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Optimisation of Industry Revolution 4.0 Implementation Strategy for Palm Oil Industry in Cyber Security

Chun Hsion Lim[a,*], Vincent Lien Kai Loo[a], Sue Lin Ngan[b], Bing Shen How[c], Wendy P.Q. Ng[d], Hon Loong Lam[e]

[a]Universiti Tunku Abdul Rahman, Department of Chemical Engineering, Jalan Sungai Long, Bandar Sungai Long, Cheras 43000 Kajang, Selangor, Malaysia.
[b]Graduate School of Business, Universiti Kebangsaan Malaysia 43600 UKM, Bangi Selangor, Malaysia.
[c]Swinburne University of Technology Sarawak Campus, Chemical Engineering Department, Faculty of Engineering Computing and Science, Jalan Simpang Tiga, 93350 Kuching, Sarawak, Malaysia.
[d]Curtin University Malaysia, Department of Chemical Engineering, CDT 250, 98009 Miri, Sarawak, Malaysia.
[e]The University of Nottingham Malaysia Campus, Department of Chemical Engineering, 43500 Jalan Broga, Semenyih Selangor, Malaysia.
chlim@utar.edu.my

Palm oil has been one of the major renewable sources for the production of energy, food, and chemicals. Despite the huge demand and production rate, the majority of the stakeholders consist of small and medium enterprise company, especially at the plantation site. Due to this, revolution of industry 4.0 in palm oil industry, especially the upstream process is a very challenging issue. Stakeholders are reluctant to move toward the new technology due to the lack of understanding of the potential features and advantages, as well as hesitate to invest in new technology. This paper proposed a novel mathematical model to evaluate potential Industry Revolution 4.0 features based on existing technologies and optimised implementation strategy for each stakeholder. Each potential feature was evaluated based on its potential impact, estimated investment cost and non-implement penalty cost. The model covers a long-term operation to consider the inflation rate and dynamic maturity of each feature. A case study focusing on cybersecurity features is discussed and the result shows that only 7 out of 16 features that are feasible to implement in oil palm industry, where blockchain and smart contract are the most promising features to be implemented. All the features are recommended to be implemented at a later stage due to the increasing maturity of the Industry 4.0 technologies and cheaper cost.

1. Introduction

In the development of renewable and green sources for food, energy and chemical generation, palm oil is considered one of the highly anticipated sources due to its high production rate as compared to other oil crops. A comparative study among several major oil crops shows that palm oil industry is able to achieve better sustainability practice in terms of high oil yield and low water usage, while perform badly in terms of deforestation activities and carbon footprint (Lim et al, 2019). This creates issues where palm oil might be banned from the European country for biodiesel production due to the contribution to deforestation. The recent development in palm oil industry is highly focused on the initiative of Roundtable on Sustainable Palm Oil (RSPO) to establish certification of sustainable palm oil production. It is observed that implementation of RSPO is still a major challenge, especially due to the involvement of a huge number of small and medium enterprises (SMEs) as main stakeholders in the industry (Higgins and Richards, 2019), as well as traceability issue of certified oil palm products. With the fast pacing in global industry development, Fourth Industry Revolution (IR4) is the next milestone for all industries to move toward digitalisation, automation, and smart system. Study shows that incorporation of IR4 features is able to promote higher sustainable performance in industry (Ghobakhloo, 2020). This could be the solution to the current oil palm industry to implement RSPO with a more robust platform. IR4 is relatively new to oil palm industry, a detailed study on its implementation strategy is required. Study on strategy planning for future technologies has shown promising assistance in decision making and

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implementation process (Chofreh et al., 2019). IR4 features can be classified into several areas, including Internet-of-Things (IoT), Big Data Analysis, Cloud Computing, Smart System, Automation, and Cyber Security which have various industry applications. IoT-enabled system provides better prediction of local weather forecast (Doeswijk and Keesman, 2005) which can be modified to improve palm oil yield prediction. Smart detection systems have been developed to detect palm fruit ripeness (Rincón et al., 2013) and palm tree trunk from images (Juman et al., 2016). The common requirement in IR4 is the intensive big data collection which requires heavy computing power for analysis prior applications. This creates issues of lack of computing facilities in many oil palm stakeholders. Cloud computing is a promising technology to minimise the requirement of capital investment into high-end computing power, where it enabled data processing to be done through a shared third-party server. Khayer et al., (2020) shows that utilisation of cloud-based computing facilities is able to reduce the operating cost and flexibility, especially among SMEs. Despite the benefits of the stated IR4 features, most of the technologies are highly dependent on constant connection and communication between various devices and systems. This creates a weakness in the security of IR4 system where all interconnected devices and systems are prone to be exposed to risk when either one of the systems is hacked under cyber-attack such as virus, Trojan horse, Denial-of-Service attack and illegal access (Srinivas et al., 2019). As such, cyber security is one of the most critical elements to be highlighted in the process of incorporating IR4 features. As one of the main global producer, many stakeholders in Malaysia palm oil industry has not actively adapted the IR4 initiative. According to MITI (2018), the barrier of IR4 implementation includes the lack of awareness of the impact (cost vs benefit analysis), high implementation cost, lack of visible success stories, shortage of talents, low digital adoption, and exposure to cyber threats, especially among SMEs. A well-establish policy and guidelines to strategically adopt IR4 features are critical. The aim of this study is to systematically evaluate and propose an implementation strategy for oil palm stakeholders to adapt IR4 with consideration of multiple variables and selection criteria. A novel mathematical model is introduced to optimise the implementation strategy for IR4 by comparing the projected impact from each implementation and optimise the implementation strategy across a lifespan of the industry. To the best of author's knowledge, no literature has been published to address the multiple Industry 4.0 technologies and their implementation strategy.

2. Methodology

Figure 1 shows the general superstructure of the proposed mathematical model. The proposed model covers the supply chain of palm oil production, from the plantation to consumers. Systematic evaluation of existing IR4 features is conducted to identify all potential implementation of IR4 technologies in each stage of the supply chain. Four parameters are considered in the model to assess the feasibility of implementation including the investment cost, operating cost to maintain the features, expected profit gain from implementation, and potential loss if the technology is not implemented. The last parameter is introduced as a penalty cost (risk) for not investing into IR4 feature to reflect the possible scenario of being outdated in the relevant industry and profit loss due to unable to compete with another competitor.

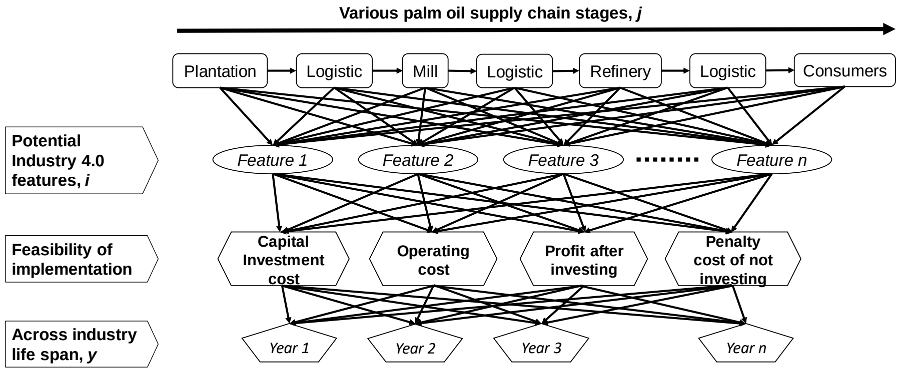

Figure 1: Superstructure of the proposed model

$$T\_Cap\_invest(i,j,y) = bin(i,j,y) \times cap\_cost(i,j,y) \tag{1}$$

$$\sum_{i=1}^{I} \mathrm{TCI(i,j,y)} \leq IB(j,y) \tag{2}$$

$$\sum_{y=1}^{Y} bin[i,j,"y" + "y+1" + "..." + "y+(lifespan_i - 1)"] \leq 1 \tag{3}$$

Eq(1) shows the calculation of total capital investment, $TCI(i,j,y)$ for each feature, *i* at respective supply chain stage, *j* across the operation year, *y* should be less than the investment budget, $IB(j,y)$. $bin(i,j,y)$ is the binary variable to show the implementation strategy where "1" will be assigned if the model chooses to implement the dedicated feature, *i* at stage *j* in year *y* of operation. Noted that this binary represents the implementation where the company is required to invest in the capital cost $cap\_cost(i,j,y)$. Eq(2) constraints the total investment into IR4 feature should not be exceeding the available budget. Note that the budget is also considered the accumulation of the remaining budget from previous years. As each feature only goes through a major upgrade (which requires investment of new capital cost) at the end of its lifespan, Eq(3) restricted the summation of $bin(i,j,y)$ for each feature, *i* at stage *j* to be equals or less than 1 within the respective feature lifespan, $lifespan_i$.

$$TOC(i,j,y) = bin(i,j,y) \times AOC(i,j,y) \tag{4}$$

$$TPro(i,j,y) = bin(i,j,y) \times APro(i,j,y) \tag{5}$$

$$TPen(i,j,y) = [1 - bin(i,j,y)] \times PenC(i,j,y) - bin(i,j,y) \times APenC(i,j,y) \tag{6}$$

The total expected operating cost, $TOC(i,j,y)$ to maintain the IR4 feature is calculated in Eq(4). Accumulative operating cost, $AOC(i,j,y)$ is used to summaries the expected operating cost of respective feature across its lifespan, $lifespan_i$. For example, a feature has a lifespan of 5 years, if the feature is proposed to be implemented in year 1 of process, AOC summaries the projected operating cost from year 1 to the end of its lifespan in year 5. Similarly, if the implementation is suggested at year 6, then the accumulative operating cost is from year 6 to year 10. Eq(5) is using the same concept as Eq(3) to determine the total projected profit increase from implementing the IR4 feature, $TPro(i,j,y)$, where the accumulative profit term, $APro(i,j,y)$ is used to calculate the impact of implantation across the feature lifespan. The total of penalty cost from potential loss of not implementing IR4 features, $TPen(i,j,y)$ for not investing in IR4 features is governed by Eq(6). The equation uses inverse of the binary variable to determine the penalty cost imposed. This creates a problem where the subsequence years of penalty will also be considered. For example, if the feature is implemented in year 1, the penalty cost will not be considered for year 1 due to the inverse binary term. The penalty cost for its subsequence years until the end of its lifespan will be included as well despite the implementation should be lasted for its whole lifespan. An accumulative penalty cost, $APenC(i,j,y)$ is introduced in the second part of Eq(6) to offset the imposed cost from the subsequence years. The main reason that accumulative costing is proposed in this model is to capture the fluctuation of costing and profit across the operation and implementation year, where some of the features may be cheaper to be implemented in future rather than now due to the increasing maturity of the technology.

$$NetProfit = \sum_{i,j,y=1}^{I,J,Y} TPro(i,j,y) - \sum_{i,j,y=1}^{I,J,Y} TCI(i,j,y) - \sum_{i,j,y=1}^{I,J,Y} TOC(i,j,y) - \sum_{i,j,y=1}^{I,J,Y} TPen(i,j,y) \tag{7}$$

Lastly, Eq(7) summaries the net profit, $NetProfit$ gain from implementing IR4 features, which is the objective function of the model to maximising the overall profit at each stage process and across the operating period.

3. Case study result and discussions

This section discusses the case study to optimise the IR4 feature implementation across a 10 y operation scenario. Table 1 shows the number of estimated workers from three major stakeholders in palm oil industry, the budget and estimated annual financial losses due to cyber-attack for the first year of operation. A relatively low budget is allocated in this case study to reflect the immaturity of cybersecurity implementation in oil palm industry and lack of interest at an early stage. A constant inflation rate of 2 % is proposed for the increment of budget and cyber losses in the consecutive operation years to facilitate the growth of the company. Table 2 summaries the key IR4 features in cyber security, their respective investment cost calculation and the expected profit gain from cyber losses. The features considered include blockchain technology (Feature A, B and C) which is a decentralise block of data that is unchangeable and highly traceable. Feature D, E and F consider the implementation of smart contract for transaction automation based on pre-agreed terms. Dynamic palm oil price can be configured based on its properties and sustainability profile; and enable reward and penalty system in on-time-delivery. The rest of the features are related to the integrity of software and computing facilities including incident response platform (IRP). The operating cost is assumed to be 10 % of the investment cost, and both are subject to a reduction of 2 % yearly due to the continuous improvement in technology maturity. Note that the profit gain is referred to the estimated cyber loss prevention at that particular year of operation as shown in

Eq(5). This study assumed a constant performance of each feature across the operation years. Figure 1 shows the penalty cost for not implement the feature. As IR4 feature is relatively new in palm oil industry, a highly accurate data such as the expected profit and penalty cost is not readily available. This information was obtained based on the input from industry experts and stakeholders projection based on current situation.

Table 1: Worker size at major palm oil plantation and mill in Malaysia

Plantations and mills	Sime Darby	IOI	KLK	Genting	Felda Global
No. of workers	73,864	33,687	45,873	55,876	27,413
Estimated budget ($)*	50,170	13,353	18,831	1,712	19,744
Estimated cyber lost ($)*	1,003,401	267,056	376,618	171,190	394,878
Logistic	Tasco Logistic		FM Global		CEVA Freight Holdings
No. of workers	2,500		1,384		341
Estimated budget ($)*	841		584		223
Estimated cyber lost ($)*	83,997		58,433		22,369
Refinery	Felda Global Ventures		Golden Agri-resources		Mewah International
No. of workers	18,740		68,600		1,865
Estimated budget ($)*	15,361		8,179		3,363
Estimated cyber lost ($)*	307,229		409,030		336,445

**currency is estimated in USD ($) from Ringgit Malaysia based on the conversion rate of 1 to 4.38.*

Table 2: Investment cost and expected profit for each IR4 feature

IR4 features	Descriptions	Investment Cost	Profit gain (protected) from estimated cyber lost (%)
A	E-wallet via blockchain	$ 1 /worker	8.25
B	Product tracing via blockchain	$ 1 /worker	8.25
C	Transaction via blockchain	$ 1 /worker	8.25
D	Smart contract in marketing	$ 50k /company	8.25
E	Smart contract in agreement	$ 50k /company	8.25
F	Smart contract in trading logic	$ 50k /company	8.25
G	Mid-end IRP	$ 60 /worker	4.13
H	High-end IRP	$ 100 /worker	6.19
I	Symmetric encryption	$ 50 /worker	7.84
J	Asymmetric encryption	$ 60 /worker	7.84
K	High-end firewall	$ 28.8 /worker	5.03
L	MId-end firewall	$ 42 /worker	6.19
M	Security team management	$ 90 /worker	4.13
N	Intrusion detection system	$ 30 /worker	4.21
O	Anti-virus software	$ 15 /worker	2.89
P	Communication content screening	$ 7 /worker	2.06

The difference in the penalty cost across the operating year is correlated to the maturity of the IR4 feature. For instance, some of the features may expect a high return in the early stage of operating years due to its novelty which able to significantly improve efficiency or increase the attractiveness of the company among competitors. Others are expected to become a common feature in future and as a basic requirement, a higher penalty cost will be imposed in future, such as a mid-end firewall system is considered as common protection in cyber security which high penalty cost at later years. Each feature is assumed to have 5 y of lifespan prior major upgrade or replacement.

The problem was solved using General Algebraic Modeling System (GAMS) with mix integer programming to obtain the optimum solution. Table 3 and 4 summarised the result obtained from the mathematical model for the optimum IR4 implementation strategy which the maximum total profit is found to be at RM 66,836,590. Based on the result, the only number of features has been selected for implementation. Blockchain features are recommended by most of the stakeholders. Blockchain not only can help to prevent cyber-attack by decentralised the server, the nature of storing each transaction information into block enable high information traceability characteristic which very helpful to improve product traceability. Smart contract features are recommended in most of the plantations and mills. These features can be integration into palm oil harvesting by proposing smart transaction or payment scheme based on the palm oil quality received, such as premium price will be awarded if the palm oil received is a RSPO certified product or the price of oil is subject to the sustainability profile of the plantation site.

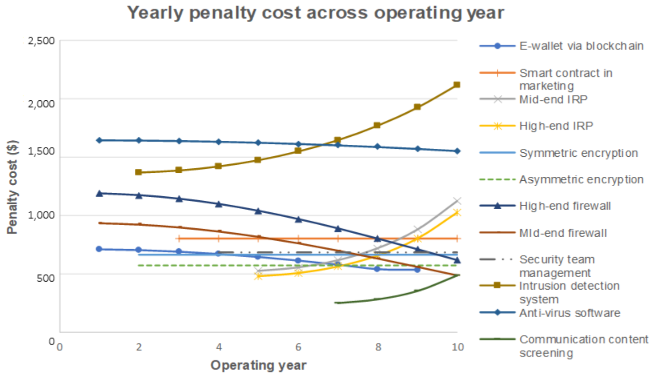

Figure 1: Projected penalty cost of each IR4 feature if failed to implement

Table 3: IR4 implementation strategy for plantation and mills' stakeholders

Plantations and mills		Sime Darby						IOI						KLK						Genting	Felda					
IR4 features		A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	D	A	B	C	D	E	F
y	5	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1		1	1	1	1	1	1
	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 4: IR4 implementation strategy for logistics and refineries' stakeholders

Logistics and refineries		Tasco Logistic				FM Global				CEVA Freight Holdings					Felda Global Ventures							Golden Agri-resources					Mewah International					
IR4 features		A	B	C	P	A	B	C	P	A	B	C	O	P	A	B	C	D	E	F	P	A	B	C	D	E	A	B	C	E	F	P
y	5	1	1	1		1	1	1		1	1	1			1	1	1	1	1	1							1	1	1			1
	7								1																							
	9				1																											
	10	1	1	1		1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Despite the profit gain across 10 y of operation, the model suggested that implementation of IR4 features is optimum at the fifth year of operation for most stakeholders. All features are proposed to be renewed/upgraded by the tenth year. This might due to the relatively low penalty cost imposed in an early stage as currently IR4 is still considered as a future-proof technology. The constant expected investment and operating cost reduction in future further promote the implementation of IR4 in the later stage of operation years. A sensitivity analysis to evaluate the scenario where a fixed investment and operation cost increases from 2 % to 5 % is conducted, the result shows no significant changes in terms of the implementation strategy for most of the stakeholders. Similar result also obtained in the extreme case where no cost reduction is expected. This shows that the cost of investment and operation is not the main factor in strategising IR4 implementation.

Despite that, various improvement can be introduced to enhance the accuracy of the case study, especially in cost estimation. Some of the simplified assumptions can be re-evaluated, such as the cost of IR4 investment for oil palm industry may be different from other industries. In the current study, the blockchain cost is estimated from application in Uber and smart contract is based on an average size Ethereum application (Tarasenko, 2019). The penalty cost for not implementing is also can be improved with more detailed financial analysis and forecasting. In another case where the penalty cost consideration is removed from the model, the optimum implementation strategy does not have major changes where most of the features are to be implemented in the fifth year followed by renewal in the tenth year. This show that even without the consideration of rivalry among competitor in terms of advancement of technology and efficiency, palm oil stakeholders should not rush for the implementation in recent year.

4. Conclusions

This paper has discussed the potential implementation of IR4 features in palm oil industry. A list of features has been identified and a mathematical model is proposed to optimise the implementation strategy for a period of operating years. The result shows that the proposed model is able to identify high impact IR4 features and recommend optimum implementation timing for each stakeholder. Sensitivity analysis shows that in all scenario, near future IR4 implementation is not recommended. The implementation should begin in the 5 years' time, considering the increased maturity of IR4 technology and reduction of investment cost.

Despite that current model has taken in the consideration of budget availability, cost of implementation, profit from implementation, and penalty cost from not implanting, more factors can be included to improve the accuracy of the model. First, the inclusion of more IR4 features including IoT features, cloud computing and big data analysis may further improve the robust selection between different features. Variable lifespan for each feature and detailed forecast and evaluation of the impact of implementing IR4 feature should be conducted to improve the accuracy of the case study. Inter-connection between various features and stakeholders can be considered to improve the robustness of the model. Game Theory optimisation concept also can be incorporated to reflect the decision making among stakeholders and competitor in Industry Revolution 4.0.

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References

Chofreh A.G., Goni F.A., Davoudi M., Klemeš J.J., Moosavi S.M.S., 2019, Strategic plan method for future renewable energy technologies, Chemical Engineering Transactions, 76, 1159-1164.

Doeswijk T.G., Keesman K.J., 2005, Adaptive weather forecasting using local meteorological information, Biosystems Engineering, 91(4), 421-431.

Ghobakhloo M, 2020, Industry 4.0, digitization, and opportunities for sustainability, Journal of Cleaner Production, 252, 119869.

Higgins V., Richards C., 2019, Framing sustainability: Alternative standards schemes for sustainable palm oil and South-South trade, Journal of Rural Studies, 65, 126-134.

Juman M.A., Wong Y.W., Rajkumar R.K., Goh L.J., A novel tree trunk detection method for oil-palm plantation navigation Mohammed, Computers and Electronics in Agriculture, 128,172-80.

Khayer A., Talukder M.S., Bao Y., Hossain M.N., 2020, Cloud computing adoption and its impact on SMEs' performance for cloud supported operations: A dual-stage analytical approach, Technology in Society, 60, 101225.

Lim C.H., Chuen W.W.Z., Foo J.Q., Tan T.T, How B.S., Ng W.P.Q., Lam H.L., 2019, Circular sustainability optimisation model for diverse oil crops feedstock system via element targeting approach, Chemical Engineering Transactions, 76, 1111-1116.

Lomotey R.K., Pry J., Sriramoju S., 2017, Wearable IoT data stream traceability in a distributed health information system, Pervasive and Mobile Computing, 40, 692-707.

MITI, 2018, Industry 4WRD: National Policy on Industry 4.0, Malaysia Ministry of International Trade and Industry, <www.miti.gov.my/miti/resources/National%20Policy%20on%20Industry% 204.0/Industry 4WRD_Final.pdf> accessed 13.03.2020.

Rincón S.M., Hormaza P.A., Moreno L.P., Prada F., Portillo D.J., García J.A., Romero H.M., 2013, Use of phenological stages of the fruits and physicochemical characteristics of the oil to determine the optimal harvest time of oil palm interspecific OxG hybrid fruits, Industry Crops Productions, 49, 204–10.

Srinivas J., Das A.K., Kumar N., 2019, Government regulations in cyber security: Framework, standards and recommendations, Future Generation Computer Systems, 92, 178-188.

Tarasenko, E., 2019, How Much Does it Cost of Blockchain Implementation – Merehead, <merehead. com/blog/how-much-does-it-cost-of-blockchain-implementation/> accessed 25.03.2020.

Wang J., Xhen M., Zhou J., Li P., 2019, Data communication mechanism for greenhouse environment monitoring and control: An agent-based IoT system, Information Processing in Agriculture. DOI: 10.1016/j.inpa.2019.11.002