

RGC Ref. No.: UGC/FDS14/E05/16 _____ (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)

<p><u>Submission Deadlines:</u></p> <ol style="list-style-type: none"> 1. Auditor's report with unspent balance, if any: within six months of the approved project completion date. 2. Completion report: within 12 months of the approved project completion date.

Part A: The Project and Investigator(s)

1. Project Title

Adaptive process optimization strategies: Sustaining the best-in-class performance of spare parts services

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

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	Dr. MO Yiu-wing/ Associate Professor	Department of Supply Chain and Information Management/ The Hang Seng University of Hong Kong
Co-Investigator	Prof. Fugee TSUNG / Chair Professor	Department of Industrial Engineering and Decision Analytics/ The Hong Kong University of Science and Technology
Co-Investigator	Dr. WONG Yin-cheung, Eugene / Associate Professor	Department of Supply Chain and Information Management/ The Hang Seng University of Hong Kong

3. Project Duration

	Original	Revised	Date of RGC / Institution Approval <i>(must be quoted)</i>
Project Start Date	1/1/2017	1/1/2017	NA
Project Completion Date	31/12/2019	30/06/2020	06/05/2019
Duration <i>(in month)</i>	36 months	42 months	Same as above
Deadline for Submission of Completion Report	31/12/2020	30/6/2021	Same as above

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. *To investigate the key considerations in the evolution of service parts operations.*
2. *To propose a new service parts management framework with a standardised process flow.*
3. *To develop a simulation platform with visualisation tools for evaluation and analysis.*
4. *To assess the economic criteria of repairing components in the reverse logistics network.*
5. *To derive optimal adaptive policies for the inventory management of service parts.*
6. *To transfer the knowledge provided by process visualisation tools as an open source to academia and the industry.*
7. *To publish the research results in journals, conference papers and case studies.*

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)

All the proposed objectives have been achieved through literature review, market study, project meeting with practitioners, survey, computer programming, etc. The research findings have been published in journal papers and presented in international conference.

The objectives 1-3 are the building blocks of this research project. Through the interview and project meeting with collaborating companies, the key considerations and generic process flow for the best-in-class service parts management framework have been identified. Afterwards, a stimulation platform with performance visualization tools has been developed to evaluate the performance of service parts management. Objectives 4-5 are then achieved by formulating the decision models and deriving the optimal policies. After obtained the analytical results, we aim to transfer the knowledge to practitioners and publish the results in journal papers for objectives 6-7. Three journal papers are published, while one of them involves the practitioner as a co-author for the publication in INFORMS Journal on Applied Analytics.

5.4 Summary of objectives addressed to date

Objectives <i>(as per 5.1/5.2 above)</i>	Addressed <i>(please tick)</i>	Percentage Achieved <i>(please estimate)</i>
1. Investigate the key considerations in the evolution of service parts operations management.	✓	100%
2. Propose a new service parts management framework with a standardised process flow	✓	100%
3. Develop a simulation platform with visualisation tools for evaluation and analysis.	✓	100%
4. Assess the economic criteria of repairing components in the reverse logistics network.	✓	100%
5. Derive optimal adaptive policies for the inventory management of service parts.	✓	100%
6. Transfer the knowledge provided by process visualisation tools as an open source to academia and the industry.	✓	100%
7. Publish the research results in journals, conference papers and case studies.	✓	100%

6. Research Outcome

6.1 Major findings and research outcome

(Maximum 1 page; please make reference to Part C where necessary)

In this research project, the major findings and research outcome are summarized into three areas: i) Process optimization for service parts operations with a case study; ii) Optimal service parts contract with multiple response times; iii) Redeploying strategy of excess inventories by reverse transshipments.

i) Process optimization for service parts operations through a case study: Collaborated with an international company, we investigate the service parts operation ranked in the best-in-class with a support of well-known inventory planning system for a case study. This study focuses on a data-driven approach for process optimization to supplement the computational logic of the system that embeds an inventory decision model. Through the case study, the major causes of insufficient stock were systematically analyzed and corrected. A cost-effective inventory solution was formulated for its inventory planning system, which resulted in a 10% decrease in the ratio of inventory to revenue and a fill-rate increase from 99.1% to 99.6%. The standard deviation of the replenishment lead time also declined from 4.97 to 1.87 days, implying that the variation of the replenishment lead time was greatly reduced. The data-driven process optimization approach, therefore, provide new insights to academics and practitioners. The research findings are published in the *INFORMS Journal on Applied Analytics* (Mo et al., 2019).

ii) Optimal service parts contract with multiple response times: One of the analytical studies focuses on user outsourcing of spare parts management to vendors through a service contract. The user's selection of a fixed-price service parts contract is formulated as a stochastic integer programming model that decides multiple response times and on-site spare parts, while considering component breakdown with uncertain failure rates. The optimality conditions are analytically derived for the continuous case for the design of an efficient algorithm. Numerical illustrations and analyses are conducted to evaluate decisions under various scenarios. It is shown that there is a cost-saving pooling effect in spare parts for identical items, which significantly raises the likelihood of having on-site stored parts. The problem becomes more complex for multiple items, reflecting bundling effects between items for a given contract. The related findings are published in the *International Journal of Production Research* (Mo et al., 2020).

iii) Redeploying strategy of excess inventories by reverse transshipments: Another analytical study focuses on the management of excess inventories by reverse transshipments in a network level. By expanding the conventional inventory management that passively focuses on the forward and lateral flows of service parts deployment, we propose a crucial but overlooked practice of inventory redeployment as an integral part of the operations that allow the proactive management of lateral and reverse flows of service parts. We formulate the service parts inventory problem with the application of an excess inventory redeployment strategy in a multi-echelon service network as a multi-period integer programming model. This optimisation model is evaluated using a case study of an international company's service parts operations and demonstrates a higher cost-saving potential. Our novel, integrated approach confers the advantage of redeploying excess inventories in a closed-loop service parts logistics network with a higher cost-saving potential that could not have been achieved in a conventional approach. The related findings are published in the *International Journal of Production Research* (Mo et al., 2021).

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

With the three journal papers published, the PI realizes the renewed interests of service parts management due to the challenge of non-stationary demand in a complex network structure. The overall management framework and the strategy is proposed for a book chapter, entitled “Adaptive Intelligent Redeployment Strategy for Service Parts Inventory Management”. Moreover, from inventory management perspective, the proposed solution approaches would be also applied in the e-commerce products which have non-stationary demand and require a quick response delivery. A two-stage decision model of reshuffling inventories and order dispatch is being investigated with the consideration of both crowdsourced and self-owned vehicles among multiple facilities in a network for future research. A proposal has been made to further investigate this complex decision problem.

7. Layman’s Summary

(Describe in layman’s language the nature, significance and value of the research project, in no more than 200 words)

With the advanced logistics developments in recent decades, various manufacturers are able to profit from the spare parts service for systems maintenance and to enhance product sustainability by managing the express delivery and the reverse logistics. These advanced logistics developments have driven the evolution of traditional spare parts management into a new service model. Apart from the on-site spare parts management, manufacturers and authorised service providers must offer more customised services and the collection of repairable items from users in the reverse logistics process. However, these evolutionary service requirements introduce procedural complexities and extends the service scope.

In this research, we aim to optimise the process of service parts management through a holistic and adaptive approach. The whole process scope includes logistics network design, inventory and warehouse management, and reverse logistics operations. To identify the numerous factors and parameters during the process optimisation, we start by standardising a generic process flow of service parts operations that align with companies’ strategic objectives. Then, we perform data collection to investigate the effects of these factors and their correlations. After identifying the critical factors, we formulate them into a generic decision model for deriving optimal adaptive policies with a data-driven process control mechanism. A simulation platform is developed to verify and monitor the proposed solutions. The performance of the optimal adaptive policies are finally benchmarked with the optimal static policy, which is commonly applied in various industries. These results provide effective guidelines for the implementation of adaptive process optimisation of service parts operations.

Part C: Research Output

8. Peer-Reviewed Journal Publication(s) Arising Directly 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 Latest Status of Publications				Author(s) (denote the corresponding author with an asterisk*)	Title and Journal / Book (with the volume, pages and other necessary publishing details specified)	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)
Year of Publication	Year of Acceptance (For paper accepted but not yet published)	Under Review	Under Preparation (optional)						
2019				Daniel Y. Mo, Stephen Ng, David Tai.	Revamping NetApp's Service Parts Operations by Process Optimization", <i>INFORMS Journal on Applied Analytics</i> , 49(6), 407-421.	2021	Yes (Annex I)	Yes	Yes
2020				Daniel Y. Mo, Yue Wang, Lawrence Leung, Mitchell Tseng.	Optimal service parts contract with multiple response times and on-site spare parts", <i>International Journal of Production Research</i> , 58(10), 3049-3065.	2021	Yes (Annex II)	Yes	Yes
2021				Daniel Y. Mo, Yue Wang, Danny C. K. Ho & K. H. Leung	Redeploying excess inventories with lateral and reverse transshipments", <i>International Journal of Production Research</i> . DOI: 10.1080/00207543.2021.1910360	2021	Yes (Annex III)	Yes	Yes

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 <i>(indicate the year ending of the relevant progress report)</i>	Attached to this Report <i>(Yes or No)</i>	Acknowledged the Support of RGC <i>(Yes or No)</i>	Accessible from the Institutional Repository <i>(Yes or No)</i>
12/2017/ Singapore	Excess Inventories Redeployment Strategy for Spare Parts Service Logistics Management	2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)	2018	Yes (Annex IV)	Yes	Yes

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

(Please elaborate)

The research experience and knowledge transfer have been achieved through supervision of group of students on a senior year project as well as updating the teaching materials in module of quality management with process analytics. A group of students have been involved to understand the planning process of service parts operations, managed by an international company. In addition, the data-driven approach for process optimization is developed as part of undergraduate teaching materials.

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.)

Apart from the journal publication, this research project also achieves technology transfer.

During the collaboration with an international company, the PI's research team conducted the investigation to analyze the inventory planning system based on the data collected. An optimization model to redeploy excess inventories and a data-driven approach was proposed to drive the company's continuous improvement. Last but not least, the trained students are able to share their project experiences during their job seeking process.

13. Statistics on Research Outputs

	Peer-reviewed Journal Publications	Conference Papers	Scholarly Books, Monographs and Chapters	Patents Awarded	Other Research Outputs (please specify)	
No. of outputs arising directly from this research project	3	1	0	0	Type	No.
					0	0

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