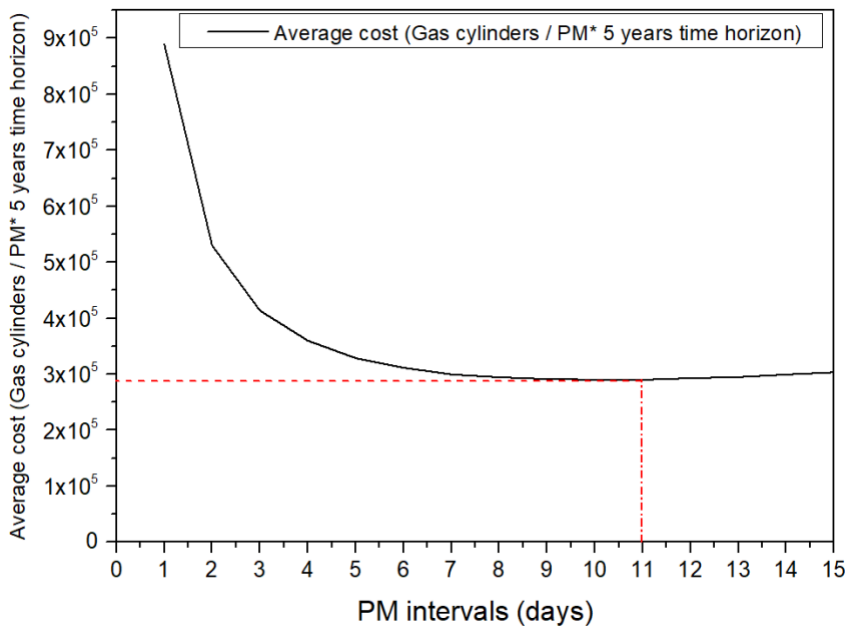
FIG. 5. COST CURVE FOR DIFFERENT MP INTERVALS (NHPP).

Conclusion

In this study, we considered an approach to optimize the preventive maintenance (PM) of an air compressor based on the dynamic modeling of its behavior. Using the maximum likelihood estimation (MLE) and the likelihood ratio test, the intensity reduction model (IRM) with the log-linear law allowed us to confirm the wear behavior of our system with a shape parameter $\beta=1.23$ as well as an effectiveness of the preventive maintenance actions expressed by a value of the multiplicative scale factor less than 1 ($\rho=0.042$). This result allowed us to optimize the periodicity of preventive maintenance by programming on MATLAB. The periodicity proposed for the air compressor has a duration of 8 days with an average cost of 145310 (Gas cylinders /PM over a period of five (05) years).

The main contribution of this preventive maintenance optimization approach revolves around its ability to consider a practicable model such as the intensity reduction model (IRM) allows to express the effectiveness of maintenance actions and capable of be extended to consider other models, as a basic intensity function, like the Kijima or virtual age model. Thus, the flexibility of the reliability model makes it possible to optimize the periodicity of preventive maintenance by considering other replacement policies in addition to those based on imperfect repair models. This widens the choice to the industrial which is often conditioned by the covariates of the system.

Short biography

Professor Abdelaziz Lebied is a Teacher-researcher at Constantine 1 University. He has his doctorate in the field of mechanical engineering and is interested in themes related to the analysis and modeling of the mechanical behavior of intelligent orthotropic materials under various stresses. His latest work focuses on the analysis of failures of complex repairable systems and the optimization of their maintenance policies.

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Faculty member perceptions at Kuwait University regarding the disciplinary accountability in 2019 "Governmental Universities Law": A Delphi Study

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Abstract:

Objectives: This study explored faculty member perceptions regarding the enforcement of disciplinary accountability in Governmental Universities Law at Kuwait University. Method: Using the Delphi technique, the researchers purposefully selected a sample of 12 Kuwait University faculty members, gathering data on their expert perspectives using semi-structured interviews and closed questionnaire, with four Delphi rounds in total. Results: The results showed strong agreement amongst participant perceptions, with the most important being: (a) disciplinary accountability articles in the law consider the common good without sacrificing the rights and duties of faculty members; however, (b) there are shortcomings in certain disciplinary guarantees; and (c) some disciplinary articles relating to disciplinary action are ambiguous. Conclusion: Based upon these results, relevant recommendations were provided.

Keywords: Higher Education law, disciplinary accountability, public universities law, Kuwait University, Delphi technique.

The main coordinates of domestic violence in Romania: What have we learned from the pandemic?

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Abstract:

Violence in the couple relationship has a major impact not only on the victim and his family, but on the entire society taken as a whole. Thus, the main objective of this study is to identify and analyze the main characteristics of family aggressors from the perspective of the victims of social services specialized services. Also, in the context of the COVID-19 pandemic, cases of domestic violence have increased both in Romania and in many other countries in the world. With the declaration of the state of emergency in Romania, between March 16 and May 15, 2020, amid the imposed quarantine and social distancing, as main forms of protection of public health and limitation of COVID-19 virus infection (SARS- CoV-2), both abuse and intimate violence are intensifying. Thus, the aim is to identify the problems faced by both the victims in trying to defend themselves from the aggressor, and the competent authorities in the process of intervention and subsequent monitoring of cases.
The study is based on six focus groups conducted at the headquarters of the six Directorates-General for Social Assistance and Child Protection in each sector of Bucharest, between 13.01.2020 and 07.11.2020.

The universe of research has consisted of the victims of violence, beneficiaries of the specialized state services in the field of social assistance, who have benefited from the services provided by the speculative institutions in social care, over the past three years, between the ages of 23 and 56.

The main findings of this study highlight the important issues: a) discovering and analyzing the main defining characteristics of the family aggressor's portrait, b) identifying the main causes of the conflict between the couple's partners, in the COVID-19 pandemic context, c) analyzing the factors favoring the appearance and maintenance of the aggressions in the couple, d) identifying the main characteristics of the dynamics of the relationship between the victim and the aggressor.

This study is useful in identifying factors favoring the emergence and maintenance of aggression and violence in the marital couple, as well as a better knowledge of the aggressor's motivations in order to design new methods and techniques of work and intervention with victims and aggressors.

Keywords: aggressor, victim, pandemic, violence.

Movement towards the sustainability of educational institutions in Thailand

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Abstract

Presently, higher education institutions in Thailand are increasingly aware of sustainability and are proposing institutional-level policy directions as mechanisms to drive university development into the 21st century. This article describes a survey study and a synthesis of knowledge gathered from documentary research and partial participant observation, focusing on policies and operations of universities located in the city. It covers challenges spanning educational, health, and social-environmental dimensions. The primary objective of this research is to extract lessons and reflect on the sustainability movement of higher education institutions in Thailand. The key findings include the following. 1) Thai higher education institutions utilize structural mechanisms to control the direction of sustainability through sustainable social development strategies and social engagement. This structural mechanism plays a crucial role in setting the agenda for managing human resources at the micro-level of university operation, particularly in teaching, research development, and creating spaces to support social activities, especially in healthy spaces, as part of social engagement. 2) The involvement of students in driving the sustainability of higher education institutions in Thailand is highly emphasized. Students are significantly motivated by fostering sustainability through sustainable social development strategies and university social engagement, as demonstrated through the curriculum of general education courses. The crucial point lies in providing students with opportunities to think critically and creatively, leading to the creation of works that respond to sustainable development and can be implemented in practice. However, universities in urban areas face limitations in translating creative ideas into practical actions due to physical space constraints and surrounding urban communities. Therefore, initiatives to promote sustainability among students often involve utilizing university spaces as centers for driving sustainability efforts.

Keywords: sustainability, higher educational institutions, Thailand

Introduction

Higher education institutions are considered to be one of the social institutions that are important in cultivating social learning behavior. In 2024, Time Higher Education published the sustainability ranking of higher educational institutions through the achievement of the United Nations Sustainable Development Goals (SDGs). The top 5 universities in Thailand with the highest sustainability rankings are Mahidol University (19th in the world), Chulalongkorn University (43rd in the world), Chiang Mai University (75th in the world), Thammasat University (81st in the world), and Asian Institute of Technology (101-200th in the world). However, Srinakharinwirot University is another university to watch because it offers a wide range of fields of study and is in line with the SDGs (Times Higher Education, 2024, Online).

Universities in Thailand are becoming more aware of sustainability as a result of higher education, science, research and innovation policies and strategies aimed at realizing sustainability in practice. Thailand is one of the countries in Asia that has made great efforts to drive sustainability, such as having a 3R waste management project to create sustainability in universities (Chaiya & Ahmad, 2021; Filho & et.al., 2021; Tangwanichagapong, Nitivattananon, Mohanty, & Visvanathan, 2017).

This study aims to explore and synthesize the status of higher education institutions in Thailand through driving sustainability as a strategic issue in accordance with the policies of the Ministry of Higher Education, Science, Research and Innovation. The researcher chose the case study as a university located mainly in the Bangkok metropolitan area. This research will help lead to the design of policy actions that will be part of driving Thailand to achieve its goals. SDGs in the future.

Methods

This research is a qualitative research that relies on documentary research and partial participant observation. There is a research area at a university in the Bangkok metropolitan area. The research is in accordance with the ethical

guidelines for human research. Therefore, the name of the university that studied is not mentioned in this article. In documentary research and participatory observational studies. I have a fieldnote to record the data obtained from each study. After receiving the information, the researcher synthesized the data systematically. Then, a content analysis is performed to present the research results in the next topics.

Result

The research results were presented under the following topics:

Structural mechanisms to control the direction of sustainability

Universities in urban areas have taken the achievement of the SDGs very seriously, as evidenced by the choice of sustainability in their strategic plans. However, the structural mechanism that is the result of the ministry's policies related to higher education has also had a great effect at universities. Choose to design the university's policies in line with the goals. In addition, the rankings by Time Higher Education itself are important in setting the goals of sustainability in universities through indicators that are designed to be evaluated and ranked. These structural issues help to show that driving sustainability goals in universities straddles the line between local and international. The researchers presented a comparison of the similarities and differences of the implementation of the University Sustainability Goals as case studies in Table 1.

Table 1. The Implementation of the University Sustainability Goals

Global sustainability goals	National sustainability goals	Local sustainability goals		
		Universities Case	Sustainability goals	Certified Green University
University supports sustainability on a global level	Prepare Thai people for the 21st century by developing an economy that provides widespread opportunities, a stable society, and a sustainable environment while strengthening cutting-edge innovations on a global scale, leading the country towards becoming a developed nation.	UC	Using knowledge and innovation to create sustainability	✓
		SK	Learning university for sustainable development	✓
		UWS	Learning university for society	✓

Student participation in the sustainability movement

The involvement of students in universities to drive sustainability is another very important factor. Student involvement is often done primarily through activities sponsored by the university. In some universities, the writing of projects to propose a budget from the university is designed for students who do activities to evaluate themselves whether the proposed activities are in line with the goals. SDGs in any of them. Budget-supported student activities have become a key factor in the university's ability to achieve its sustainability goals by combining bottom-up and top-down mobility. The findings are reflected in the case studies of universities that have designed policies to develop student potential by stimulating learning about sustainability in a concrete way.

In additional, supporting student participation in the drive for sustainability is not done in isolation, but is integrated into the university's teaching and learning through Expected Learning Outcomes (ELOs), which allows various subjects in the curriculum to integrate the SDGs into the teaching and learning content. In the past semester, the researcher taught in a course on social problem issues. The researcher himself read the details of the course he was responsible for, and found that the course has ELOs for students to invent social innovations to solve social problems in line with the SDGs. Students choose to present social problems that are close to them and participate in activities in areas of interest. Such classroom activities are also a small part of helping the university achieve its sustainability goals.

Discussion and conclusion

The following are some of the main conclusions: 1) through social engagement and sustainable social development methods, Thai higher education institutions use structural mechanisms to govern the direction of

sustainability. Setting the agenda for managing human resources at the micro-level of university operations—especially in teaching, research development, and establishing spaces that enable social activities—especially in healthy environments—as part of social engagement—is made possible by this structural mechanism; 2) there is a strong emphasis on the role that students play in ensuring the viability of higher education institutions in Thailand. As evidenced by the general education course curriculum, students are highly motivated to promote sustainability through university social involvement and sustainable social development techniques.

This study reflects that the participation of people at all levels of universities contributes significantly to driving the Sustainable Development Goals, with institutional roles that should be self-regulating and opening up opportunities for participation by seeing that everyone in the university has the potential to create new ideas about sustainability (Chaiya & Ahmad, 2021; Filho, et.al., 2024). Policy decisions on sustainability in universities should be based on creating public awareness along with the common sustainability goals of all stakeholders in the university, which has a better chance of success than just implementing top-down policies. (Khatibi, Dedekorkut-Howes, Howes, & Torabi, 2021).

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Immersive Learning in Virtual Science Centres: Investigating the Role of Task-Oriented Experiences for Enhancing Student Success

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Abstract

Students frequently require assistance in comprehending scientific concepts due to the challenge of connecting abstract knowledge to practical application. Informal learning settings, such as science museums, play a crucial role in enhancing students' experiences through extracurricular activities. Interactive exhibits facilitate experiential learning, solidifying scientific principles and converting theoretical constructs into enduring cognitive schemas. Furthermore, the integration of advanced virtual educational technologies offers immersive learning models. This study introduces an innovative methodological framework within a VR-based educational milieu to discover the influence of task-oriented experiences on learning levels among students. The methodological approach involves a virtual science centre integrated with teenage avatars in accordance with a predictive model. The environment is designated for 7th- grade students in two groups comprising 80 students in total to interactively experience an educational tool on life sciences, specifically cell structure. The objective of this study is to investigate the relationship between students' learning levels, and the spatial attributes of an informal learning environment. The spatial scenario for the first group was designed as a game-like task-oriented virtual experience, whereas the spatial scenario for the second group was designed as a free navigation-oriented virtual experience environment. The results of the correlational analysis indicated that the success performances of the task-oriented group were significantly higher than those of the other group, both at the single-question level and at the overall success score level. This study provides a valuable discussion for the literature on science learning through technological tools, with the potential for further investigation into the impact of task-oriented experiences that integrate competition motivation during school trips to science centres.

Keywords: immersive learning; informal learning; learning in middle-year school children; learning science; spatial preference; VR-based education

Cultural capital and the value of employment for the elderly population based on studies of an elderly occupational group in the northeastern region of Thailand

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Abstract

This article describes a survey and synthesis of knowledge from field studies on an occupational group which consists of elderly executives in a total of three organizations in Khon Kaen province, in the northeastern region of Thailand. The study employed qualitative research tools, including research observations, interviews, practical seminar workshops, and group discussions. The study finds that firstly, cultural capital can generate the development of resources that are innovative and transmit local wisdom. By integrating and adding value to products and goods, it can attract more income from tourists. The second aspect regarding the value of employment for the elderly population is the support provided to enable the elderly to have jobs, thereby creating significant value in three areas. (1) The social value is that elderly individuals with a strong social network have increased opportunities to receive understanding and support from others. This is beneficial for personal development and societal advancement through engaging in social and economic activities that foster social interactions. Networks enable the elderly to exchange experiences and knowledge with others, leading to learning and personal growth. (2) The economic value lies in providing employment opportunities for the elderly, which helps supplement their income. This, in turn, expands spending potential and stimulates the local economy. The income of the elderly contributes to consumption of various goods and services, thereby stimulating the local economy. (3) The psychological value lies in having employment and relationships within the elderly network, which helps facilitate the exchange of experiences and beneficial knowledge between the elderly and other groups in society. This fosters confidence and stability among the elderly, affirming their value to others. It serves as a social mechanism that supports mental and spiritual well-being.

Keywords: cultural capital, employment for the elderly, aging society, Thailand

Introduction

Thailand has been a complete-aged society since 2023 and is likely to become a super-aged society in 2030. Currently, Thai society has the second largest number of elderly people in ASEAN after Singapore, which has led the Thai government to focus on developing policies to support the rapid growth of the elderly, such as human resource development, health care, and promoting economic participation. (UNFPA, 2021).

The statistics of the elderly population in Thailand can be classified as 4,197,897 people aged 60–64 years, 3,180,499 people aged 65–69 years, 2,419,901 people aged 70–74 years, 1,512,811 people aged 75–79 years, and 1,882,139 people aged 80 years and over. In order to see the data more clearly, the data is used to create the population pyramid according to Figure 1. (The Bureau of Registration Administration, 2024, online).

Figure 1. Population Pyramid: Thailand in 2023

Population Pyramids: Thailand in 2023
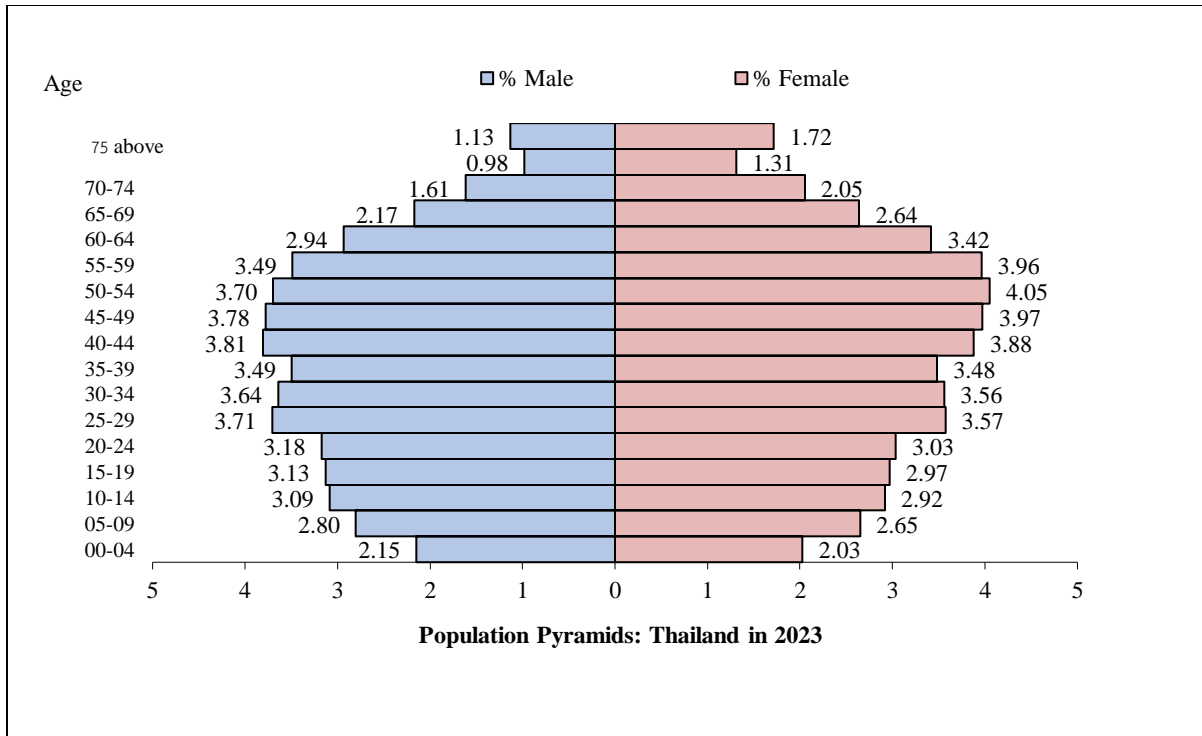
In a society where the elderly are increasing rapidly, cultural capital is a capital that has been accumulated for a long time among the elderly, which appears in the form of wisdom, which contributes to income growth very well. In Thai society, efforts are made to encourage the elderly to age in their original places and support social and economic activities through local community enterprises, that the elderly will have a well-being by promoting active aging (Jearajit, 2022; Jearajit, Promjittiphong, Soonsinpai, Panyachit, & Wanitchanon, 2022). Cultural capital contributes to the determination of the working status of the elderly, as well as a bargaining tool for the work of the elderly and their existence in society (Gilleard & Higgs, 2016; Lima, Figueira, Carvalho, Kusumota, & Caldeira, 2023).

This study aims to study the role of cultural capital in contributing to the development of human capital among the elderly in Thai society. The researcher chose Khon Kaen Province as a case study this time by selecting three community enterprises with potential for the development of the elderly. Khon Kaen province is considered a province that has rapidly become urbanized, both in terms of population growth, economic development, and infrastructure. Once the research is complete, this research will help fill the gap in the policy on the elderly in Thai society.

Methods

Qualitative research methods were used in the study, such as group discussions, practical seminar workshops, interviews, and research observations. The area of research is at community enterprises in Khon Kaen province, Thailand, selection of areas to participate in the research from areas with the use of cultural capital to economic creation with the participation of the elderly in the area. There are 3 organizations, including silk making group, herbal processing group, and food processing group. The researcher conducted data collection 3 times, then carried out local operational activities to bring lessons to the use of cultural capital for the work of the elderly in Khon Kaen province with community enterprises as the base. For data analysis after data collection is completed, the researcher used content analysis to analyze the data.

Result

The research results were presented under the following topics:

The social value of the elderly

The use of cultural capital for work in community enterprises by the elderly in Khon Kaen province reflects that the elderly feel an increased sense of social value. Activities that the elderly engage in, such as silk weaving, herbal planting, and cooking, are all activities they perform in their daily lives. Community enterprises serve as spaces

that allow the elderly to integrate their individual cultural capital, thereby significantly strengthening the social fabric for the elderly in the group.

The important outcome of integrating cultural capital in the social aspect lies in creating a unique identity for the network, enabling the creation of cultural products, and fostering a sense of appreciation for their own wisdom among the elderly. However, the differences in the cultural capital of community enterprises are presented in Table 1.

Table 1. Differences in Cultural Capital of Community Enterprises in Case Studies

Case	Characteristics of cultural capital	Impact to social value
Silk making group	Wisdom passed down from generation to generation, which is a cultural capital passed down within the family	The integration of cultural capital together results in the use of creativity and jointly develops the strength of the group. The elderly have used the accumulated cultural capital to build their own value and place in society.
Herbal processing group	Relying on herbal wisdom to develop new products for the group. In addition, they learn from other groups and apply them in their own groups.	Building social solidarity through the use of cultural capital that provides opportunities for members within the group to exchange, learn and develop together.
Food processing group	Relying on the wisdom of food that is already done in daily life to export food processing that is unique to Khon Kaen province.	The elderly actively participate in food processing activities and participate in joint activities, but in food processing, there are still health barriers that make it possible for the elderly to participate in little.

Increasing economic- psychological value from activities of the elderly

Cultural capital that affects the employment of the elderly in community enterprises helps to create economic added value at the community level. Although the economic added value is not much compared to employment in government or private organizations, the difference is that the elderly working in community enterprises are "self-sufficient, in a good mood, happy", which is an important feature of the development and care of the elderly in Thai society today.

Products that are the product of the use of cultural capital to work for the elderly in community enterprises help generate income for the group. At the end of the year, income will be allocated systematically through participatory joint management. The products that the three groups of community enterprises often produce are silk, herbal compresses, and processed foods, which are exported both inside and outside Khon Kaen province. However, the elderly added that the online market is very important nowadays. Learning about digital technology is another factor that the elderly think will help them create additional economic value.

In terms of psychological value, cultural capital that is intensively used in community enterprises helps to recreate the social identity of the elderly as "people with social value." Working in community enterprises allows the elderly to build their own identity firmly by meeting and discussing common things in life. Gathering for social activities with the elderly also contributes to building psychological strength. It makes the elderly think positively and can help them live happily.

Discussion and conclusion

Among the principal conclusions are the following ones: 1) the social value is that older people who have a strong social network are more likely to get empathy and assistance from others. Through participation in social and economic activities that promote social relationships, this is advantageous for both individual growth and the improvement of society. Seniors can learn and develop personally by exchanging experiences and information with others through networks. 2) Giving older people job chances that complement their income is valuable economically. Thus, the local economy is stimulated and spending potential is increased. The elderly's income boosts the local economy by encouraging the consumption of a range of products and services. 3) The psychological benefits come

from employment and connections within the senior network, which support the sharing of experiences and useful information between senior citizens and other social groups.

The findings of this research reinforce that for the elderly who work in community enterprises, their cultural capital is intensively used within social networks. Social networks vary according to social and cultural contexts, with very strong networks often being those in which stakeholders participate. Furthermore, having a social network contributes to the well-being of the elderly. (Jearajit, 2022; Wongsala, Anbäcken, & Rosendahl, 2021). However, in order to develop the elderly for active aging, it is still necessary to have a strong policy mechanism in both central and local policies (Haque, 2016; Jitapunkul & Wivatvanit, 2009). The results of this research will help drive the development of the elderly in Thai society by valuing the value of decentralization in the local area so that the care of the elderly can be appropriate to the social and cultural context.

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Development of essential future skills for the elderly in Thai society

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Abstract

This article describes a qualitative research study focusing on the development of social policies related to the enhancement of skills and knowledge among the elderly in Thai society. The research employed qualitative data collection methods, including policy review related to hiring elderly individuals (re-reading), free-listing, in-depth interviews, and focus group discussions, involving five representatives from government agencies at the ministerial level and 15 representatives from elderly business networks in Chiang Mai and Lampang provinces. In total, there were 20 key informants providing data. The findings of the study on the policy of developing essential skills for the elderly showed that there were three key skills. (1) In terms of health, the focus is on the rights and quality of life of the population, developing skills for the elderly in both physical and mental health dimensions, leading to the promotion of good physical and mental health. This will contribute to engaging in social group activities in terms of interactions and positive future work. (2) In terms of finance, focusing on promoting savings and providing financial education should start from childhood because it is an age where habits can be easily cultivated and changed compared to other age groups. Discipline in saving among working-age individuals, especially informal laborers without social security, is crucial. Forced saving could be another option to help Thailand avoid becoming a fully aging society without sufficient financial resources. (3) In terms of technology, emphasis is placed on developing knowledge in information technology to understand social and economic innovations that align with the future world. This is a preventive measure against technological crimes against the elderly. In terms of policy recommendations, it is evident that the Ministry of Interior and the local government organizations in Chiang Mai and Lampang provinces should develop activities that foster collaboration to drive the policies of local government organizations in developing essential skills for the future of the elderly population.

Keywords: skills, aging society, Thailand

Introduction

Thailand has become a completed aged society as the second country in ASEAN, and the government is trying to find ways to care for and manage the development of the potential of the elderly in line with the 20-year National Strategic Plan on the issue of "Developing Human Potential throughout Life". As Thai society is rapidly moving towards Society 4.0, skill-sets are an important issue that Thai society drives success under the view that each age group of the population has different skill needs. For older adults, the skills needed must cover basic skills, emotional and social skills, and vocational skills (UNFPA, 2021). Successful skill development requires an in-depth understanding of the characteristics of that population. Even though they are in the same age range, there is a complexity in skill development, and the skills that are developed are related to each other and cannot be developed separately, such as social skills and creative skills. (Hendarman & Cantner, 2018; Thianthai & Sutamchai, 2022).

In addition to the skills that need to be developed among the elderly, an important issue that cannot be ignored is to make life skills funding flexible and long-term. Therefore, the cultivation of literacy is an important factor that enables the elderly to develop life skills regularly at any time and without dependence on the government. There are many important know-how of the elderly, and these know-how affect the quality of life, such as internet literacy, health literacy, and financial skills (Diteeyont & Ku, 2021; Sirisuwan, Phimha, & Banchonhattakit, 2022; Xue, Gepp, O'Neill, Stern, & Vanstone, 2019).

This paper explores and develops essential future skills for the elderly in Thai society. The research sites covers Chiang Mai and Lampang, which are considered provinces in the northern part of Thailand with a rapid increase in the rate of elderly people (The Bureau of Registration Administration, 2024, online). In addition, local policies have been updated several times to accommodate the increase in the number of elderly people, however most local policies are often isolated and routinely implemented. This study will help fill this gap and reflect that the development of human capital of the elderly needs to be integrated in order to achieve sustainability in the development of the potential of the elderly in Thai society.

Methods

The study included qualitative data gathering techniques, such as focus groups, free listing, in-depth interviews, and policy reviews pertaining to hiring senior citizens (re-reading). Based on 15 participants from elderly business networks in the provinces of Chiang Mai and Lampang, and five representatives from ministerial-level government institutions. Field data collection is systematically managed and on-site data collection is carried out. 3 times. The data will be analyzed by content analysis, and the presentation will be presented into 3 themes, including health, finance, and technology.

Result

From the analysis of the collected data, the research results can be summarized as follows:

Health skills

The gathering of elderly people to carry out social and economic activities in Chiang Mai and Lampang provinces has health skills as an important basis for the grouping. Various networks in the area are aiming to develop activities that want to improve health skills for the elderly (see Table 1.). In addition, healthy older people enable older people to perform their jobs according to their assigned roles within the social group to which they belong. Activities that are often done regularly within the group are inviting the elderly to exercise. Health check-ups for the elderly and regular meetings and talks so that the elderly can be mentally strong and free from feeling lonely.

Table 1. Health skills for the elderly in Chiang Mai and Lampang provinces

Level of Policies	Role of practices
Elderly networks	Comprehensive physical, mental, social, and intellectual health care for the elderly. These activities help to promote the holistic well-being of the elderly. The elderly will be happy because they choose to do activities according to their interests.
Local administration	Local administration often has limited health care activities for the elderly with organizational roles. The organization will carry out activities according to the plan/strategy that has been laid out and is mainly directed by policies from top to bottom. Therefore, most local health activities only act as supporters and generous non-monetary resources.
Provinces	The design of policies on the elderly at the provincial level is also seen as separate from other skills, so there is a lack of integration of policies and obligations of agencies. At the provincial level, the work is often intensively divided to develop the skills of the elderly according to the scope of their own obligations.
Central government	The central government plays a role in policy supervision regarding the elderly. Ministries design activities and plans related to the elderly according to their aptitudes, however the central government has established the National Committee on Aging, which plays an important role in taking care of the quality of life of the elderly.

Financial skills

The fact that the elderly continue to participate in economic activities Therefore, financial skills are one of the important skills that enable the elderly to manage themselves. The operation of this research has created participation for the elderly to be able to design their own money management. Financial skills are in line with future-looking skills. Most of the elderly who participated in the study predicted that they would live to an average age of 80-85 years and wanted to have an average monthly income of 5,000 baht. The fact that the elderly have come to work from gathering into a network may contribute to the elderly being able to manage their lives more effectively. Currently, the government itself provides a stepped living allowance to the elderly, with 60-69 years old receiving 600 baht/month, 70-79 years old receiving 700 baht/month, 80-89 years old receiving 800 baht/month, and 90 years and older receiving 1,000 baht/month, which is considered the most obvious elderly care policy of Thai society.

Figure 1. Examples of financial planning for the elderly in Chiang Mai and Lampang provinces

Basic Information	
1. What is your current age?	61.15
2. What age do you plan to retire?	73.85
3. What age do you plan to use your accumulated savings?	87
4. How much do you expect your monthly expenses to be after retirement?	3,965
5. Annual inflation rate (assumption)	3%
Goals	
Number of years to invest	12.7
Number of years to use money after retirement	13.15
The total amount of money you need by the time you retire	1,081,625.16

Technology skills

Entering Thai Society 4.0, the elderly are a population group affected by the rapid growth of digital technology. The characteristics and identities of the elderly using digital technology may differ from those of other population groups. Most elderly people in Chiang Mai and Lampang provinces are proficient in using communication tools and media. However, there has been an increase in online criminals in Thai society, posing a risk to the elderly regarding technology-related crimes. Developing skills for the elderly to keep up with the digital world is, therefore, another essential skill. Additionally, technology skills are linked to health and financial skills. Some elderly individuals use online media for health care and exercise based on media recommendations, while others use digital technology to systematically manage their finances through mobile banking. Having technology skills thus enables the elderly to gain long-lasting knowledge and sustainability.

Discussion and conclusion

The study on policies for developing essential skills for the elderly identified three primary areas of focus: 1) emphasizes the importance of rights and quality of life, with a focus on enhancing both physical and mental health skills for the elderly. This leads to improved overall health and facilitates participation in social activities and future positive work engagements; 2) stresses the need to promote savings and financial education from a young age, as habits are more easily formed during childhood. It's crucial to instill saving discipline in working-age individuals, especially informal workers lacking social security. Implementing forced savings could help Thailand avoid financial difficulties as its population ages; 3) highlights the importance of developing IT knowledge to comprehend social and economic innovations that are in line with future global trends.

This study effectively fills the gap in skill development across different age groups, particularly among the rapidly increasing elderly population in society. However, when developing skills for the elderly, it may be necessary to consider the cultural significance these skills hold for them. Emphasizing subcultures is essential to broadening perspectives on skill sets, as different subcultures may have varying skill requirements. Moreover, each skill is interconnected (Hendarman & Cantner, 2018; Thianthai & Sutamchai, 2022). Additionally, health skills, financial skills, and digital skills each consist of various sub-skills. Therefore, considering the social and cultural context is crucial when examining the application of these skills (Diteeyont & Ku, 2021; Sirisuwan, Phimha, & Banchonhattakit, 2022; Xue, Gepp, O'Neill, Stern, & Vanstone, 2019). The researchers hope this study will help enhance local policies concerning the elderly, based on future-oriented skills, and lead to sustainable practices in the future.

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Utilizing Local Climate Zone and Convolutional neural networks for Enhanced Prediction of Thermal Risk Assessment

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Abstract

The intensity of urban heat islands (UHI) has markedly increased with the progression of urbanization. Utilizing building and landscape layout and planning to mitigate the UHI effect presents a promising adaptation strategy. However, previous research on the urban heat environment often encountered limitations due to the lack of real-time built environment data. Additionally, conventional built environment information, such as land use, frequently lacks three-dimensional context. Furthermore, the relationship between urban factors and temperature is often non-linear. This study addresses these limitations by employing open-source, real-time updated Landsat 8 satellite imagery to obtain comprehensive built environment data. It utilizes local climate zones (LCZ), which incorporate three-dimensional urban information, to classify urban textures systematically. Convolutional neural networks (CNN), a machine learning technique, are then employed to train models using LCZ classifications and their corresponding temperature levels as training samples. This approach aims to predict the thermal potential levels of various urban areas accurately. For climate data acquisition, the study integrates data from government meteorological stations and a self-established measurement network to generate detailed temperature distribution maps. The findings indicate that with a sampling rate of 50%, the optimal prediction accuracy achieved is approximately 82%. This research substantiates the feasibility of employing the proposed predictive model and LCZ classification to ascertain heat risk levels. Moreover, it effectively identifies potential hotspot areas, providing valuable feedback for the formulation and implementation of urban cooling policies.

Keywords: Satellite image, Local Climate Zone, Convolutional Neural Network, Urban Heat Island, Urban pattern

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