FDS8 (Oct 2019)

RGC Ref. No.: UGC/FDS14/E06/19 (please insert ref. above)

#### RESEARCH GRANTS COUNCIL COMPETITIVE RESEARCH FUNDING SCHEMES FOR THE LOCAL SELF-FINANCING DEGREE SECTOR

# FACULTY DEVELOPMENT SCHEME (FDS)

## **Completion Report**

(for completed projects only)

Submission Deadlines:	1.	Auditor's report with unspent balance, if any: within six months of
	•	the approved project completion date.
	2.	Completion report: within $\underline{12}$ months of the approved project completion date.

# **Part A:** The Project and Investigator(s)

## 1. Project Title

Blockchain-based E-Commerce Analytics Model for Facilitating Trusted Data Exchange and

Digital Supply Chain Integration

# 2. Investigator(s) and Academic Department(s) / Unit(s) Involved

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	Dr. HO To Sum / Associate Professor	Department of Supply Chain and Information Management, The Hang Seng University of Hong Kong
Co-Investigator(s)	Dr. CHOY King Lun Tommy / Senior Project Fellow	Department of Industrial & Systems Engineering, The Hong Kong Polytechnic University
Co-Investigator	Dr. TSE Ying Kei Mike / Reader	Department of Logistics and Operations Management, Cardiff University

# 3. Project Duration

	Original	Revised	Date of RGC / Institution Approval (must be quoted)
Project Start Date	01/01/2020	01/01/2020	
Project Completion Date	31/12/2022	30/06/2023	09/06/2022 (HSUHK)

Duration (in month)	36 months	42 months	09/06/2022 (HSUHK)
Deadline for Submission of Completion Report	31/12/2023	30/06/2024	09/06/2022 (HSUHK)

4.3 Please attach photo(s) of acknowledgement of RGC-funded facilities / equipment. NA

#### Part B: The Final Report

#### 5. Project Objectives

- 5.1 Objectives as per original application
  - 1. To apply blockchain technology as the foundation of information architecture for facilitating upstream and downstream supply chain/logistics data exchange, and to integrate the machine learning (ML) and artificial intelligence (AI) techniques, big data analytics tools for generating decision support to underpin supply chain efficiency enhancement.
  - 2. To engage with stakeholders and regulators from across the retail and logistics network with blockchain research capability in order to identify the requirements for information architecture that will contribute to e-commerce supply chain efficiency enhancement.
  - 3. To enhance the core competence of the supply chain practitioners in Hong Kong in capturing e-commerce business through streamlined supply chain data exchange and information management.
  - 4. To develop a novel blockchain-based e-commerce analytics model that assists supply chain stakeholders in data sharing and integration and enables industry practitioners to make accurate and timely decisions based on e-commerce order arrival prediction under the e-commerce operating environment.

#### 5.2 Revised objectives

Date of approval from the RGC:	NA
Reasons for the change:	NA

#### 5.3 Realisation of the objectives

(Maximum 1 page; please state how and to what extent the project objectives have been achieved; give reasons for under-achievements and outline attempts to overcome problems, if any)

The objectives 1 to 4 of this project have been fully achieved, as shown in part 5.1. The accomplishments of project objectives 1 to 4 inspired three research publications, including two journal publications and one conference publication.

Journal Publications:

- [1] Ho, G. T. S., Choy, S. K., Tong, P. H., & Tang, V. (2022). A forecasting analytics model for assessing forecast error in e-fulfilment performance. Industrial Management & Data Systems, 122(11), 2583-2608.
- [2] Ho, G. T. S., Tang, Y. M., Tsang, K. Y., Tang, V., & Chau, K. Y. (2021). A blockchain-based system to enhance aircraft parts traceability and trackability for inventory management. Expert Systems with Applications, 179, 115101.

Conference publication:

[3] Ho, G. T. S., Tang, Y. M., Lam, H. Y., & Tang, V. (2023). A Blockchain-based Decision Support System for E-commerce Order Prediction. International Conference on Artificial Intelligence in Information and Communication (ICAIIC) Bali, Indonesia, pp. 041-045.

In this project, our team has developed a Forecasting analytics model in order picking (FAAOP) and the research results were published in the journal publication [1]. The FAAOP extracts historical data from cloud database, including order demands and total travel times as the basis to predict potential forecasting variability. With the FAAOP, forecast errors in actual travel time can be predicted and corresponsive actions can be taken, such that practitioners can organize the resources for addressing the potential threat in advance, which contributes to project objective (3).

Also, a blockchain-based system has been developed to provide a platform for tracing and tracking aircraft spare parts using Hyperledger Fabric and Hyperledger Composer. The proposed model, executed under decentralized ledger mechanism, enhances information sharing throughout the supply chain safely and visibly. The research result in the journal publication [2] achieves objective (2) by demonstrating the architecture of the system and its requirements which can be applied in e-commerce to strengthen efficiency.

Moreover, the project team has developed a novel blockchain-based e-commerce analytics model, which can improve the quality of traceability data and reliable information sharing for sufficient data analysis. Conference publication [3] is the result of achieving objective (1). A Blockchain-based E-Commerce Analytics Model is developed by integrating blockchain technology and Artificial Neural Network (ANN) in logistic data management and e-orders forecasting. Such blockchain-based decision support system also achieves project objective (4) by enabling data sharing and integration between supply chain stakeholders. Thus, industry practitioners can make accurate and timely decisions based on order arrival prediction under the e-commerce operating environment. The presentation posters included in Annex 4 demonstrate how this conference publication accomplished the objectives.

To conclude, in this project, we have developed the Forecasting analytics model in order picking (FAAOP) for predicting potential travel time fluctuations [1], a blockchain-based system for tracing and tracking aircraft spare parts [2], and a Blockchain-based E-Commerce Analytics Model to enable accurate and timely decisions based on e-commerce order arrival prediction [3]. In addition, a seminar is conducted to share the project outcomes.

# 5.4 Summary of objectives addressed to date

<b>Objectives</b> (as per 5.1/5.2 above)	Addressed (please tick)	<b>Percentage Achieved</b> (please estimate)
1. To apply blockchain technology as the foundation of information architecture for facilitating upstream and downstream supply chain/logistics data exchange, and to integrate the machine learning (ML) and artificial intelligence (AI) techniques, big data analytics tools for generating decision support to underpin supply chain efficiency enhancement.	1	100%
2. To engage with stakeholders and regulators from across the retail and logistics network with blockchain research capability in order to identify the requirements for information architecture that will contribute to e-commerce supply chain efficiency enhancement.	~	100%
3. To enhance the core competence of the supply chain practitioners in Hong Kong in capturing e-commerce business through streamlined supply chain data exchange and information management.	1	100%
4. To develop a novel blockchain-based e-commerce analytics model that assists supply chain stakeholders in data sharing and integration and enables industry practitioners to make accurate and timely decisions based on e-commerce order arrival prediction under the e-commerce operating environment.	1	100%

#### 6. Research Outcome

# 6.1 Major findings and research outcome (*Maximum 1 page; please make reference to Part C where necessary*)

In the first part of the project, we have developed a blockchain-based system that emphasizes the traceability and trackability of aircraft parts, whereas also focusing on secured information sharing through the supply chain. The sensitivity analysis proves that the proposed model satisfied the requirements for Aircraft Spare Parts Inventory Management (ASPM); the system can handle a throughput of over 2000 transactions per second, which is greater than the 0.16 tps requirement by a large margin. In addition, the suggested model is competent in handling authorization from different sources and mapping rules of operational process. With all these traits combined, different stakeholders along the supply chain can communicate freely and safely, allowing for better monitoring of aircraft parts. The research outcomes led to journal publication [2].

In the second part of this project, a forecasting analytic model, Forecast Accuracy Analysis in Order Picking (FAAOP), has been developed to assess the error in forecasting. The results of the journal publication [1] indicates the accuracy and robustness of the model; the discrepancies between forecast travel time and actual travel time for batching by order and wave picking are only 0.11% and 0.05%, which refers to 0.38 min and 0.05 min respectively. FAAOP has also been examined in contrast with existing studies to exhibit its advantage. Previous studies were conducted under the assumption of either unambiguous order demand pattern or packing is the most time-consuming task, which are both not the case in e-fulfilment center. Nonetheless, FAAOP studies the impact of forecast error under different picking methods of e-order, filling the gap by assessing the impact demand forecast error has on order picking performance through consolidating error fluctuation in demand forecasting model on the order picking aspect using the FAAOP. With the decisional support from FAAOP, the chances of mismatching staff and workload would be lowered to save costs. This research outcome led to journal publication [1].

In the last part of the project, we developed a Blockchain-based E-Commerce Analytics Model through the integration of blockchain technology and the machine learning (ML) algorithm. The construction of a blockchain-based data management framework facilitates the data exchange and integrity along a supply chain network, while the data in blockchain can be learned by the machine learning model named ANN. With the proposed model, practitioners can flexibly re-allocate the right number of resources in real time to deal with the hour-to-hour fluctuating arrival of orders in distribution centers. To examine the applicability of the proposed model, a dynamic e-fulfillment environment was built for predicting the e-order arrival in a period of time. To generate the ANN models the input data is firstly divided into two different parts, namely training set and validation set. The training set is used to train the network with historical data, while the validation set is used to evaluate the ANN performance. In this case, 70% of the data was used as the training set and 30% of the data was used as the validation set. The Mean Squared Error (MSE) was used to measure the prediction error and evaluate the performance of the ANN models. The results showed that e-orders prediction accuracy can be optimized, by using the ANN training to find the optimal model. The high prediction accuracy enables LSPs to handle dynamic e-commerce order demand so that logistic service providers are able to sustain and expand their logistics business under e-commerce environment. This research outcome led to conference publication [3].

6.2 Potential for further development of the research and the proposed course of action (*Maximum half a page*)

For the further development of journal publication [2], statistical functions can be designed to calculate the number of damages that happened in each species and the life cycle of parts. Therefore, practitioners can conduct further investigation by checking these records and improve the reliability performance of spare parts. Practitioners can benefit from controlling the number of purchases and achieve just-in-time inventory management, which can minimize storage costs and increase efficiency.

For the journal publication [1], future studies can include real-time forecast methods with industrial warehouse data and consider the role of inventory management in warehouse operations. This can lay the foundation for creating a decision support system for staffing problems in an e-commerce scenario.

For the conference publication [3], we can collect real data by implementing the proposed Blockchain-based E-Commerce Analytics Model. This not only allows the verification to be done through physical data but also enables those data to be analyzed further. Therefore, the proposed Blockchain-based E-Commerce Analytics Model can be extended to other domain applications.

#### 7. Layman's Summary

(Describe <u>in layman's language</u> the nature, significance and value of the research project, in no more than 200 words)

Blockchain-based E-Commerce Analytics Model is a novel model integrated by blockchain technology and data analysis. Blockchain is a distributed transactional data structure that stores records and other information managed by the consensus mechanism and secured by cryptography, which improve the quality of traceability data and reliable information sharing within the supply chain. The data in blockchain can be analyzed to enhance the performance of logistics services providers. An intelligent model has been developed to predict the future e-order arrivals by the ANN model. Moreover, the FAAOP has been developed that translates the error of forecast accuracy in order demand to the performance fluctuations in e-order fulfilment. With the developed models in the project, practitioners can realize the e-commerce order arrival patterns, enabling flexible re-allocation of the right number of resources in real time to deal with the hour-by-hour fluctuating arrival of orders in the distribution centers. Also, it allows retailers to predict the sales volume among various e-commerce sales channels, the sales volume from different customer segments, and the e-commerce sales performance of different product categories. Consequently, the proposed system can help sustain and expand the e-business of all stakeholders in the supply chain.

# Part C: Research Output

8. Peer-Reviewed Journal Publication(s) Arising <u>Directly</u> From This Research Project (Please attach a copy of the publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The	e Latest Stat	us of Publica	ations		Title and Journal /	Submitte			
Year of Publication	Year of Acceptance (For paper accepted but not yet published)	Under Review	Under Preparation (optional)	Author(s) (denote the correspond- ing author with an asterisk <sup>*</sup> )	Book (with the volume, pages and other necessary publishing details specified)	d to RGC (indicate the year ending of the relevant progress report)	Attached to this Report (Yes or No)	Acknowledged the Support of RGC (Yes or No)	Accessible from the Institutional Repository (Yes or No)
2021	-	-	-	Ho, G. T., Tang, Y. M., Tsang, K. Y., Tang, V., & Chau, K. Y.	A blockchain-b ased system to enhance aircraft parts traceability and trackability for inventory management. Expert Systems with Applications, 179, 115101.	Has been submitted with the midterm progress report as an accepted paper March 2021	Yes (Annex 1)	Yes	Yes https://resear chdb.hsu.edu hk/view/pub lication/2021 00110
2022	-	-	-	Ho, G. T. S., Choy, S. K., Tong, P. H., & Tang, V.	A forecasting analytics model for assessing forecast error in e-fulfilment performance. Industrial Management & Data Systems, DOI 10.1108/IMD S-01-2022-00 56	NA	Yes (Annex 2)	Yes	Yes https://resear chdb.hsu.edu hk/view/pub lication/2022 00277

# 9. Recognized International Conference(s) In Which Paper(s) Related To This Research Project Was / Were Delivered

(Please attach a copy of each conference abstract)

Month / Year / Place	Title	Conference Name	Submitted to RGC (indicate the year ending of the relevant progress report)	Attached to this Report (Yes or No)	Acknowledged the Support of RGC (Yes or No)	Accessible from the Institutional Repository (Yes or No)
Feb/2023/ Bali, Indonesia	A Blockchain-based Decision Support System for E-commerce Order Prediction.	International Conference on Artificial Intelligence in Information and Communication (ICAIIC)	NA	Yes (Annex 3)	Yes	No

# 10. Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning

(Please elaborate)

NA

# 11. Student(s) Trained

(Please attach a copy of the title page of the thesis)

Name	Degree Registered for	Date of Registration	Date of Thesis Submission / Graduation
NA	NA	NA	NA

#### 12. Other Impact

(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)

Annex 4: Conference Presentation Posters

Annex 5: Seminar on Blockchain-based E-Commerce Analytics Model for Facilitating

Trusted Data Exchange and Digital Supply Chain Integration.

# **13. Statistics on Research Outputs**

	Peer-reviewed Journal Publications	Conference Papers	Scholarly Books, Monographs and Chapters	Patents Awarded	Other Rese Output (please spe	earch s cify)
No. of outputs arising directly from this research project	2	1	NA	NA	Type NA	No.

# 14. Public Access Of Completion Report

(Please specify the information, if any, that cannot be provided for public access and give the reasons.)

Information that Cannot Be Provided for Public Access	Reasons
NA	NA