

**RESEARCH GRANTS COUNCIL
THEME-BASED RESEARCH SCHEME (TRS)**

Completion Report on Funded Project

Project start date: 1 November 2014
Project completion date: 31 October 2019

1. Project Title: Delivering 21st Century Healthcare in Hong Kong – Building a Quality-and-Efficiency Driven System

2. Names and Academic Affiliations of Project Team Members[#]

Project team member	Name / Post	Unit / Department / Institution	Average number of hours per week spent on this project in the <u>whole</u> project period
Project Coordinator (PC)	CHEN Youhua, Frank, Chair Prof/Head	MS Dept., CityU	12
Co-Principal Investigator(s)	CAI Xiaoqiang, Prof.	CUHK	8
	YE Hengqing, Assoc Prof	LMS/PolyU	8
	YAU Kelvin, Prof.	CityU	6* (retired, 09/2018)
	CHIN K.S., Assoc Prof.	CityU	8
	LAI K.K., Chair Prof.	HKU (Former affiliation: CityU)	12
	HUANG George,	HKU	8

	Prof./Head		
	TSUI K.L, Chair Prof., Head	CityU	6
	YAN Houmin, Dean & Chair Prof.	CityU	4
	YAO David D., Chair Prof.	ColumbiaU	8
	WONG Eliza, Prof	CUHK	8
	YEOH Eng-kiong / JC School of Public Health and Primary Care	CUHK	4
Co-Investigator(s)	CHAU Patsy YK / Research Associate	CUHK	12
	GUO Pengfei, Prof	LMS/PolyU	8
	OR Calvin, Assist Prof.	HKU	12
	LIANG Liping, Assoc Prof	CDS/LingnanU	8
	LIN Carrie, Assoc Prof.	CityU	12
	ZHOu Sean, Assoc Prof.	CUHK	4
	LEUNG Eman, Assist Prof.	CityU	12
	ZHAO Leon J., Chair Prof.	CityU	4
	SINGPURWALLA Nozer, Chair Prof.	CityU	8
	PANG Zhan, Assoc Prof. Note 1	Purdue University (Former affiliation: CityU)	6* (left CityU, 09/2018)
	HU Joice Qiaohai, Assist Prof. Note 2	University of Missouri-St. Louis (Former affiliation: CityU)	4* (left CityU, 09/2017)
	KIM J.B., Prof.	CityU (Former affiliation: U of Waterloo)	4
	LEE Andy, Chair Prof.	Curtin Univ.	8
	HUI Y.V., Prof.	Hang Seng Management College	8
	LI David Y.Z., Assoc Prof.	CityU	8
	ZHANG Qingpeng, Assist Prof.	CityU	12

	XIE Min, Chair Prof.	CityU	8
	YU Yimin, Assist Prof.	CityU	10
	HUANG Junfei, Assist Prof.	CUHK	8
	ZHANG Jiheng, Assist Prof.	HKUST	8
	WONG Zoie, Assoc Prof.	St. Luke's International University (Former University of New South Wales staff)	12
Collaborators	QI Jin, Assist Prof.	HKUST	4 N/A
	LIM Andrew, Prof.	CityU	1* N/A (left CityU 09/2016)
	FUNG Richard, Assoc Prof.	CityU	4 N/A
Advisory Board#	Fung Hong, Dr./Hon. Prof.	CUHK/ JC School of Public Health and Primary Care	N.A
	HUNG Chi-Tim, Chief Executive & Cluster CEO	Prince of Wales Hospital & New Territories East Cluster	N.A
	LIT C.H. Albert, Dr./Chief of Ser.	Yan Chai Hospital and PMH	N.A
	KO Susanna, General Manager of Admin. Serv.	Kowloon Central Hospital Cluster and QEH	N.A
	LEE T.F. Diana, Prof.	The Nethersole School of Nursing, CUHK; board member of the Hospital Authority; member of the Elderly Commission	N.A

*Retired or left CityU during the project duration

Please highlight the approved changes in the project team composition and quote the date when the RGC granted approval of such changes. For changes in the project team composition, please submit a separate request, together with the justification and the curriculum vitae of the new member(s), to the RGC three months prior to the intended effective date of the change.

Note 1: The RGC approved addition of Co-Investigators, Dr. Eman Leung and Dr. Zhan Pang on 29th June, 2016. They have contributed a total of 18 hours per week in this project, so the total time spent on the research was actually more than what we committed in the beginning of the project -- Dr Leung and Dr Pang could absorb the reduction of hours spent on research due to the retirement of Prof Kelvin Yau and the departure of Prof Joice Hu. Moreover, Dr. Pang remained active after his joining Purdue Univ. (09/2018), for example, he published a paper in 2020 (see T5.58 in Appendix B).

Note 2: The project team apologizes for not reporting the departure of Dr. Joice Hu Qiaohai in time. Indeed this was only a change of her affiliation. Dr Joice Hu also remained active after she joined University of Missouri–St. Louis. In the initial proposal, she was expected to take part in the sub-task “capacity purchase” under the Task “Study of public-private partnership and capacity purchase”. After the Midterm Panel Review, our focus was shifted on elderly care, and her hours contributed was thus reduced.

3. Project Objectives

Summary of objectives addressed/achieved:

Stage Start Date (Month/Year)	Objectives*	Percentage achieved	Remarks**
11/2014 Stage 1	Working papers in (i) Healthcare Management; (ii) Healthcare Analytics/Informatics (All institutions)	100%	
	2) Systematic review on healthcare data in Hong Kong, focusing on clinical, community, and government sources; comparison studies against similar data and facts in other countries such as Australia and Singapore (led by CUHK team and participated by CityU team)	100%	
	3) Case studies on a select set of hospitals/clinics, which will be used for model formulation and tool development (PolyU, LU, CityU & HKU)	100%	
	4) A report on the study of existing cross-cluster referral booking system (CityU, CUHK & HKUST)	100%	Fulfilled during Stage 4
	5) Webpage based platform setup for team communication and coordination	100%	
9/2015 Stage 2	1. A preliminary design of a patient-centric health system framework with cost-and-efficiency driven (led by CUHK team and participated by CityU team)	100%	
	2. A workshop on healthcare management with local and international participants	100%	

Stage Start Date (Month/Year)	Objectives*	Percentage achieved	Remarks**
	(CityU leads and all institutions join force to organize)		
	3. Working papers in (i) Healthcare Management; (ii) Healthcare Analytics/Informatics (All institutions)	100%	
	4. Conference papers in (i) Healthcare Management; (ii) Healthcare Analytics/Informatics (All institutions)	100%	
	5. Preliminary report on causes for different mortality rates among hospitals (CityU & CUHK)	100%	Completed in Stage 5
5/2016 Stage 3	1. A list of healthcare data in Hong Kong, including sources and type, for the development of framework – a preliminary study for the data repository framework (led by CUHK team and participated by CityU team)	100%	
	2. Journal/working papers in (i) Healthcare Management; (ii) Healthcare Analytics/Informatics (All institutions)	100%	
	3. Conference papers (≥ 5 papers) (All institutions)	100%	
	4. A workshop on healthcare management (All institutions)	100%	
	5. Organizing an invited session in major international conf. (such as INFORMS or POM Annual Meeting) (All institutions)	100%	
	6. A report to summarize risk-adjusted monitoring models and tools (CityU and CUHK)	100%	Completed in Stage 5

Stage Start Date (Month/Year)	Objectives*	Percentage achieved	Remarks**
05/2017 Stage 4	1. Working papers in (i) Healthcare Management; (ii) Healthcare Analytics/Informatics (All institutions)	100%	
	2. The patient-centric health system framework in the context of HK (led by CUHK team and participated by CityU team)	100%	
	3. Journal Publications (≥ 5 papers) (All institutions)	100%	
	4. Conference papers (≥ 5 papers) (All institutions)	100%	
	5. Organizing an invited session in major international conf. (such as INFORMS or POM Annual Meeting)	100%	
	6. A workshop on healthcare management	100%	
05/2018 Stage 5	1. Journal/conference publications in (i) Healthcare Management; (ii) Healthcare Analytics/Informatics ($> 8/8$ papers) (All institutions)	100%	
	2. Working papers in (i) Healthcare Management; (ii) Healthcare Analytics/Informatics (All institutions)	100%	
	3. Organizing two invited sessions in major international conf. (such as INFORMS and POM Annual Meeting) (All institutions)	100%	
	4. A feasibility study to investigate the mechanism and (data) infrastructure of the framework (continued with Item 2 in Stage 4; led by CUHK team and participated by CityU team)	100%	
	5. A workshop on healthcare management (All institutions)	50%	Multi-mini workshops were held. An int'l conf. was scheduled originally in Nov 2019. See 6.9 below

Stage Start Date (Month/Year)	Objectives*	Percentage achieved	Remarks**
	6. Demo version of analytics tools for hospital resources planning (CityU & PolyU)	100%	Dr. Eman Leung's work at HA Data/working papers (CUHK)
	7. Formation of the HK Healthcare Operations Management Chapter (All institutions)	60%	Delayed to Dec. 2019 - see the Event Minute in Appendix E (Upcoming POMS-HK 2020 Conference meeting minutes). Also refer to 6.9 below.
5/2019 Final Stage	1. Hierarchical hospital resource planning system models & tools	100%	Working papers from collaboration with HA Data Lab
	2. Data analytics models & tools	100%	
	3. A patient-centric healthcare delivery framework that is based on data and emphasizes resource planning/optimization and patient-centric service innovation	100%	Reflected in the report "Fit for Purpose: A Health System for the 21st Century" (30 November 2018, Hong Kong), Our Hong Kong Foundation ("OHKF").
	4. To recommend governance mechanism of healthcare data management	100%	The PC was on the consultation committee informing the setting up of the HA Data Collaboration Lab (in terms of privacy and end-user management and governance, HADCL, 2018); and with the HADCL project, the team provided further feedback to HA data infrastructure and information architecture. And so does the Strategic Public Policy Research project (see 7.1), sponsored by primary care office, in the context of primary care office's governance in integrating data.
	5. Risk-adjusted monitoring models and tools	100%	A paper published (see 6.4 (c) below), and a proposal submitted for research grant (GRF) "Development of artificial intelligence-enabled algorithm for postoperative outcome prediction using 12-year surgical records from all public hospitals in Hong Kong"
	6. Research papers in academic journals and conference presentations and proceedings	100%	

Stage Start Date (Month/Year)	Objectives*	Percentage achieved	Remarks**
	7. A healthcare management research community in Hong Kong	70%	See 6.9 below

* Please highlight the approved changes in objectives and quote the date when the RGC granted approval of such changes.

** Please provide reasons for significantly slower rate of progress than originally planned.

6. Research Highlights and Outputs

6.1 What are the most exciting research accomplishments of the project?

(Please list five or more of the team's best research accomplishments, such as journal and conference papers, software codes, research infrastructure, etc. For each item, please clearly justify how it has achieved international excellence (e.g. best paper award, invited presentation, citations, product licensed to industry, etc.))

1. Our "Double-down effort" and re-prioritizing on elderly care, as advised by the Panel has yielded the following fruitful outcomes.

- 1) The team led by the College of Business, CityU, in collaboration with Jockey Club School of Public Health and Primary Care, CUHK, has been awarded \$23.8M funding from Bank of China (HK, BoCH) Centenary Charity Programme (Secretariat: The Hong Kong Council of Social Service). Under the project title "HomAge: Home-based aging for transformative community care", we propose a pilot project to implement the home-based care programme based on the global phenomenon, Buurtzorg homecare model. It will leverage on an IT platform for service planning and coordination, and deploy the AI/data analytics tools developed in this TRS project to identify target patient segment(s) for the most effective and affordable post-discharge care portfolios, etc. This 3-year project started in October 2020 and is coordinated by Prof Frank Chen (PC).
- 2) Under the Strategic Public Policy Research (SPPR) Funding Scheme (2019-20), Dr. Eman Leung (CUHK) co-leads a team with Dr. Albert Lee for the project "Profiling Older Population's Risks in the Kwai Tsing Neighbourhood and Optimising the Service Operations at District Health Centres: Data-driven Service Model and Policy Design"(about \$5M). It aims to develop AI algorithms to optimize the match between patient risk profiles and the portfolios of health and social services across the care continuum, which are upgraded from the data analytic tools developed in the current TRS project, in collaboration with the Hospital Authority's Data Collaboration Lab.
- 3) Under the Public Policy Research (PPR) Funding Scheme (2020-21, 2nd round), the proposal from a CityU team for a pilot project "Development of a Longitudinal Database on Adult Development and Aging" was funded. This project will synergize the BoCH project in data collection.
- 4) Sensor technology has been utilized in the project for monitoring and assessment of the health of the elderly, including general wellness, blood pressure, gait and balance. We found that sensors provided researchers with big data, from which more features could be extracted for comprehensive evaluation of wellness, gait and balance. The research outcomes have been published in referred international journals (Appendix B T5.30, T5.34, T5.37), including IEEE Transactions on Industrial Informatics, IEEE Access, IEEE Sensors Journal, etc. Moreover, the system developed will be applied

and further tested in the BoCH project.

- 5) We have also developed a general framework of system health monitoring and management (SHMM), which is a framework for continuous surveillance, analysis and interpretation of related data for system monitoring, management and strategic planning. We provide a new perspective on the health monitoring and management of complex systems, such as a health system in a big data environment. The research outcome has been published in IEEE Access (Appendix B T5.9).
2. We developed a number of machine learning models to predict the onset of various diseases that are critical in Hong Kong, including
 - 1) heart failure (ESC Heart Failure 2020, Appendix B T5.21)
 - 2) mitral regurgitation (EJCI 2020, Appendix B T5.20)
 - 3) acute myocardial infarction (Atherosclerosis 2020, Appendix B T5.15)
 - 4) dementia (Journal of Alzheimer's Disease 2020, Appendix B T5.22)
 - 5) suicide and depression risk assessment in Hong Kong (Journal of Affective Disorders 2020, 2019; IJIM 2019, Appendix B T5.35)
 - 6) Brugada syndrome (JAHA 2020; FiP 2020), and others (IEEE-IS 2020; Appendix B T5.18).
3. We developed advanced machine learning models for predicting future high-cost patients with COPD (Int'l J. of Med. Informatics 2019, Appendix B T5.27, T5.42),
4. We developed infectious disease models for HIV and other infectious health behaviours (IEEE-TCyb 2018 and Sci Rep 2018, Appendix B T5.40 & T5.4, resp.; IDH 2019, Appendix B T5.7). Recently we devoted effort to combating the COVID-19 pandemic.
5. We developed models to compare subsidy schemes that are widely used in reducing waiting times for public healthcare service (POM 2017, Appendix B.) and to analyze hospital resource planning (POM 2020, Appendix B T2.3), and tools for appointment-scheduling problems in public hospitals (Management Sci. 2020) and for managing elective admission in public hospitals (Oper. Res. 2015).
6. Multiple healthcare-related projects have been funded over the past 4 years by competitive grants, including 4 GRF, 1 Health and Medical Research Fund (HMRF), 2 Natural Science Foundation of China grants.
7. A Professional Certificate Program in The Health System Leadership Program has been developed since 2017, CUHK JC School of Public Health and Primary Care:
<https://www.hsl.sphpc.cuhk.edu.hk/about-the-programme-1>
- 6.2 What was the added value of the TRS funding, rather than standard project grant funding?
(For example, could this work have been achieved with other funding scheme, such as the General Research Fund or Collaborative Research Fund? If not, why?)

Other RGC programmes would not be effective in accomplishing the objectives of this TRS project. They either lack the thematic unity and coherence (e.g., individual earmarked grants) or are simply not “grand” enough in scale and scope, CRF included. Healthcare spans a multitude of “areas” that are best developed alongside each other while housed within a coordinated framework. A theme-based format, in all aspects, is the perfect approach. It

provides the necessary structure and rigour, and the resources for building a coherent body of knowledge to support healthcare research, the indispensable ingredient and impetus in developing new healthcare delivery systems that are quality- and efficiency-driven, and innovative value propositions. This is truly a grand challenge of our time.

6.3 If the project has not met its original objectives, why?

Overall, all original objectives have been achieved, except an international conference, which was first planned in Nov. 2019, but cancelled due to social unrest, and then re-scheduled to June 2020, again cancelled in March because of COVID-19 pandemic. We now target it for late 2021.

- 6.4 (a) Peer-reviewed journal publication(s) arising directly from this 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. Please mark the symbol “#” next to the publications involving inter-institutional collaborations)

Please refer to Appendix B. Overall, ~~65~~ 109 refereed journal papers have been published with RGC being acknowledged, ~~and more than 10 submissions are under review.~~
Another 7 submissions are under review amnd 2 papers are under preparation.

- (b) Recognised international conference(s) in which paper(s) related to this project was/were delivered:

(Please attach a copy of each conference abstract)

Please refer to Appendix C

- (c) RGC funding should have been acknowledged in all publication(s)/conference papers listed in (a) and (b) above. If no acknowledgement has been made in any of the publications/ papers, please indicate and provide explanations.

Please refer to Appendix B. Note: Article Appendix B T5.49 was published without acknowledging this TRS. Justification: C-PI Prof Kelvin Yau took early retirement, commencing in July 2018, yet the paper was prepared while he was still active in the TRS team, (in fact several members at CityU were working closely with Queen Elizabeth Hospital (QEH) on several projects.) However, because of his retirement and miscommunications, the TRS project was un-acknowledged. It partially fulfils the Objective “Risk-adjusted monitoring models and tools” (Task #5 in Final Stage).

6.5 To what extent this project has strengthened inter-institutional collaborations and other partnerships?

Through the TRS project, the CityU team has developed close collaboration with the Hospital Authority and its hospitals, such as Queen Elizabeth Hospital (QEH). For example, besides research projects, multiple master student projects were conducted at QEH; and most notably, the team led by Dr. Eman Leung and Professor Chen has developed a hybrid machine learning model that can enable QEH to monitor the risk of readmission of its monthly discharged patients up to one year after their discharges (28 to

365 days), and the algorithm has been piloted at the medical ward for a year with above 85% confidence in monthly prediction.

The collaboration with QEH has enabled Dr. Eman Leung and Professor Chen to engage social services whose catchment areas overlaps with QEH; through a collaborative project whose goal was to foster better integration between medical and social service deliveries, the team developed machine learning algorithms based on patients' medical and social service data, with the aim to apply operation analytics to optimize integrated medical-social service portfolios in a particular district. With this project, the exchange of domain knowledge and research methodology between the College of Business at CityU and School of Public Health and Primary Care at CUHK has been strengthened, which in the short-run, has resulted in the BoCH project and several (working) papers, and in the long-run, will impact on public health education and research in healthcare system development and management in Hong Kong.

The fruits borne from our research collaboration with QEH fostered our subsequent collaboration with the Hospital Authority at the corporate level, with the objective of informing the development of healthcare policy in Hong Kong. For example, a consultancy project was awarded in 2018 for Review of Patient Transport Service for the Hospital Authority, based on which a five-year plan for the non-emergency ambulance service was developed. In addition, an algorithm developed with the support of the TRS forms the basis of a project selected as the inaugural cohort of Hospital Authority's Data Collaboration Lab (HADCL; led by Dr Leung and Professor Chen), whose objective was to apply machine learning algorithm to identify the optimal pairing between patients' clinical profiles and ambulatory/post-acute service portfolios; the finding has been used to inform NGOs' planning of local District Health Centres at Kwai Tsing and Sham Shui Po, and will be used to inform Primary Care Office's policy decision concerning future District Health Centres, which is substantiated by the Strategic Public Policy Research (SPPR) project reported above.

In sum, we have not only leveraged the support of TRS to bring together different university partners, but with the help of TRS we have also created a platform for knowledge transfer between hospitals and local community services, and among Hospital Authority Headquarters Office, the Primary Care Office and NGO operators of District Health Centres. In addition, the PolyU team has established close connections with the industry (hospitals and healthcare businesses).

6.6 Research students trained (registration/awards):

Please refer to Appendix D. Overall, more than 40 PhD graduated or to be graduated, who have been partially supported by or worked on topics related to the TRS Project.

6.7 Specific products (e.g. software or netware, instruments or equipment developed):

N.A.

6.8 Other education activities and/or training programmes developed:

In particular, “Professional Certificate Program in The Health System Leadership Program” has been developed since 2017, CUHK JC School of Public Health and Primary Care: <https://www.hsl.sphpc.cuhk.edu.hk/about-the-programme-1>, The knowledge generated from this project is an important input for the teaching material and design in the leadership programme. And the project's findings play a significant role in the healthcare professional training, one of the key sustainable activity which extends beyond the project. The CityU team assisted in the design of the Master of Science in Health Sciences and Management at CityU, and developed the course MS5411 Healthcare Management: <http://www.cityu.edu.hk/bms/prog/mshsm/cur.htm>

6.9 Please highlight any deliverables indicated in the project implementation timetable endorsed by the RGC which have not been covered or achieved as per sections 6.1 to 6.8 above, and explain/ elaborate.

No significantly under-delivered items and 3 tasks have not been 100% fulfilled: an international conference and official formation and activities for Hong Kong interest group/section of healthcare management. The conference was delayed twice – first by social unrest and then by COVID-19, which should have served as the platform for carrying out the other two tasks. A conference that was cancelled twice will be re-scheduled in late 2021 or June 2022, by then we will officially form the HK Group of Healthcare Operations Management Society (under the HK Chapter of Operations Management Society. Once the social distancing restrictions is removed, a monthly seminar series on healthcare management will be launched, targeting in the second half of 2021.

6.10 Please elaborate how the PC has played his/her role in coordinating and managing the project.

The PC has played an important role both internally and externally. Overall, during this reporting period, the PC made strategic investment in new initiatives and projects that enabled the project to follow RGC Panel's recommendation and broaden the impact of the project beyond the academic discipline of OR/MS and beyond the care of the elderly.

Internally, the PC has been responsible for managing and scheduling the milestones and deliverables from each project teams. As teams at HKU and PolyU have been established in the projects over the years, we believe that it has been much easier for them to coordinate and manage their deliverables. Therefore, the PC has put great effort in fostering collaboration between CityU and CUHK Public Health teams to achieve the core goals and objective. CUHK team has participated in other projects with greater funding support, so it is a difficult task to align their priority with this project's goals. Therefore, formal meetings were arranged for the individuals from the two teams to discuss and identify several common interests, such

as integrated elderly care and resources allocation. The PC has established further collaborations between CityU and CUHK teams, culminating in the BoCH joint project between CityU and CUHK Public Health.

Externally, the PC got in touch with the industry and the community to understand what kind of challenges they were facing. For instance, after the PC initiated meetings with Queen Elizabeth Hospital General Manager, Hong Kong Christian Service or Caritas Medical Centre, collaboration opportunities were then identified for further follow up by different teams (such as HKU and CUHK).

7. Awards and Recognition

7.1 Have any research grants been awarded that are directly attributable to the results obtained from this project?

Yes. Two grants from the Public Policy Research (PPR) Funding Scheme: 1) Development of a Longitudinal Database on Adult Development and Aging (about \$1.2M, 2020-2022), PI: Dr YEUNG Yuen Lan, Dannii (CityU). As a Co-I, Prof Frank Chen has been instrumental in initializing and preparing the proposal. 2) A Feasibility Study on A Healthcare Voucher Scheme for Screening and Management of Cardiovascular Risk Factors Associated Chronic Diseases in the General Population: A Mixed Methods Evaluation (about \$1M, 2019-20), led by Prof YEOH Eng Kiong. One Strategic Public Policy Research (SPPR) Funding Scheme project Profiling Older Population's Risks in the Kwai Tsing Neighbourhood and Optimising the Service Operations at District Health Centres: Data-driven Service Model and Policy Design (about \$5M, 2020-2022), co-led by Dr LEUNG Eman and with Dr. Albert Lee (CUHK Public Health).

Dr. Qingpeng Zhang at CityU (Co-I of TRS) obtained 3 grants as PI, including 1) Health and Medical Research Fund (HMRF): Health and Medical Research Fund (HMRF), Food and Health Bureau, A High-Dimensional Machine Learning Approach to the Individualized Prediction of Hospital Readmissions for the Elderly with Chronic Diseases, ref. 16171991 (2019-2021); 2) National Natural Science Foundation of China (NSFC), Modeling of depression patients' online behaviors and the prediction of the depression severity, no. 7197020132 (2016-19); 3) NSFC, Understanding the Evolution of Users' Roles in Online Health Communities for Mental Health and the Impact on Community Development: A Case with Depression, no. 71672163 (2018-20).

There were 4 GRF grants: 1) Study on Doctor-Shopping Behavior among Patients and Methods to Reduce This Problem (2018-20), and 2) a Study of Congestion Measurement in Health Care Systems: Why Patients' Waiting Time is not a Good Indicator? (2017-20), Prof. GUO Pengfei as PI (Co-I of TRS); 3) Dynamic Appointment Scheduling with Waiting Time

Targets (2019-21), and 4) Data-driven Operating Room Scheduling in Public Hospitals (2017-19), Prof QI Jin as PI (TRS Collaborator).

For the project supported by Bank of China (HK)- Centenary Charity Programme (\$23.4M, 2020-2023, Prof Frank Chen as PC) HomAge: Home-based aging for transformative community care, part of which qualifies for the Government's Research Matching Fund; over \$12M is of research nature and will be applied for through the Government's Research Matching Scheme.

- 7.2 Have any project team members participated as invited speakers in or organisers of international conferences as a result of this project?

Please refer to Appendix A section 1.3

- 7.3 Have any project team members taken leadership positions in editorial boards, scientific and professional organisations?

Editorial Boards (Currently)

1. Prof. Frank CHEN (PC): Associate Editor for Flexible Services and Manufacturing Journal
2. Prof. Pengfei GUO (Co-I): Senior Editor, Production and Operations Management; Associate Editor, Queueing Models and Service Management
3. Prof. Sean Zhou (Co-I): Associate Editor, Naval Research Logistics, Operations Research Letters, and IIE Transactions
4. Prof. George G.Q. HUANG (Co-PI): Editor, Asia Pacific for International Journal of Computer Integrated Manufacturing, Associate Editor of IEEE Transactions on Automation Science and Engineering (TASE), Area Editor, Business & Management for International Journal of Research in Engineering Design, and Associate Editor for Journal of Intelligent Manufacturing.
5. Prof. Ming XIE (Co-I): Department Editor, IIE Transactions; Area Editor, Computers and Industrial Engineering; Associate Editor, IEEE Transactions on Reliability; Quality Technology & Quantitative Management; Asia Pacific Journal of Operational Research; Computational Statistics and Data Analysis; International Journal of Systems Science
6. Prof. K. S. CHIN (Co-PI): Area Editor (Quality and reliability) for Industrial Engineering & Management Systems, Regional Editor (East Asia) for International Journal of Computer-aided Engineering and Technology, Associate Editor for Asian Journal on Quality, Associate Editor for Advances in Decision Sciences and Editorial Board Member for International Journal of Quality, Statistics and Reliability
7. Prof. David YAO (Co-PI): Associate Editor, Operations Research; Stochastic Systems (INFORMS/APS Journal)

8. Prof. Houmin YAN (Co-PI): On the Editorial Review Board of Production and Operations Management
9. Dr. Calvin OR (Co-I): Associate Editor of BMC Health Services Research; On the Editorial Board for the International Journal of Medical Informatics; Guest Editor of special issue on “Matching Policies and Sociotechnical Challenges to Enhancing the Uptake of Health Information Technologies (HITs)” in Health Policy and Technology
10. Prof. K. L. TSUI (Co-PI): Department Editor, Quality and Reliability Engineering, IIE Transactions; US Representative, ISO/TC 69, Statistical Methods Technical Committee, International Organization for Standardization

Professional Organizations (Currently)

11. Prof. David YAO: A member of the National Academy of Engineering, he has also been an IEEE Fellow, an INFORMS Fellow, and a Guggenheim Fellow.
12. Prof. E.K. YEOH: International Advisory Board member, National University of Singapore Initiative to Improve Health in Asia (NIHA) Chairman of Asia Network for Capacity Building in Health System Strengthening (ANHSS)
13. Prof. Eliza WONG: Project Supervisor for Hong Kong College of Health Service Executive, and Sub-committee Member of the Family Planning Association of Hong Kong.

7.4 Any documentary proof of the application of technologies arising directly from this project?

N.A.

7.5 Other awards and recognitions as a result of this project (please specify):

N.A.

8. Impacts

8.1 What are the current and expected impacts of the project on the long-term development of Hong Kong (social or economic development, e.g. patent, technology transfer, collaboration with external organisations, etc.)?

The (HK) Government has decided to set up District Health Centres (DHCs) in all 18 districts to provide primary healthcare services through medical-social collaboration and public-private partnership, with the focus on elderly residents (The Chief Executive’s 2018 & 2019 Policy Address). A DHC will be a service hub with a Core Centre serving as the headquarters and complemented by Satellite Centres in sub-districts at convenient locations. The Government envisages “the DHC to be a model for district-based medical-social collaboration, using big data to identify the areas of medical care services, establishing a framework to implement measures on disease prevention in a more systematic manner ... and strengthening scientifically proven service provision and policy-led development work.” (The Chief Executive’s 2017 Policy Address). The first DHC was implemented in Kwai Tsing District.

In applying our TRS-developed algorithms to HK-wide Electronic Health Records (EHRs) made accessible by the Hospital Authority's Data Collaboration Lab (HADCL), we were able to characterize district-specific profiles of high-risk residents in the community and their secondary and tertiary prevention needs. Those tools can be further developed and used to inform service planning for DHCs.

Service innovations include new service models which can expand the capacity of primary care in Hong Kong and better utilize the resources. The new projects evolved from this TRS project enable us to pilot new elderly care models and programmes which can help to achieve this goal. Moreover, these models and programmes will enhance or complement the DHCs model.

Under the support of the TBRS project, the PolyU team has established close connections with the industry (hospitals, healthcare businesses), and made substantial progress in research, particularly related to healthcare service management for specialist out-patient appointment, in-patient bed allocation, healthcare economic, machine learning/AI application to ICU patient management, etc.

8.2 Others (please specify):

N/A

9. Sustainability of the Project

9.1 Whether there are new ideas evolved directly from this project?

Developing different service models of community care is one of the key areas in the effort to enhance/expand the capacity of primary care in Hong Kong. The TRS project led to the new concept of the "community nurse in neighbourhood" as a case manager to take care of neighbourhood health with the application of healthcare voucher and public-private partnership. This concept was substantiated by our proposal to pilot a home-based care programme/model, which led to the BoCH project.

9.2 Whether there are new projects evolved directly from this project?

Yes, for example, 1) the project "Profiling Older Population's Risks in the Kwai Tsing Neighbourhood and Optimising the Service Operations at District Health Centres: Data-driven Service Model and Policy Design", supported under the Strategic Public Policy Research (SPPR) Funding Scheme (2019-20); 2) The BoCH project "HomAge: Home-based aging for transformative community care" (2020-2023); 3) 2 Public Policy Research (PPR) Funding Scheme: (i) Development of A Longitudinal Database on Adult Development and Aging (2020-2022) and (ii) A Feasibility Study on A Healthcare Voucher Scheme for Screening and Management of Cardiovascular Risk Factors Associated Chronic Diseases in the General Population: A Mixed Methods Evaluation (2019-20).

9.3 Whether there are new collaborations developed directly from this project?

The BoCH project will be in close collaboration with the Buurtzorg Organization from the Netherlands.

9.4 Please give details on how much money and from which sources has been obtained/requested

for the specific purpose of continuing the work started under this project.

The project "HomAge: Home-based aging for transformative community care" (2020-2023): \$23.4M, source: Bank of China (HK, BoCH) Centenary Charity Programme (Secretariat: The Hong Kong Council of Social Service); 2) the project "Profiling Older Population's Risks in the Kwai Tsing Neighbourhood and Optimising the Service Operations at District Health Centres: Data-driven Service Model and Policy Design": \$4.95M, source: Strategic Public Policy Research (SPPR) Funding Scheme (S2019.A4.015.19S, 2019-20, for 3 years).

10. Statistics on Research Outputs

(Please ensure the statistics in this section are consistent with the information presented in other sections of this report.)

	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	67 109 (with another 7 under review, 2 working)	50	0	0	Type	No.

11. Public Access of Completion Report

(PCs of projects funded in 2010/11 academic year or onwards are required to release the completion reports to the public through the RGC website. Completion reports containing information such as abstracts in non-technical terms, objectives, research output including the list of conference papers / publications / journals and research findings and contact information of PCs should be open to public access.)

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

12. The Layman's Summary

(describe in layman's language the abstracts and research impact of the project.)

The overall objective of the project is to help develop a quality-and-efficiency driven healthcare delivery system in Hong Kong. Such a system is built upon data science and compatible with the internet age. Its theme is to provide *better care at affordable cost, for a healthier life*. Our primary focus is on public hospital resources management. As the majority of resources in public hospitals in Hong Kong have been taken up by elderly patients and the Hong Kong population is aging rapidly, our secondary focus is hence on coordinated elderly care.

The project started in November 2014 and completed in October 2019, with tremendous achievements. Besides over 115 mentions in publications in reputable, 65 referred journals papers have been published with RGC being acknowledged, over 40 PhD students have benefited from the project and graduated or will graduate soon. Research outputs include the application of data

science and artificial intelligence to identify target elderly patient segments for most effective and affordable post-discharge care portfolios in the community and to predict the onset of many chronic diseases, and the development of sensor technology for the elderly's health monitoring and management and scientific tools for hospital resource planning.

The completion of this project is just the start of a new phase of healthcare management research in Hong Kong. The achievements in the past 5 years have provided us an opportunity for long-term interdisciplinary collaboration and sustainable development in elderly care in Hong Kong. For example, a team comprising faculty members from the College of Business, CityU and Jockey Club School of Public Health and Primary Care, CUHK, has been recently awarded \$23.8M funding from Bank of China (HK, BoCH) Centenary Charity Programme (Secretariat: The Hong Kong Council of Social Service). Under the project title "HomAge: Home-based aging for transformative community care", we propose a pilot project to implement a home-based care programme based on the global phenomenon, Buurtzorg homecare model. This 3-year project will leverage on an IT platform for service planning and coordination, and deploy the AI/data analytics tools developed in this TRS project to identify the elderly segment(s) for the most effective and affordable community-based cares, including post-discharge care portfolios. The proposed home-based care programme will provide care services that complement the District Health Centres model.