Development of Refined Population-based Model to Inform Resource Allocation

FINAL REPORT

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Executive Summary

Background

In response to the recommendations made by the Steering Committee on Review of Hospital Authority (HA) in July 2015, HA committed to developing a refined population-based model to inform resource allocation. In view of the knowledge and expertise required for building a robust and scientific model, and the need to address complex interactions of various population factors and supplier factors in determining the population's healthcare utilisation pattern, HA commissioned the Jockey Club School of Public Health and Primary Care of The Chinese University of Hong Kong (CUHK) in April 2016 as the external consultant to help developing the model.

Healthcare Funding Strategies and Population-based Models

Funding Strategy for Public Healthcare

Resource allocation is a mechanism for distributing resources between competing claims to meet certain pre-specified goals. The capitation approach based on population has the potential to address equity in healthcare provision and provides incentives for efficiency. The main aim of resource allocation is to drive efficiency and equity in healthcare provision, and in particular, in this study, to foster the goal of equity between Clusters in the long run as well to drive changes in the healthcare system without causing unintentional and undesirable impact on existing baseline services. However, there is no universal model for resource allocation. Penno et al. (2013), through a comparative analysis of the resources allocation model of different health systems worldwide, found that development of funding formulae/ model is a dynamic process taking into account the availability of data to reflect health needs, and the local context e.g. influence of the socioeconomic-political factors and health system determinants.

The establishment of HA coincided with the transition from a historical and activity-based strategy towards a population-based strategy, which began to take shape in 2000 where the Government and HA explored the population-based model and came up with a methodology for projecting the population's need for public healthcare. With this in mind, we will examine the values and limitations of population-based model in allowing independent checks at different levels of healthcare funding flow.

Healthcare Funding Flow in Hong Kong

Level 1 – Government to Hospital Authority (Government Subvention)

Level 2 – Hospital Authority to Clusters (Internal Resource Allocation)

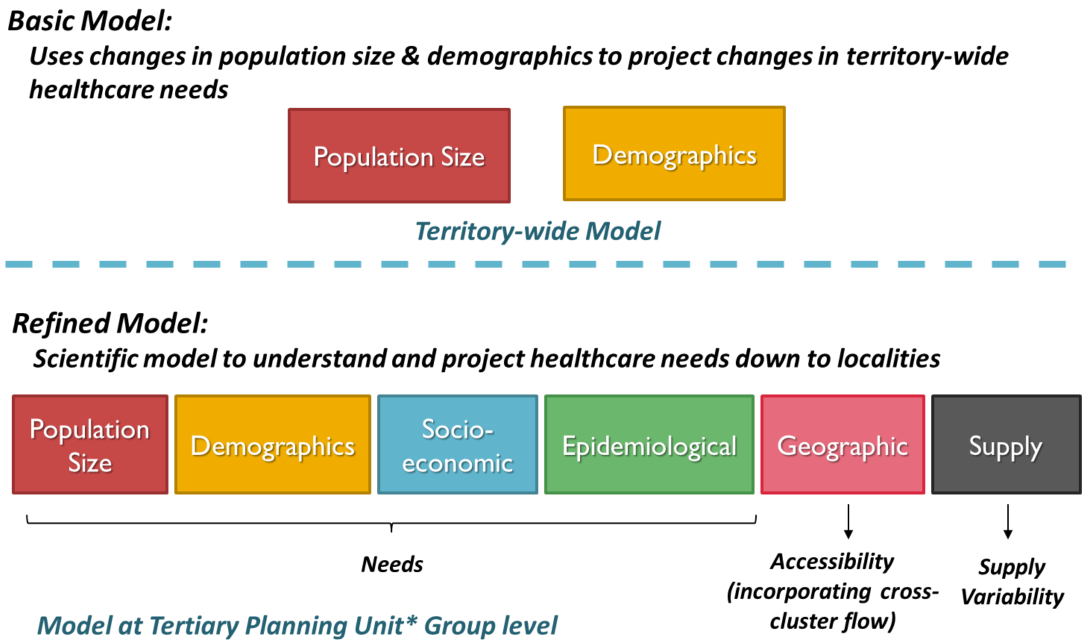
Level 3 – Clusters to Hospitals

On the first level, it is sufficient to focus on population factors alone to project the overall changes in public healthcare needs, and use that as the basis for assessing the growth in HA's need for recurrent Government Subvention, which supports its day-to-day operation. The second level of funding flow (from HA to Clusters) is the subject of interest related to the resource allocation recommendation made by the Steering Committee on the Review of HA. With population as the most fundamental consideration for healthcare, it is logical to extend the population-based model, from projecting the healthcare funding need of HA, down to the Cluster level so as to guide hospital services planning and resource allocation towards enhancing health equity of the population across different localities of Hong Kong.

Notwithstanding the third level of funding flow (from Clusters to hospitals) is not within the scope of the population-based model, the resource allocation from Clusters to hospitals has to be considered after the implementation of the population-based model if the objectives of the Cluster resource allocation to drive equity and efficiency are to be achieved. All the hospitals within a Cluster are designed to complement each other in providing a comprehensive range of healthcare services needed by the local population. As such the resource need of the individual hospitals and clinics is defined by the role it plays in providing the comprehensive range of healthcare services in the Cluster. It will be the responsibilities of Cluster management to define the optimal input-mix of resources as a basis for allocating the funding to individual hospitals to enable the appropriate mix of health services output of the Cluster to meet the healthcare needs of the population served.

Refining the Basic Population-based Model

A population-based model can do more than just projecting changes in the overall public healthcare needs of Hong Kong and assessing the corresponding changes in funding requirement of HA, as what the Basic Model introduced in 2000 had sought to do. Extending the analysis to local communities will help quantifying healthcare needs down to small pockets of population, thereby enhancing the granularity of analysis which captures the effects of accessibility on health service utilisation. The model allows one to look for correlations between factors like socioeconomic, epidemiological factors, distance (proximity to care), availability of supply (provider’s capacity constraint), etc. against the utilisation of different healthcare by care type. With Hong Kong being a small city with a highly-efficient public transportation network, cross-cluster movement of patients is a common phenomenon and therefore the model should also take into account cross-cluster patient flow and the impact of this on the objective of the population-based resource allocation model viz equity and efficiency. This will generate information and insight on how the local communities’ healthcare needs are related to hospitals and Clusters. This does not only explain the resource requirement of different Clusters but also enrich our understanding on how well the population’s healthcare needs (other than Designated Services) can be met locally, i.e., regional supply-demand gap. The main refinements made to the Basic Model are summarised in the figure below:



* The Tertiary Planning Unit (TPU) is a geographic reference system demarcated by the Planning Department for town planning purposes.

Refined Population-based Model: Conceptual Framework, Scope and Methodological Approach

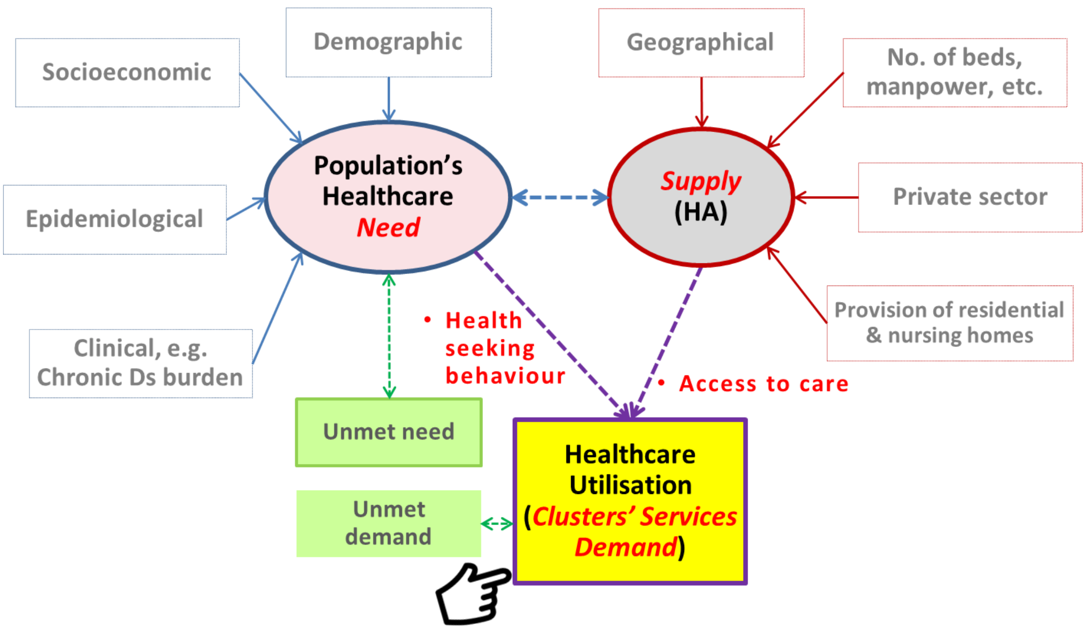
Population-based resource allocation is a mechanism to estimate the healthcare expenditure required to provide the healthcare services needed by the population served. It is a capitation approach based on population counts and adjusted to take into account the population characteristics that influence health service needs and utilisation. The rationale for using population-based resource allocation is to drive

(i) Equity, both in access to health services and in health outcomes for the (Cluster) population served, and

(ii) Efficiency, both technical and allocative, in ensuring the allocation of resources is consistent with the health services needed by the (Cluster) population.

Conceptual Framework

Starting with the usual understanding of population-based model, making reference to overseas countries' experience in using population-based models to guide public healthcare funding, and taking into consideration the way the public hospital system is organised and funded in Hong Kong, a conceptual framework was drawn up to address the complex interplay between "population healthcare needs" including demographic, socioeconomic, and epidemiological, etc. variables, health-seeking behaviour and "supply variables" (which affects utilisation through the effect of distance on accessibility, capacity, efficiency and policy) in shaping healthcare utilisation (demand) of individual Clusters, as depicted in the figure below.



Modified from Carr-Hill, R. A., Sheldon, T. A., Smith, P., Martin, S., Peacock, S., & Hardman, G. (1994). Allocating resources to health authorities: development of method for small area analysis of use of inpatient services. BMJ: British Medical Journal, 309(6961), 1046-9.

Resource allocation does not exist in a vacuum but is linked to a Cluster's existing scale of operation and changes over time subject to the short- and longer-term planning of infrastructure and services. The Refined Population-based Model can help enhance the understanding of inter-relationship between healthcare need and demand expressed as healthcare utilisation, and the influence and constraints of supply on utilisation. To drive equity it serves as a critical tool to adjust the influence of (under) supply to enable better access for the Cluster catchment population. It can be used as a tool to predict future healthcare needs and the resources and services required to meet these needs for each of the Clusters. Tools can also be developed to understand both the health-seeking behaviour of Cluster population in models and for simulation of the impact arising from changing strategies in service provision of individual Clusters on cross-cluster flow or patients residing in different localities.

Scope of Model

There are a variety of healthcare services provided by HA, which require different levels of resources. By considering the structure of service provision, availability of utilisation and costing data of different healthcare activities, eight core service categories were used as the basis of the analysis, namely Acute Inpatient (Acute IP), Non-acute Inpatient (Non-acute IP), Specialist Outpatient (SOP), Primary Care (PHC)[1], Accident and Emergency (A&E), Allied Health Outpatient (AHOP), Day Hospital, and Community Care. Such granular analysis would facilitate inter-cluster comparison down to core services.

As the subject of interest is equity of healthcare expenditure by population consideration, it is most relevant to compare the recurrent operating expenditure used on core hospital services that are common across Clusters, i.e. to compare like-with-like. As such, highly specialised services and operations provided in designated institutions for the entire population of Hong Kong so as to benefit from concentration of expertise and economies of scale (labelled as Designed Services (DS) for the purpose of this project) are outside of the scope of the Clustering concept and in turn the Refined Population-based Model to inform resource allocation, so that the remaining core hospital and clinic services are more comparable in terms of scope, nature, and the target population (i.e. within the Cluster's catchment locations) intended to serve. Apart from excluding the

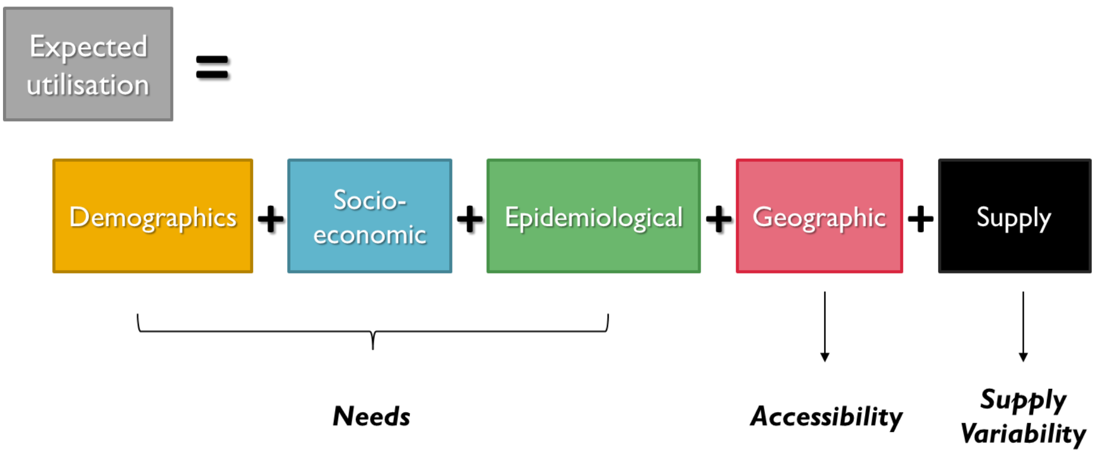
[1] Includes General Outpatient Clinic, Family Medicine Specialist Clinic, Integrated Mental Health Programme, Risk Factor Assessment and Management Programme.

resources and activities of Designed Services, other adjustments (e.g. on expenditure not related to day-to-day public services, expenditure borne by patients, etc.) have been performed in order to derive the resources used for the provision of core hospital services of each Cluster to facilitate like-with-like comparison.

Building and Validating the Statistical Model

As mentioned, utilisation in HA was delineated into eight core services for model building. However, due to the heterogeneity of service models for Community Care and Day Hospital, and the lack of structured electronic data, these two services, which accounted for only 4% of Cluster recurrent expenditure on core hospital services, were excluded for statistical modelling.

In essence, the statistical model seeks to identify factors with good correlation / predictive values over the population's healthcare utilisation pattern by localities (i.e. by Tertiary Planning Unit[2] (TPU) groups). The structure of the statistical model is depicted in the figure below:



Through a vigorous variable selection process, 16 variables were shortlisted based on their relevance in the local context and data availability, where they

2 The Tertiary Planning Unit (TPU) is a geographic reference system demarcated by the Planning Department for town planning purposes.

are subject to testing by statistical techniques for examination of their degree of effect on healthcare utilisation.

Through the building of two-level generalised linear mixed effect models, all 16 factors were found to have a statistically significant effect on healthcare utilisation. Among the 16 factors, two were consistently found to be the most influential factors for the six service categories studied, namely, “supply” (e.g. number of beds, the doctor manpower strength, etc.) and “distance” (between the patient’s residence and the location of the healthcare facilities where the patient sought care, whether within or across Clusters).

To assess how the results of the models built using 2011/12 to 2013/14 data will generalise to an independent data set, a cross-validation process using out-of-sample data (i.e. 2014/15 and 2015/16 data) was employed.

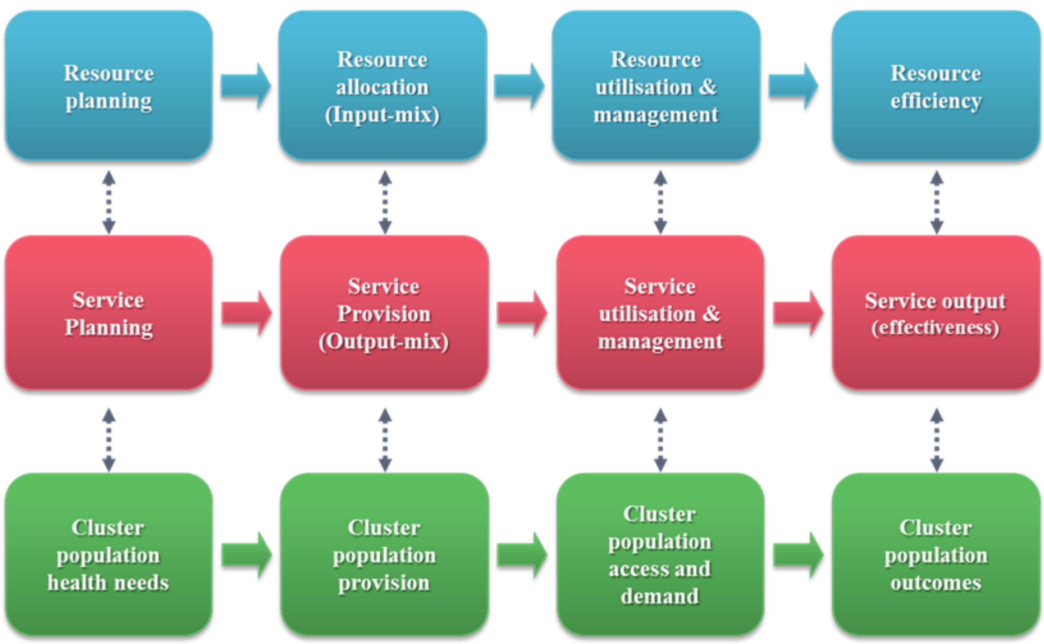
Proposed Application

Guiding Principles for Model Application

In the application of the Refined Population-based Model, it is essential to examine how the objective of a population-based resource allocation is able to drive or enhance equity and efficiency (both in terms of allocative efficiency and technical efficiency). The very dominant effect of supply on utilisation needs to be addressed as well as the understanding of cross-cluster flow of patients arising from patients’ health seeking behaviour.

Conceptual Framework for Model Application

It is crucial to discuss how the model is applied to inform resource management in the context of prospective planning of facilities and services to enable the public equitable access to a comprehensive range and optimal mix of healthcare services and continuity of care in each Cluster. A conceptual framework linking the three key dimensions i.e. population healthcare needs, service planning and resource planning for model application is depicted below. The framework shows the importance of relating resource allocation in the context of resource management, service planning, provision and utilisation based on the population healthcare needs to achieve resource efficiency and service effectiveness. The Refined Population-based Model provides the leverage for this framework that links "resource allocation, utilisation and management" and "services provision, utilisation and management" with "population health needs". Cluster population health needs will inform the resources needed to provide the healthcare services required. The determination of the optimal input-mix of resources will be an important determinant of "technical efficiency", whereas the appropriate output-mix of service that needs to be provided will be a critical consideration for "allocative efficiency". Therefore, there is a need to study what input-mix is desirable and the types and output-mix of services appropriate to meet the health needs of the catchment population, identify the gaps and shortfalls in provision and feedback to inform resource facility and service planning. The determination of the optimal input-mix of resources and the appropriate output-mix of services would enable the next level of resource allocation from the Clusters to the hospitals which is necessary to enable equitable access to a comprehensive range of healthcare services.



Proposed Tools for Application

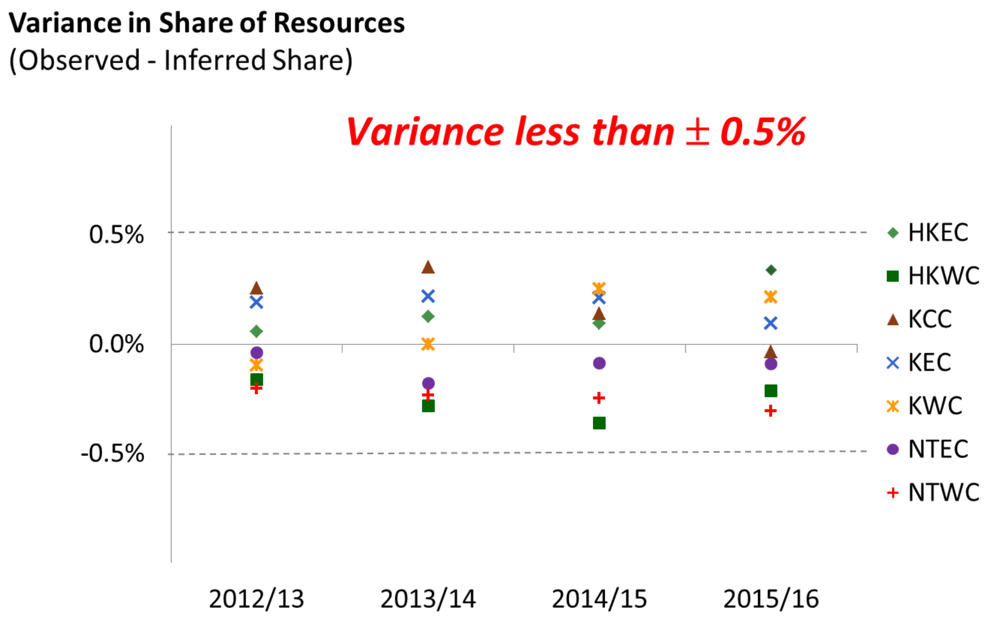
The Refined Population-based Model would provide analytical tools to generate business intelligence on Cluster resource against utilisation, as well as Clusters' ability in accommodating demand growth projected by the model, from both the hospital and TPU perspective.

Tools	Description on application	Objectives
Tool 1	Did Cluster spend similar resources for similar core service utilisation?	Identify Clusters which need to catch up and explore catch up measures
Tool 2	Were there variances in the mix and configuration of services among different Clusters?	Identify optimal mix and configuration of service type to improve efficiency and enable Clusters to better use resources
Tool 3	Do Clusters have similar ability (regarding capacity elasticity) to accommodate demand growth as projected by the Refined Model?	Identify Clusters' need for building up capacity and inform short-term measures to accommodate expected growth in utilisation (through Annual Plans)
Tool 4	How can healthcare facility plans be aligned with population developments in the long term?	Identify Clusters' need for building up capacity to meeting population healthcare needs by TPU-based analysis and inform intermediate-term measures (through 5-year Strategic Plans)

Tool 1: Cluster Resource Analysis – Parity of Resources vs. Utilisation

The objective of Cluster resource analysis is to assess whether similar service utilisation of Clusters are supported by similar resources. After carving out the resource and activity of DS and making other adjustments to facilitate like-with-like comparison, Clusters' operating expenditure on core services can be compared against the inferred operating expenditure calculated by multiplying Cluster's core activities with HA average cost of each core service. This will help in identifying which Clusters' resources are below HA average with respect to their service output and provide insights as to which Clusters would need to catch up.

As an illustration, result of such analysis using 2012/13 to 2015/16 data is shown below (with each data point representing the variance in the observed and inferred share of resources of one Cluster). It revealed inter-cluster variance to be within 0.5% over the years, reflecting the fact that under the existing service planning and budgeting mechanism, Cluster expenditure generally corresponded to their respective scales of service provided.



Tool 2: Mix and Configuration of Services

As depicted in the conceptual framework for model application, there is a need to study the types and mix of services required to meet the health needs of the population. The study results would have implications for identifying the gaps and shortfalls in healthcare provision and informing facility and service planning. As a start, the utilisation among various core services should be compared, which would provide a current-state understanding on the various mix and configuration of service type among Clusters, so that better use of resources would be enabled among Clusters for improved efficiency.

Tool 3: Capacity Utilisation Analysis

While Tool 1 would analyse whether Clusters had been receiving similar resources for similar activity, another valuable tool would be to measure Clusters' capacity loading with respect to their ability to accommodate growth in demand. Capacity utilisation analysis (service utilisation divided by capacity) reflects the elasticity of Cluster capacity in accommodating further growth in utilisation as projected by the Refined Population-based Model in coming years, where Clusters with more constrained capacity (less elastic) would have a greater need for expansion. This piece of information is particularly useful in short-term facility and service planning.

To understand whether Clusters would face similar capacity utilisation pressure, a measure of capacity elasticity to accommodate growth in local healthcare needs i.e. parity regarding capacity vs. utilisation would be needed. For this purpose, the ratios of utilisation and capacity for each core service could be compared longitudinally and among Clusters (and to the HA average), so as to identify Clusters' need for building up capacity and inform short-term measures to accommodate expected growth in utilisation.

While the evaluation of relative elasticity through capacity utilisation is useful, one has to be mindful if the potential perverse incentive in focusing solely on one measure of capacity (e.g. number of acute beds for Acute IP). It is therefore recommended that additional metrics (e.g. length of stay, relative stay index, length of stay of linked episode, etc.) be supplemented when analysing capacity utilisation.

Tool 4: Hospital Utilisation vs. Local Population Needs

For longer-term facility planning in HA, health service needs of the local population by TPU would need to be modelled by assuming there is no variance in the supply constraints among Clusters, so as to identify Clusters' legitimate need for building capacity to meeting population healthcare needs. Hence, a

TPU-based model was developed in addition to the original hospital-based model described above to model the healthcare need of the catchment areas of Clusters at the TPU level. The main difference between this TPU-based model and the hospital-based Model is the exclusion of the “distance” and “capacity” variables in the model formulation.

While the hospital-based model reflects healthcare needs and accessibility of services and capacity (at each TPU to hospital-level), the TPU-based model estimates the normative local healthcare needs of the population, irrespective of where they sought care (i.e. within Cluster or cross-cluster). The difference between the Cluster utilisation based on the hospital-based model and the estimated need of a Cluster’s catchment population calculated by the TPU-based model would reflect a net inflow (if the hospital-based figure is larger than the TPU-based one) or net outflow (if the hospital-based figure is smaller than the TPU-based one) of utilisation. The TPU-based model addresses the historical legacy of inequity in the supply and provision of healthcare services and is the critical tool in the application of the Refined Population-based Model.

Limitation

While the model was rigorously constructed based on sound scientific principles and methodologies, a model is an abstraction of reality and application should be considered in view of its inherent limitations, both on data availability/accuracy (costing of DS and other adjustments, limited availability of clinical and epidemiological data, census data not updated annually, and time lag of data) and on the actual modelling (complexity in understanding healthcare needs, inherent margin of error of statistical model, and model covering six core services only). These limitations also make it necessary for the model to undergo periodic refinement in the future.

Recommendations for Application and Future Developments

The Refined Population-based Model incorporates factors influencing population healthcare needs (demographic, socioeconomic, epidemiological), accessibility (distance), capacity (supply), and addresses DS and cross-cluster movement of patients. It projects healthcare needs of localities (by TPU), instead of relying on crude inference from District Council Election Constituency Boundaries. Furthermore, the analysis of population healthcare needs (legitimate healthcare needs) by evening out (disregarding) "supply" effect enhances equity and efficiency and addresses the historical legacy of inequitable provision between Clusters. Not only will it inform resources and service planning, the model can also provide the leverage in a framework that links "resource allocation, utilisation and management" and "services provision, utilisation and management" with "population health needs" which will drive equity and efficiency in healthcare provision.

With the adjustment mechanisms of (1) population healthcare needs, (2) supply effect, and (3) cross-cluster effect, the model can be applied to inform short term, intermediate term and long-term services and resources planning. For example, in short term, Tool 3 on "capacity utilisation" can be used to identify Clusters' need for building up capacity and inform short-term measures to accommodate expected growth in utilisation, and should be used in conjunction with Tool 4 for both short and intermediate term to identify Clusters' legitimate need for resources and to build up capacity to meeting population healthcare needs by TPU-based analysis. As supply affects utilisation, when supply is increased in the underprovided Clusters in the intermediate and long term, the health-seeking behaviours of the Cluster populations will be affected and the cross-cluster flow will change. Models to study the effect on cross-cluster flow should be developed and further studied.

It has to be noted that the Refined Population-based Model alone is necessary but not sufficient to direct resources to where they are most needed. Population-based resource allocation needs to be an integral part of a holistic approach of strategic service and resource planning, provision, and management. The model would generate business intelligence and facilitate better understanding of healthcare needs and the most efficient mix of resource input to generate the optimal output-mix of healthcare services needed by the population. It is therefore crucial to examine how this can be applied in resource and service planning, provision, and management to enable equitable access to a comprehensive range of healthcare services for the local populations.

To supplement the Refined Population-based Model, more detailed study should be conducted to provide insights to identify issues relating to the mix or configuration of service types. Future Cluster resource analysis could be reviewed together with performance indicators to provide insight on the mix and configuration of service types.

Implementation

Resource management cannot be isolated from the overall planning activities regarding capacity of service provision including facilities, technology and service delivery (the optimal mix of type, level, configuration and volume) as well as capability such as financial and human resources. With resource allocation linked to a Cluster's existing scale of operation and infrastructure, having the Refined Population-based Model alone is necessary but not sufficient to direct resources to where they are most needed. Instead, as an integral part of a holistic approach for service planning and resource management, the model will serve to facilitate better understanding of healthcare needs and contribute to service planning by generating business intelligence under the existing service and budget planning mechanism of HA.

Model Providing Business Intelligence for Planning

The essence of the subject matter is to address resource management from the population's perspective. Sharing the same objective basis as the population-based approach for government funding review adopted since 2000, the Refined Population-based Model is valuable in meeting this objective by extending the population concept to resource analysis at Cluster level. In addition, the Refined Population-based Model projects the healthcare needs down to localities (by TPU), and this would allow a better understanding of the health seeking behaviour of the population.

Under the prevailing planning mechanism, HA uses population projection figures published by the Government's Census & Statistics Department as well as a set of detailed breakdowns by geographical areas from Planning Department to project demand growth in terms of the different categories of services provided by HA. This serves as a common basis for service, facility and workforce planning within the HA in longer term. The Refined Population-based Model would not replace the existing planning projection tools but could complement each other by taking into account factors other than demographics (e.g. social-economic and epidemiological factors), DS and other adjustments.

In view of the long implementation lead times for building up capacity and also the inherit limitations of the statistical model, the Refined Population-based Model can identify challenges such as capacity (often facility constraint). The Refined Population-based Model can be applied in the short and intermediate term in adjustment mechanism to inform resource service needs for underprovided Clusters. It should be used for resource analysis to generate business intelligence and inform service planning in short and longer terms.

Way Forward

System changes are expected to be gradual and incremental considering the long implementation lead times for building up capacity and inertia in health-seeking behaviour. As such, instead of updating the Refined Population-based Model and conducting resource analysis annually, it would be more practical to monitor the trend and analyse at regular intervals such as dovetailing with HA's five-yearly development cycle under its Strategic Plan.

While the Refined Population-based Model enables analyses from multiple perspectives and time points that aim to identify the relative needs of Clusters in aligning with population development, there are other equally important factors for determining the pace of development which need to be comprehensively considered. The analysis under the Refined Model would inform HA's planning through existing planning mechanism starting from the 2018/19 cycle onwards.

I. Background

(A) Review of Hospital Authority

A Steering Committee was set up by the Government in August 2013 to conduct an overall review of the Hospital Authority (HA) to examine its operation in response to the changes in society such as an expected ageing population. The Steering Committee made ten recommendations to HA in its published report in July 2015[3], one of which addressed the subject of equity in resource management:

Recommendation 3 :

HA should adopt a refined population-based resource allocation model by reviewing the present approach and taking into consideration the demographics of the local and territory-wide population. The refined population-based model should take into account the organisation of the provision and development of tertiary and quaternary services, and hence the additional resources required by selected hospitals or Clusters, as well as the demand generated from cross-cluster movement of patients; and

HA should develop the refined population-based resource allocation model and implement through its service planning and budget allocation process within a reasonable timeframe. To avoid unintentional and undesirable impact on the existing baseline services of individual Clusters, HA should consider appropriate ways to address the funding need of Clusters identified with additional resources requirement under the new model, while maintaining the baseline funding to other Clusters.

[3] The report of the Steering Committee can be found on the website of the Food and Health Bureau at http://www.fhb.gov.hk/en/committees/harsc/report.html

(B) Action Plan in Response to HA Review

In response to the above, HA committed to developing a Refined Population-based Model to inform resource allocation, as part of the Action Plan[4] formulated by the HA Board and submitted to the Government on 22 October 2015 in response to the HA Review recommendations. According to the Action Plan, an Internal Resource Allocation Model Development Steering Committee (IRAMD SC) involving senior executives from Head Office (HO) and all Clusters was set up in 2Q 2015 to oversee model development and to advise on its application.

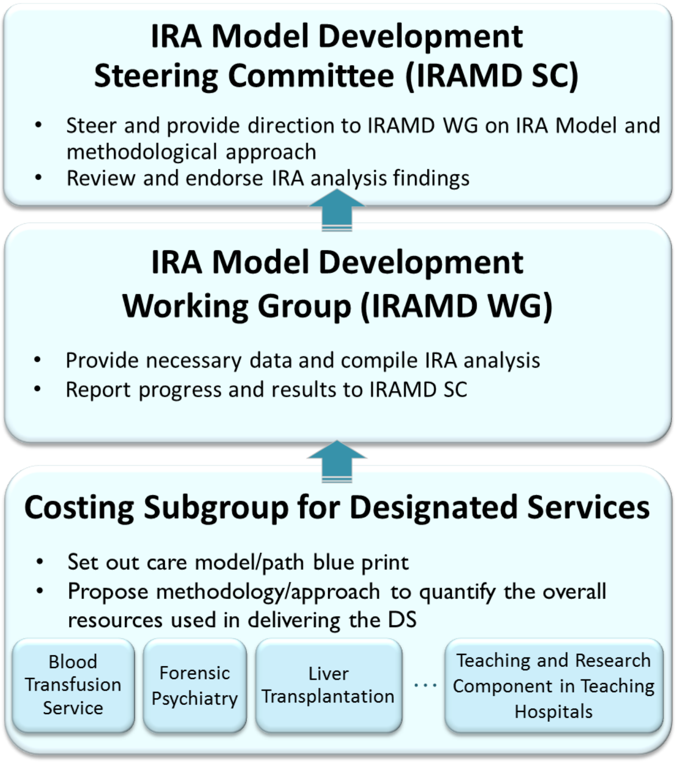


Figure 1 – Project governance structure

At the same time, an existing platform for deliberating technical issues of resource management was revamped to become an IRA Model Development Working Group (IRAMD WG), comprising representatives at the working level from HO and all Clusters. This group, as well as the various Costing Subgroups

[4] The Action Plan can be accessed at http://www.ha.org.hk/haho/ho/cc/HA_Review_Action_Plan_Final_en.pdf

for Designated Services (DS), supported the Project Team in tackling methodology and other technical issues and report to the IRAMD SC as summarised in Figure 1. The terms of reference and membership of the IRAMD SC and WG are set out in Annex A.

In view of the complexity of the subject, model development was an interactive process, involving different levels of stakeholders. The list of engagement activities is presented in Annex B.

(C) Engagement of External Consultant

In view of the knowledge and expertise required for building a robust and scientific model to inform healthcare resource allocation, and the need to address complex interactions of various population factors and supplier factors in determining the population's healthcare utilisation pattern, HA commissioned the Jockey Club School of Public Health and Primary Care of The Chinese University of Hong Kong (CUHK) in April 2016 as the external consultant to help developing the model. The objectives of the consultancy study are set out below:

(a) Developing the "refined population-based resource allocation model" and validating the analysis;

(b) Proposing how the model can be applied to analyse resource distribution between Clusters in order to identify Clusters that are relatively disadvantaged in resources as compared to their serving populations;

(c) Proposing how HA can make use of the information generated above to drive equity across Clusters in a controlled manner, through improving resource management and service planning over time, without causing disruption to patient services, and,

(d) Engaging stakeholders during the model development and application process to enhance communication and obtain their buy-in.

(D) The Context

Public Healthcare System in Hong Kong

The healthcare system of Hong Kong runs on a twin-track basis in which the public and private sectors operate independently of one another. The public hospital system is tax-funded and accessible to Eligible Persons (EP)[5] at highly subsidised rates. Being a safety net of the society, service priority was given to the provision of acute and emergency care; treatment of illnesses that entails high cost, advanced technology and multi-disciplinary collaboration; and to ensure no one is denied of adequate healthcare through lack of means.

Besides, it plays a crucial role in the training of healthcare workforce to meet the growing healthcare needs of the population. In fact, promoting, assisting and taking part in "the education and training of persons involved or to be involved in hospital services or other services relevant to the health of the public" is one of the functions of HA stipulated in Section 4 of the HA Ordinance (Cap 113). HA is therefore committed to supporting the healthcare workforce with high quality training, including providing specialty training for doctors, nurses and allied health professionals, and scholarships for overseas training. Specifically, HA supports clinical teaching for medical students (Years 4 to 6) through collaboration with the medical schools of the two local universities, while also offering the majority of specialist medical training in Hong Kong based on guidelines of the Hong Kong Academy of Medicine.

In the early 1990s, Hong Kong echoed the New Public Management Reform trend among the Western developed countries and initiated a number of public

[5] In accordance with Gazette, patients falling into the following categories are eligible for the rates of charges applicable to EP:

- holders of Hong Kong Identity Card issued under the Registration of Persons Ordinance (Chapter 177), except those who obtained their Hong Kong Identity Card by virtue of a previous permission to land or remain in Hong Kong granted to them and such permission has expired or ceased to be valid;
- children who are Hong Kong residents and under 11 years of age; or
- other persons approved by the Chief Executive of the HA.

sector reforms. One of the reforms was the dissolution of the Medical and Health Department (M&HD) through the creation of a new Department of Health (DH) to take over responsibility for public health and general outpatient clinics (GOPC), and the establishment of HA to take over the management of public hospitals. This was primarily a structural reorganisation of the M&HD and not a reform of the health system as a whole, the objective of which was to modernise healthcare through business process reengineering and unleashing innovations to improve efficiency, performance and standard of care from the patient perspective. In 2003, the GOPCs of DH was also transferred to HA.

Clustering in HA

Among the many reforms introduced by HA, a key development was the networking of hospitals and facilities into Clusters starting from 1992 onwards. The idea was to consolidate resources for economies of scale and expertise, and integrate them functionally towards providing a comprehensive range of hospital services to meeting patient needs throughout the illness trajectory. The Cluster structure is crucial in providing a basis for positioning hospital, planning services, and organising of care delivery towards a continuum of care through the patient journey. Networking hospitals also opened up opportunities for removing redundancy, streamlining workflow and rationalising operation to enhance efficiency.

There are currently seven Clusters in HA, namely, the Hong Kong East Cluster (HKEC), Hong Kong West Cluster (HKWC), Kowloon East Cluster (KEC), Kowloon Central Cluster (KCC), Kowloon West Cluster (KWC), New Territories East Cluster (NTEC) and New Territories West Cluster (NTWC). Despite being an administrative arrangement, the Cluster structure draws public's attention to scrutinise HA from the perspective of local communities. This creates some challenges though, as the Cluster structure is not a registration system to link specific districts and enrollees, and boundaries are largely inferred from election district boundaries. As such, there are bound to be margins of error in estimating the size of population served by individual Clusters. It is not unreasonable for people living near such perceived boundaries to consult nearby hospitals that are under the network of a neighbour Cluster. Classifying such activities as cross-cluster traffic invariably gives a negative connotation, and will be misleading unless there are ways to reliably differentiate the nature of cross-cluster patient movement. There are a variety of reasons for people to seek care from hospitals outside the Cluster they are residing in; for example, some may choose to stick with the hospital they have been following up despite moving to a new residence, or prefer a particular hospital due to relationship with other family members, or as a result of their daytime activities.

Notwithstanding the above limitations, the Cluster concept is well accepted and has been evolving towards providing services to meet the healthcare needs of the population in its vicinity. With an ageing population, it is increasingly important for Clusters to be able to provide a comprehensive range of core hospital services to cater for the needs of the local communities (taking aside highly complex and specialised services that are needed to be located in designated sites).

Population-based Information Guiding Service Planning

Resource allocation does not exist in a vacuum but is linked to a Cluster's existing scale of operation and changes incrementally over time subject to short- and longer-term planning of infrastructure and services. In this regard, HA has been using population projection statistics made available by the Government's Census and Statistics Department (C&SD) as well as breakdowns of dataset by geographical areas from the Planning Department to project the healthcare needs in different areas of Hong Kong and to plan prospectively. The population-based model is particular valuable for prospective planning as healthcare infrastructure and human resources development takes a long time. For example, the planning, development and implementation of the KEC Oncology Service would span over 10 years. In a way, the population-based model is upstream of service planning and system development, whereas resource allocation is downstream and is the outcome of successfully implementing the plans.

(E) Internal Resource Management in HA

Prior to the establishment of HA, public hospitals were largely funded according to size, using number of beds as a reflection of workload. As such, the funding strategy was arguably a mix of Government policy driven, historical- and input-based. Following the inception of HA, and along with a growing emphasis on performance and efficiency, resource management started to focus on output although the hospital infrastructure and existing levels of activity remained to be key determinants of funding decision. In order to drive efficiency, resource allocation became an integral part of HA's business planning process realised through the annual submission of "Hospital Plans" by individual hospitals to HO. Under this arrangement, hospital service agreements were formulated to specify the scope and level of services to be provided, which in return determined the hospital budget basing on the services and agreed level of prices.

In 2000, the Government and HA agreed on a methodology for assessing HA's funding need by a population-based approach (which is further discussed in Chapter II). Against this background, HA explored strategies to adjust Cluster funding for the differences they face in terms of population effect and cross-cluster patient movement. The intention was not to upset their baseline funding (as each Cluster has its own system constraints and baseline activity cannot be drastically changed overnight) but to promulgate the idea of population-based healthcare and give financial incentives for Clusters to organise their services to better suit the local population. Despite a number of attempts, the baseline activity of each Cluster continues to contribute heavily to its funding need.

At present, resource allocation in HA is under the scrutiny by the Service and Budget Planning Committee (SBPC), which is the decision-making platform for the HA Annual Plan. Each year, HA calls for submission of service development bids from Clusters, Coordinating Committees (COC) and HO. Submissions are broadly categorised under four priority areas, namely, “improve service quality”, “optimise demand management”, “attract & retain staff” and “enhance staff training & development”. They will undergo deliberation in Annual Planning forums represented by senior management and clinical leaders, and then prioritised by the SBPC for submission to the Government’s Resource Allocation Exercise (RAE). Meanwhile, Clusters and HO will work up budget plans to SBPC for endorsement. Budget planning is an interactive process between Clusters and HO, giving consideration to the baseline budget (for sustaining the existing workforce and levels of services), additional funds for new initiatives supported by Government (subject to the prevailing systems and manpower constraints), and HA’s financial position (Government Subvention, fee income and other income for the coming financial year and availability of internal revenue reserve).

There is no dispute about the benefit of population-based model in public healthcare. The challenge lies in its application and a tendency to oversimplify reality which is inherently complex, e.g. the quest to compare Cluster funding by simply dividing their budget by the residential population inferred from election district boundaries, without taking into consideration of facts such as: (i) there are specialised services needed to be located in specific hospitals, (ii) Cluster structure is an administrative arrangement without a restrictive boundary and not linked to specific target populations, etc. Nonetheless, equity of public healthcare is an important subject of great public concern, and technical difficulties are not justification for not addressing it. Therefore, it is a high priority of HA to tackle the subject of equity by developing a Refined Population-based Model to inform resource management and short- and longer-term planning by addressing the following concerns raised in the Review of HA and other occasions:

(i) Did Clusters spend similar resources for similar core service utilisation?

(ii) Do Clusters have similar ability (regarding capacity elasticity) to accommodate growth in service demand?

(iii) How can healthcare facility plans be aligned with population developments in the long term?

The rest of this report will be split into two parts:

Part A: outlining the Refined Population-based Model's conceptual framework, the model building and validation process, the developed model, proposed tools for application, limitation as well as the application and future developments recommended by the CUHK consultancy team

Part B: illustrating the analyses conducted by HA under the Refined Population-based Model as recommended by the CUHK consultancy team

PART A: POPULATION-BASED MODEL TO INFORM RESOURCE ALLOCATION (CUHK)

II. Healthcare Funding Strategies and Population-based Models

(A) Funding Strategy for Public Healthcare

Resource allocation is a mechanism for distributing resources between competing claims to meet certain pre-specified goals. There are various approaches for resource allocation including political patronage, historical, bid-based, expenditure-based, and formula-based using either case / activity or capitation (Penno, Gauld & Audas, 2013; Rice & Smith, 2001; World Health Organisation, 2008). The capitation approach based on population has the potential to address equity in healthcare provision and provides incentives for efficiency. The main aim of resource allocation is to drive efficiency and equity in healthcare provision, and in particular, in this study, to foster the goal of equity between Clusters in the long run as well to drive changes in the healthcare system without causing unintentional and undesirable impact on existing baseline services. However, there is no universal model for resource allocation. Penno et al. (2013), through a comparative analysis of the resources allocation model of different health systems worldwide, found that development of funding formulae/ model is a dynamic process taking into account the availability of data to reflect health needs, and the local context e.g. influence of the socioeconomic-political factors and health system determinants. The special features, strengths and weaknesses of different public healthcare funding approaches, as well as the international experience in employing the population-based model, is further presented in Glossary Part A.

(B) Healthcare Funding Flow

The establishment of HA coincided with the transition from a historical- and activity-based strategy towards a population-based strategy, which began to take shape in 2000 where the Government and HA explored the population-based model and came up with a methodology for projecting the population's need for public healthcare. The method shared similarity to the United Kingdom Treasury's Wanless projection method (Wanless, 2002) but without gender (i.e., based on age-specific utilisation instead of age-sex-specific utilisation) and used only inpatient activity and the corresponding cost as proxy to infer the entire spectrum of healthcare. While the initial method was rather crude (as it was limited by data availability then), the change was nonetheless a groundbreaking step towards modern funding strategy placing people (population) at the forefront of consideration.

The transition is not a complete switch to formula funding but a shift of emphasis in examining the relationship between population and public healthcare, particularly in projecting changes in healthcare demand in relation to population projection, and in using that as a basis for assessing changes in funding need. Each year, the Government determines the exact level of subvention to HA basing on a basket of considerations, including (i) the baseline subvention granted to HA in the preceding year and the cashflow projection by HA needed to sustain the existing workforce and levels of services (primarily a reflection of the historical development), (ii) financial implication of service initiatives for meeting the population's growing demands for new public healthcare services (subject to population effect, manpower supply, and bidding to the Government's Resource Allocation Exercise), (iii) a reality check on the healthcare funding need by using the population-based model, which was lately expanded from demand-driven projection to also include supply-driven projection, and (iv) other considerations like the prevailing Government fiscal policy.

While the population-based model forms only a part of the basket of considerations for recurrent Government Subvention to HA, and not strictly a funding formula, population is nevertheless the main rationale for evaluating health equity and the model. With this in mind, we will examine the values and limitations of population-based model in allowing independent checks at different levels of healthcare funding flow, namely, from the Government to HA (the first level), from HA to Clusters (the second level), and from Clusters to hospitals (the third level).

Healthcare Funding Flow in Hong Kong
Level 1 – Government to Hospital Authority (Government Subvention)
Level 2 – Hospital Authority to Clusters (Internal Resource Allocation)
Level 3 – Clusters to Hospitals

Level 1 – Government to Hospital Authority

On the first level (from Government to HA), it is sufficient to focus on population factors alone to project the overall changes in public healthcare needs, and use that as the basis for assessing the growth in HA's need for recurrent Government Subvention, which supports its day-to-day operation [6]. As mentioned above, the Government and HA explored the population-based model and came up with a methodology for projecting the population's need for public healthcare in 2000 (Basic Model), which aimed at examining the relationship between population and public healthcare, thereby providing an independent reality check on the funding need of HA.

From 2010/11 to 2015/16, HA recorded operating surplus for six consecutive years, primarily due to underspending from unfilled vacancies due to manpower shortage. Despite the impression that HA had sufficient funding, demand for public hospital services had indeed been growing in excess of HA's ability to expand its capacity, with ensuing widening of the supply-demand gap. In view of

[6] The major source of funding for Hospital Authority (HA) comes from the Government, in the forms of recurrent and various capital subventions, each serving a different scope and purpose. There are established mechanisms for the annual review between HA and the Government on each of the different Votes. For example, during the annual Resource Allocation Exercise (RAE), HA would submit to the Food and Health Bureau (FHB) a shortlist of new / enhanced initiative options together with a medium term financial projection to bid for recurrent Government Subvention under One-Line-Vote, and shortlists of equipment and Information Technology (IT) project options to bid for funding under the Capital Block Vote (CBV) and Information Technology Block Vote (ITBV) respectively.

the above, a medium term financial projection via a two-pronged approach (i.e. population-based approach and capacity-based approach) has been conducted annually since 2015 to provide a context for deliberating recurrent Government Subvention to HA with the Government. Details of the medium term financial projection can be found in Glossary Part B.

Level 2 – Hospital Authority to Clusters

The second level of funding flow (from HA to Clusters) is the subject of interest related to the resource allocation recommendation made by the Steering Committee on the Review of HA. With population as the most fundamental consideration for healthcare, it is logical to extend the population-based model, from projecting the healthcare funding need of HA, down to the Cluster level so as to guide hospital services planning and resource allocation towards enhancing health equity of the population across different localities of Hong Kong. The challenge of applying population-based model to Clusters is that there are conditions other than population demographics that would affect healthcare utilisation. These need to be identified and have the size of their impact assessed so that proper adjustment can be made to refine the analysis and interpretation under the population-based model.

Level 3 – Clusters to Hospitals

Notwithstanding the third level of funding flow (from Clusters to hospitals) is not within the scope of the population-based model, the resource allocation from Clusters to hospitals has to be considered after the implementation of the population-based model if the objectives of the Cluster resource allocation to drive equity and efficiency are to be achieved. All the hospitals within a Cluster are designed to complement each other in providing a comprehensive range of healthcare services needed by the local population. As such the resource need of the individual hospitals and clinics is defined by the role it plays in providing the comprehensive range of healthcare services in the Cluster. It will be the responsibilities of Cluster management to define the optimal input-mix of resources as a basis for allocating the funding to individual hospitals to enable the appropriate mix of health services output of the Cluster to meet the healthcare needs of the population served.

(C) Refining the Basic Population-based Model

The population-based concept has a number of advantages over alternative ones that makes it popular in many developed countries. Besides providing a common language to promote a shared vision of healthcare that put people first, a population-based model removes incentives for provider-induced demand, and most importantly, provides objectivity in assessing equity and enables tools for projecting future healthcare needs to guide prospective planning.

As discussed, a population-based model can do more than just projecting changes in the overall public healthcare needs of Hong Kong and assessing the corresponding changes in funding requirement of HA, as what the Basic Model introduced in 2000 had sought to do. Extending the analysis to local communities will help quantifying healthcare needs down to small pockets of population, thereby enhancing the granularity of analysis which captures the effects of accessibility on health service utilisation. The model allows one to look for correlations between factors like socioeconomic, epidemiological factors, distance (proximity to care), availability of supply (provider's capacity constraint), etc. against the utilisation of different healthcare by care type. With Hong Kong being a small city with a highly-efficient public transportation network, cross-cluster movement of patients is a common phenomenon and therefore the model should also take into account cross-cluster patient flow and the impact of this on the objective of the population-based resource allocation model viz equity and efficiency. This will generate information and insight on how the local communities' healthcare needs are related to hospitals and Clusters. This does not only explain the resource requirement of different Clusters but also enrich our understanding on how well the population's healthcare needs (other than

Designated Services) can be met locally, i.e., regional supply-demand gap. The main refinements made to the Basic Model is summarised in the figure below:

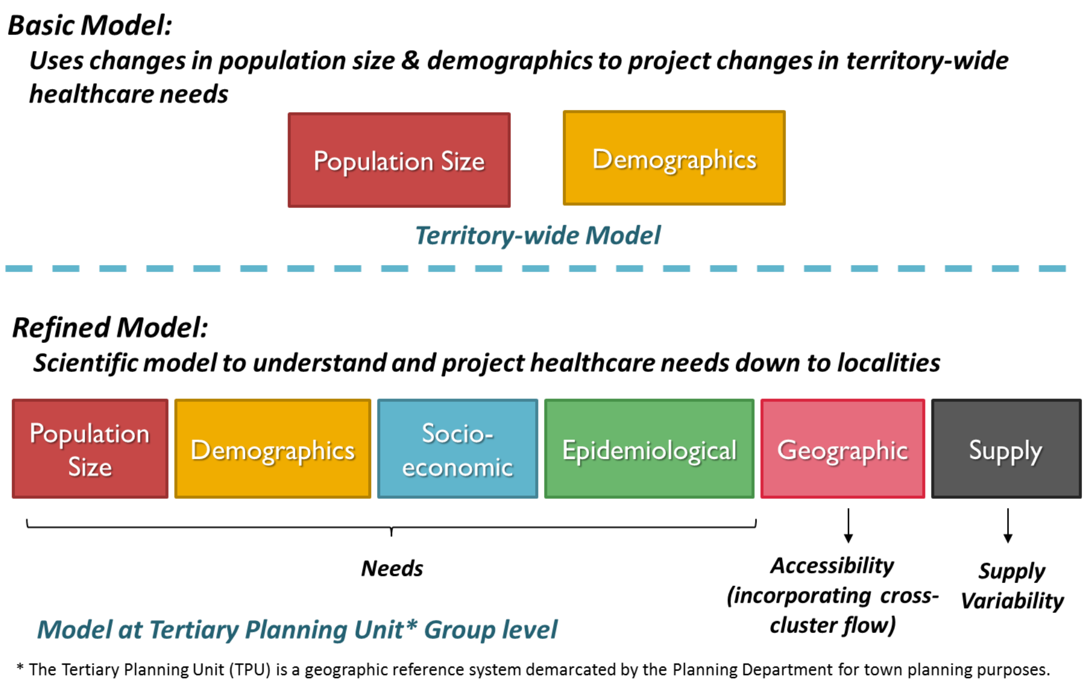


Figure 2 – Refinements on the Basic Model

While it may not be possible to entirely eliminate the gap between supply and demand for public healthcare, the gap needs to be managed through better planning of resources, designing / re-engineering care delivery and workflows to achieve synergy and efficiency, establishing fair principles and transparent procedures for deciding priority of access according to clinical judgment, and pledging determination to working towards equal access to HA services across Hong Kong. The key for executing change, however, lies in the ability to measure healthcare needs at the local level and means to assess parity of access to care across Hong Kong. Making available information of regional supply-demand gap can provide objectivity for assessing equity and create incentives to deal with the disparities observed, and projected, using existing population data and future population projections.

III. Refined Population-based Model: Conceptual Framework, Scope and Methodological Approach

As illustrated in earlier chapters, the rationale for adopting a population-based model to inform resource allocation is compelling. Through the development of the Refined Population-based Model, we aim to develop a more comprehensive analytical framework in estimating the potential needs for healthcare which enables the goals of equity and efficiency in the Cluster healthcare provision and utilisation (Rice & Smith, 2001; NHS Executive, 2011; Gravelle, Sutton and Windmeijer, et al., 2003). This chapter sets out the conceptual framework, scope and methodological approach in building the model.

(A) Conceptual Framework of Refined Population-based Model to Inform Resource Allocation

Concept of Population-based Model to Inform Resource Allocation

Population-based resource allocation is a mechanism to estimate the healthcare expenditure required to provide the healthcare services needed by the population served. It is a capitation approach based on population counts and adjusted to take into account the population characteristics that influence health service needs and utilisation. The rationale for using population-based resource allocation is to drive

(i) Equity, both in access to health services and in health outcomes for the (Cluster) population served, and

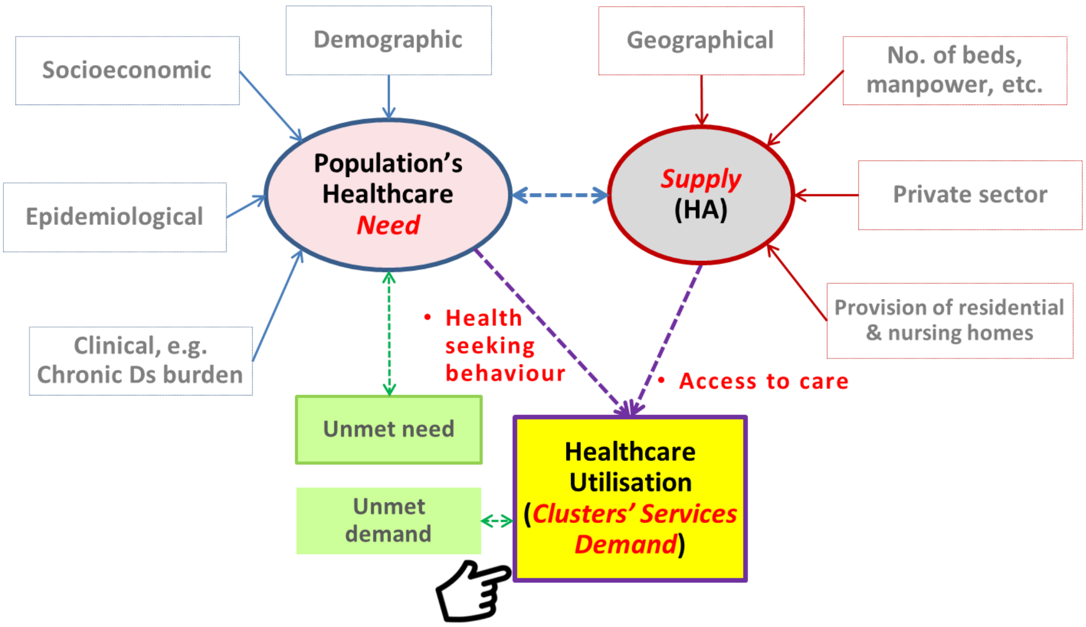
(ii) Efficiency, both technical and allocative, in ensuring the allocation of resources is consistent with the health services needed by the (Cluster) population.

As described in the Chapter II, the focus of the current exercise is the second level of healthcare funding flow, i.e. the allocation of resource from HA to the seven Clusters. At this level of estimates of healthcare expenditure, consideration of population characteristics alone is insufficient as supply factors (of individual Clusters) also affect health-seeking behaviour of the population. Hence, the Refined Population-based Model's framework would address the complex interplay between population factors, healthcare needs, health-seeking behaviour and supply factors in shaping healthcare utilisation (demand) of individual Clusters.

In line with the population-based funding models employed in other countries, healthcare utilisation (or demand for healthcare services) is assumed to be the most relevant and practicable outcome measure for predicting healthcare needs of the population. In general, healthcare utilisation reflects the healthcare needs and health-seeking behaviour of a population, and is determined by population size and the characteristics of that population. Through review of previous literature, it is found that potential variables from demographic, socioeconomic, epidemiological and clinical aspects affect relative healthcare needs of a population (Penno, Gauld & Audas, 2013; Smith, 2008; Ministry of Health of New Zealand, 2015).

Notwithstanding the effect of population needs, an earlier work conducted by Carr-Hill et al. (1994) emphasised that healthcare utilisation is also affected by the supply of healthcare facilities in two ways. First, when there is excess demand, supply constraints affect the care that can be offered, and, secondly, supply of doctors and other healthcare professionals can induce demand due to information asymmetry (Carr-Hill et al., 1994). Supply not only affects current use but is itself influenced by past use and need. As a consequence, both need- and supply-related variables should be considered in constructing the Refined Population-based Model. This is particularly relevant for the HA, which has a historical legacy of undersupply of healthcare services in a number of Clusters.

Starting with the usual understanding of population-based model, making reference to overseas countries' experience in using population-based models to guide public healthcare funding, and taking into consideration the way the public hospital system is organised and funded in Hong Kong, a conceptual framework was drawn up (Figure 3) to address the complex interplay between "population healthcare needs" including demographic, socioeconomic, and epidemiological, etc. variables, health-seeking behaviour and "supply variables" (which affects utilisation through the effect of distance on accessibility, capacity, efficiency and policy) in shaping healthcare utilisation (demand) of individual Clusters, as depicted in the figure below.



Modified from Carr-Hill, R. A., Sheldon, T. A., Smith, P., Martin, S., Peacock, S., & Hardman, G. (1994). Allocating resources to health authorities: development of method for small area analysis of use of inpatient services. BMJ: British Medical Journal, 309(6961), 1046-9.
Figure 3 – Conceptual framework for the Refined Population-based Model

Resource allocation does not exist in a vacuum but is linked to a Cluster's existing scale of operation and changes over time subject to the short- and longer-term planning of infrastructure and services. The Refined Population-based Model can help enhance the understanding of inter-relationship between healthcare need and demand expressed as healthcare utilisation, and the influence and constraints of supply on utilisation. To drive equity it serves as a critical tool to adjust the influence of (under) supply to enable better access for the Cluster catchment population. It can be used as a tool to predict future healthcare needs and the resources and services required to meet these needs for each of the Clusters. Tools can also be developed to understand both the health-seeking behaviour of Cluster population in models and for simulation of the impact arising from changing strategies in service provision of individual Clusters on cross-cluster flow or patients residing in different localities.

Before constructing the Refined Population-based Model under the aforementioned conceptual framework, the scope of the model, as well as various important parameters in the model, would need to be accurately defined. It is discussed in the next sections.

(B) Scope of the Refined Population-based Model

Service Categories

There are a variety of healthcare services provided by HA, which require different levels of resources. By considering the structure of service provision, availability of utilisation and costing data of different healthcare activities, eight core service categories were used as the basis of the analysis, namely Acute Inpatient (Acute IP), Non-acute Inpatient (Non-acute IP), Specialist Outpatient (SOP), Primary Care (PHC)[7], Accident and Emergency (A&E), Allied Health Outpatient (AHOP), Day Hospital, and Community Care. Such granular analysis would facilitate inter-cluster comparison down to core services.

With regard to the measure of utilisation, bed days occupied (BDO), number of patients, and number of episodes could be used for inpatient services. As variations in terms of BDO could imply significant cost differences in quantifying healthcare expenditures, it is proposed that BDO would be a more relevant cost

[7] Includes General Outpatient Clinic, Family Medicine Specialist Clinic, Integrated Mental Health Programme, Risk Factor Assessment and Management Programme.

driver for the analysis. On the other hand, number of attendance would be used for other services (i.e. SOP, PHC, A&E and AHOP).

Expenditure Covered by the Model

As the subject of interest is equity of healthcare expenditure by population consideration, it is most relevant to compare the recurrent operating expenditure used on core hospital services that are common across Clusters, i.e. to compare like-with-like. Clusters' operating expenditure includes all day-to-day service costs incurred by Clusters attributable to the provision of services, as well as corporate-wide expenditure processed by HO that are necessary for the provision of hospital services.

On the other hand, capital expenditure, which includes facilities maintenance and improvement projects, major equipment acquisitions, and Information Technology developments, is not the subject of analysis under the population-based model as they are incurred for designated uses and are centrally planned under a separate mechanism for corporate-wide standards, and that year-to-year comparison would be misleading due to their long planning cycles and different phasing between Clusters. Separate mechanisms are currently in place to strive for a comparable level of standard for these items across Clusters in HA.

In addition, it is common for public healthcare systems to organise highly specialised services and operations in designated locations so as to benefit from concentration of expertise (not only of healthcare professionals but also technology setup and facility design, etc.) and economies of scale. This is particularly relevant in Hong Kong in view of the size of its population and territory. As these services (labelled as Designated Services (DS) for the purpose of this project) are provided in designated institutions for the entire population of Hong Kong, they serve populations beyond their Cluster boundary and thus are outside of the scope of the Clustering concept and in turn the Refined Population-based Model to inform resource allocation. As such, after deliberation at the IRAMD SC, it was decided that DS should be carved out from the Refined Population-based Model such that the remaining core hospital and clinic services are more comparable in terms of scope, nature, and the target population (i.e. within the Cluster's catchment locations) intended to serve, which in turn would minimise any potential bias that may result from the varying provision of DS in different Clusters. For example, assessing whether outpatient resource utilisation is comparable between hospitals that provide territory-wide AIDS services and hospitals without such service would be biased and would provide misleading information.

With regard to the definition of DS, Tertiary and Quaternary (T&Q) services served as a convenient starting point for defining DS as discussed in the Finance Committee (FC) of the HA Board in March 2016[8]. However, it was noted that some T&Q services are available in most Clusters (e.g. autologous bone marrow transplantation), and hence, should not be adjusted for whereas some non-T&Q services (not limited to clinical services) are provided by specific location(s) (e.g. Blood Transfusion Services) and should be properly accounted for. Through discussing with frontline and deliberating at the IRAMD SC, the following definition for DS was formulated.

Designated Services mainly follow corporate direction when setting out corresponding service delivery models, and are:

(a) highly complex in nature with respect to skill, technology and/or expertise that are only adequately available in specific Cluster(s) to serve populations beyond its Cluster boundary, or

(b) being centralised at specific Cluster(s) to serve populations beyond its Cluster boundary on operational reasons or economy of scale.

An identification and vetting mechanism based on materiality and data availability was set up by the IRAMD SC. Two rounds of DS proposals were

[8] Vide Finance Committee Paper FC-P705

called from Clusters and an initial list of 13 DS was shortlisted. While Teaching and Research Component in Teaching Hospitals is not strictly a DS under the aforementioned definition, it is treated in a similar way as the two Teaching Hospitals, namely Queen Mary Hospital and Prince of Wales Hospital, are the main clinical education and research centres in Hong Kong.

Designated Services	Cluster(s)
1. AIDS Service	Kowloon Central Cluster Kowloon West Cluster
2. Blood Transfusion Service	Kowloon Central Cluster
3. Bone Marrow Transplantation (Allogeneic)	Hong Kong West Cluster
4. Cardiothoracic Surgery	Hong Kong West Cluster Kowloon Central Cluster New Territories East Cluster#
5. Heart Transplantation	Hong Kong West Cluster
6. Lung Transplantation	Hong Kong West Cluster
7. Developmental Disabilities Unit	Kowloon West Cluster
8. Forensic Psychiatry	New Territories West Cluster
9. Infectious Disease Centre	Kowloon West Cluster
10. Liver Transplantation	Hong Kong West Cluster
11. Severe Mentally Handicapped Services	New Territories West Cluster
12. Toxicology	Kowloon East Cluster Kowloon West Cluster New Territories East Cluster
13. Teaching and Research Component in Teaching Hospitals	Hong Kong West Cluster New Territories East Cluster

 # With a Thoracic Surgery satellite site in New Territories West Cluster

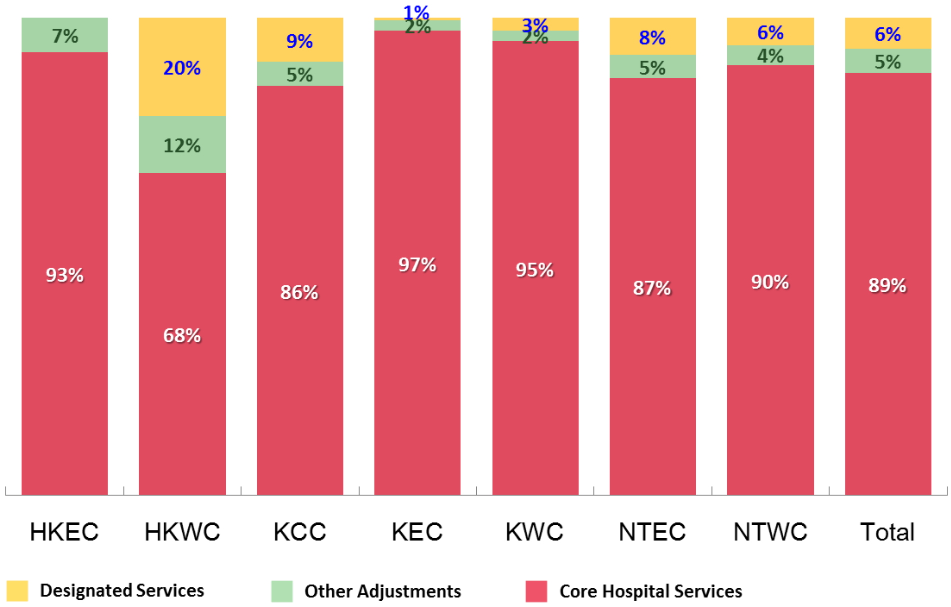
Table 1 – Initial list of DS

The background information on the initial list of DS is set out in Glossary Part C. For a detailed discussion on the costing methodologies as well as the corresponding results, please refer to the report "Costing Report of Designated Services: Year 2012/13 to 2015/16".

Apart from excluding the resources and activities of DS, other adjustments listed below have been performed in order to derive the resources used for the provision of core hospital services of each Cluster to facilitate like-with-like comparison (please refer to Glossary Part G for their detailed descriptions):

- Expenditure not related to day-to-day public services (e.g. private services)
- Expenditure borne by patients (e.g. self-financing drug items)
- Expenditure related to policy directed initiatives (e.g. clinical public-private partnership programmes)
- Technical adjustments (e.g. on differential electricity tariff)

Figure 4 illustrates the relative magnitude of the resources in 2015/16 for DS, other adjustments, and core hospital services for the seven Clusters as well as the HA.



Cluster-specific expenditure on DS can be found in Chapter VIII of "Costing Report of Designated Services: Year 2012/13 to 2015/16", while detailed breakdown on the other adjustments can be found in Glossary G of this report.

Figure 4 – Resources for DS, other adjustments, and core hospital services

In summary, resources to be analysed under the Refined Population-based Model are depicted in Figure 5 below.

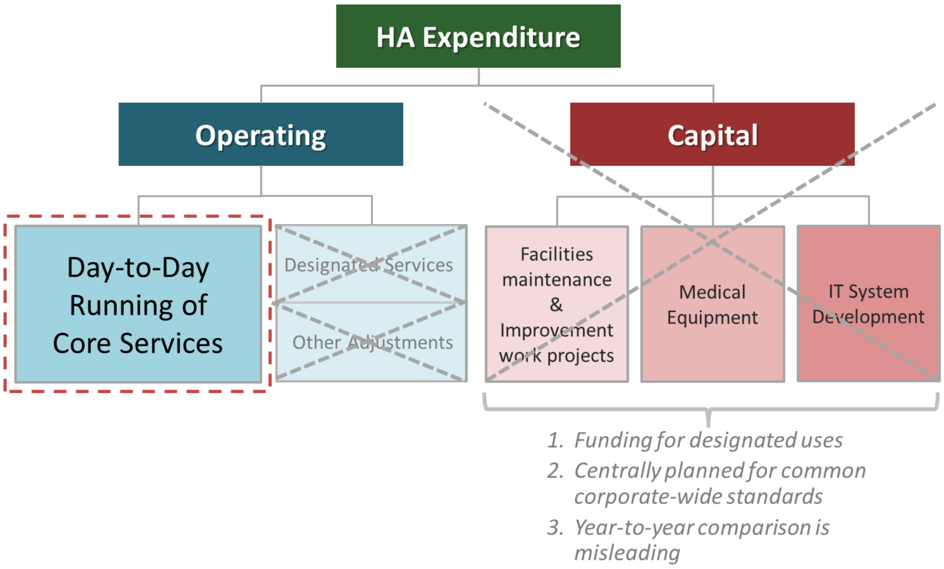


Figure 5 – Expenditure covered by the model

(C) Definition of Population and Spatial Unit of Measurement

Under the population-based methodology, one of the main determinants of healthcare needs, and therefore resource requirements, is the size of the population.

The major source of population figures in Hong Kong is C&SD, which is responsible for collection, manipulation, estimation and dissemination of such information in a regular basis. Population census is conducted every 10 years, while one population by-census is carried out between each population census. Apart from population census and by-census, population figures are estimated and projected at a shorter interval. In building a Refined Population-based Model, definition and figures of Hong Kong population are directly adopted and extracted from Hong Kong Population Census 2011, which is the latest report available (Census and Statistics Department, 2012). The population figures to be used for the Refined Population-based Model refer to Hong Kong Residents Population, covering both “Usual Residents”[9] and “Mobile Residents”[10].

[9] Refers to the Hong Kong Permanent Residents who had stayed in Hong Kong for at least 3 months during the 6 months before or for at least 3 months during the 6 months after the census reference moment, regardless of whether they were in Hong Kong or not at the

The size of Hong Kong Residents Population is generally reported at different spatial units for basic description of geographical difference or other purposes. Common spatial units being used in Hong Kong Population Census 2011 include area (n=3; Hong Kong Island, Kowloon and the New Territories), District Council District (n=18), District Council Constituency Area (DCCA) (n=412) and Tertiary Planning Unit[11] (TPU) (n=289). While choosing the spatial unit for constructing the Refined Population-based Model, there are a number of considerations that shall be taken:

- Alignment with the boundaries of HA Cluster catchment areas
- Consistency of the boundaries of the spatial unit over time
- Homogeneity of the population characteristics within the same spatial area
- Ability to capture the effects of accessibility of health services on utilisation
- Availability of supplementary data (population projection)

In spite of the consistent boundaries over time, area and District Council District are of inadequate granularity, leading to a difficulty of matching with the boundaries of HA Cluster catchment areas. For example, population residing in Islands District are in the catchment areas of two HA Clusters, (HKEC and KWC respectively. To tackle such inconsistency, model construction process would

census reference moment; and Hong Kong Non-permanent Residents who were in Hong Kong at the census reference moment. (source: C&SD)

[10] Refers to Hong Kong Permanent Residents who had stayed in Hong Kong for at least 1 month but less than 3 months during the 6 months before or for at least 1 month but less than 3 months during the 6 months after the census reference moment, regardless of whether they were in Hong Kong or not at the census reference moment. (source: C&SD)

[11] The Tertiary Planning Unit (TPU) is a geographic reference system demarcated by the Planning Department for town planning purposes. The whole territory of Hong Kong is divided into 289 TPUs, which are aggregated under 52 Secondary Planning Units and in turn under nine Primary Planning Units (as of 2011). The TPU boundaries are mainly delineated by the nature of the geographic features of the area such as roads, railway lines, zoning boundaries of town plans, etc. They also provide a common geographic system for the compilation of statistical data. In particular, statistical data from the population census/by-census are produced using this basic system.

inevitably involve additional assumption, estimation and adjustment, which are undesirable.

Better choices go to DCCA and TPU, which are two spatial units of finer granularity and better homogeneity of the population characteristics. Boundaries of both spatial units can largely match with the boundaries of HA Cluster catchment areas. While DCCA is defined for election purposes, its boundaries are subject to amendment, according to election schedule. The consistency of DCCA boundaries is thus relatively lower than that of TPU. Furthermore, population projection figures are available for TPU, but not DCCA. For a Refined Population-based Model with forward looking objectives, the availability of such supplementary information is important. Therefore, the recommended spatial unit for the Refined Population-based Model is TPU.

According to the C&SD, having regard to data precision and protection of data privacy of individual respondents, a TPU with less than 1,000 persons is merged with adjacent TPU(s) for the release of statistics. The resultant 209 TPU groups are employed in the model.

(D) Statistical Model

In essence, the statistical model seeks to identify factors with good correlation / predictive values over the population’s healthcare utilisation pattern by localities (i.e. by TPU groups). The structure of the statistical model is depicted in the figure below:

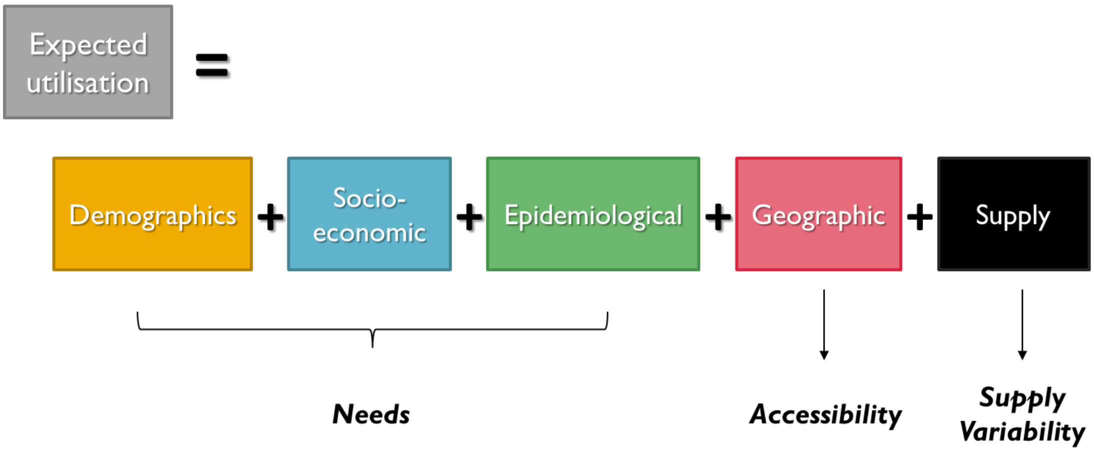


Figure 6 – Structure of the statistical model

Variables for Consideration in the Statistical Model

Taking reference from overseas experiences on the population-based resource allocation approach, various adjustment factors are reported which capture the variation of healthcare needs of different structure and composition of Cluster. As mentioned in Chapter II (and illustrated in detail in Glossary Part A), there are different approaches in the development of population-based models around the world. One can observe that different metrics are used to quantify differential healthcare needs of population.

According to a local research study conducted by Wong et al. in 2009, levels of healthcare utilisation were highly influenced by various social and geographical factors in Hong Kong. The following section on "Literature Review on Potential Variables" serves to discuss the selection and rationale of the choice of adjustment factors / variables, which are potentially relevant for the Refined Population-based Model to inform resource allocation in HA.

Literature Review on Potential Variables

To identify variables with good correlation and predictive values of healthcare utilisation patterns of the population, the literature in international studies has been reviewed. A systematic search of Pubmed and Medline was conducted for

English-language articles published from 1996 to April 2016. The initial search retrieved a total of 521 articles, which was limited to 44 potentially relevant papers after perusal of the titles and abstracts of the papers by two independent reviewers. In the next step, the CUHK consultancy team identified another 20 papers in grey literature (including 15 articles from reference lists of the selected articles and five Government reports from England, New Zealand and New South Wales of Australia). After reading the full text of these 64 papers, 18 papers from nine jurisdictions [12] were selected for inclusion in the body of the review.

Variable Evaluation Process for the Statistical Model

Selection of variables is a complex, and may be a controversial process (Smith, Rice and Carr-Hill, 2001) due to a number of reasons. Firstly, there could be shortage of relevant data. Secondly, it is often difficult to disentangle legitimate needs factor from other influences on utilisation, such as supply factors. Thirdly, adjustment of statistical independence among needs factors is complex. Fourthly, political influences and manipulation of input factors are not uncommon.

In view of these challenges, processes and selection criteria in the choice of variables for model building need to be transparent and robust, such that the influence on the need of healthcare can be reflected. Both qualitative and quantitative methods will be used, taking data availability and local context into account. Take reference from the international literature and in particular the 2015 population-based Funding Formula Review in New Zealand, a three-step approach (Figure 7) using (i) four qualitative criteria, (ii) taking into account the data availability and local context, and (iii) two quantitative criteria for evaluation of the potential variables synthesised from the international literature is recommended.

[12] Belgium, England (UK), Germany, Italy, New South Wales (Australia), New Zealand, Stockholm (Sweden), The Netherlands and United States

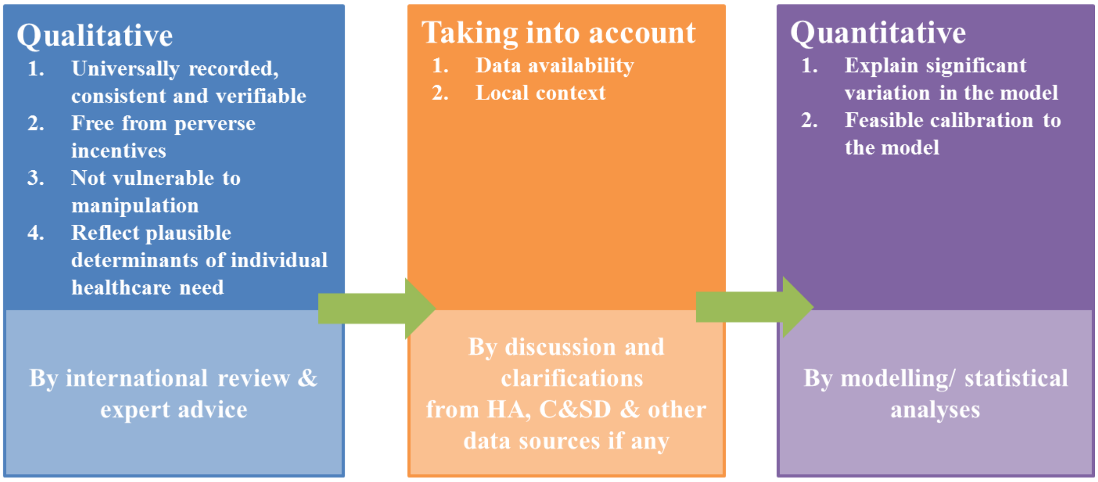


Figure 7 – Three-step approach for evaluation of the potential variables

The selection of potential variables starts with review of international publications and consultation of expert advice using the four qualitative criteria (Step 1). After discussion and clarification for data availability and local text with stakeholders, the potential variables would be included for statistical testing and modelling via regression analysis (Step 2). The final choice of variables was based on their significance for explaining the outcome measure of the model (Step 3), such as the number of BDO for inpatient services and the number of attendances for outpatient services. The model will be calibrated for validity of the selected variables.

List of Potential Variables in Consideration

Following overseas experience where potential variables included for further analysis should be (i) documented in previous analyses, (ii) included in capitation models in other health systems, and (iii) judged as plausible from medical literature, an initial list of 38 potential variables were identified before the aforementioned three-step selection approach. They were categorised into seven dimensions, including (i) demographic, (ii) socioeconomic, (iii) epidemiological, (iv) clinical, (v) geographic, (vi) unmet needs and (vii) other variables (e.g. supply).

The 38 identified variables were further deliberated on their relevance in the local context and data availability for detailed analysis and validation in the Statistical Model (Figure 8). A description of each variable, their application in other capitation payment systems, and an assessment on whether subsequent work is warranted to analyse in the context Hong Kong is provided in Glossary Part D.

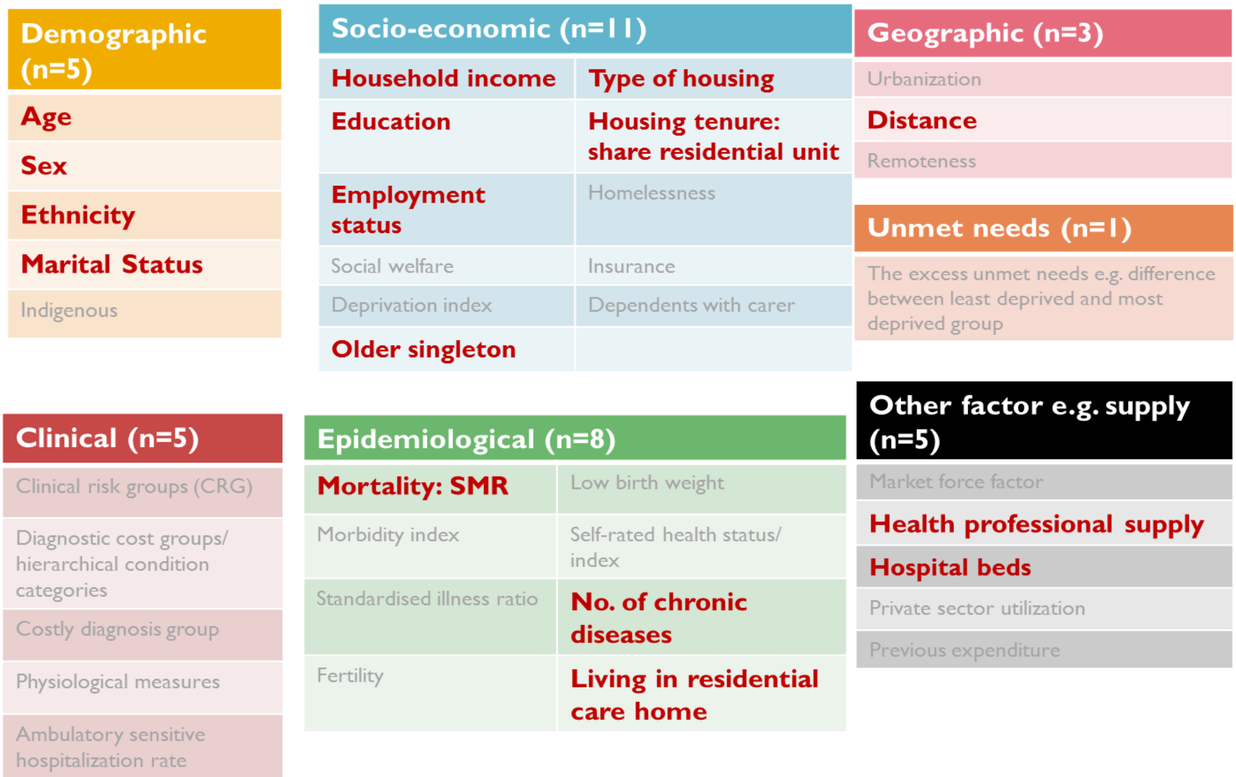


Figure 8 – Factors considered in the statistical model

A total of 16 variables were finally shortlisted based on their relevance in the local context and data availability, where they are subject to testing by statistical techniques for examination of their degree of effect on healthcare utilisation. The shortlisted 16 variables are highlighted in red in Figure 8.

The above 16 factors are then used to construct the statistical model. The structure of the statistical model covers the above five major areas i.e. demographics, socioeconomic, epidemiological, geographical and supply. Demographics, socioeconomic and epidemiological variables reflect the healthcare needs, whereas geographic and other supply variables represent the services accessibility and supply variability respectively.

IV. Model Development

The statistical model was built taking into account the conceptual framework and various model building considerations as illustrated in Chapter III. This chapter discusses the model building and validation process, as well as the models built.

(A) Variables in the Statistical Model

Table 2 shows the 16 variables under the 5 major areas and its data source. While the demographics and socioeconomic variables were obtained from C&SD, the supply variables were collected from within HA. Due to the unavailability of "chronic diseases" at TPU Group level from C&SD, the variable "chronic diseases" was proxied through HA utilisation data, defined as the proportion of population aged 60 and over, who were admitted to the specialty of Medicine in HA with any of fifteen pre-defined chronic conditions. The detailed description of each variable is in Glossary Part E.

Category	Variables	Data source
Demographics	Age	Census & Statistics Department, and Planning Department
	Gender	Census & Statistics Department
	Ethnicity	Census & Statistics Department
	Marital Status	Census & Statistics Department
Socioeconomic	Household income	Census & Statistics Department
	Educational level	Census & Statistics Department
	Employment status	Census & Statistics Department
	Type of housing	Census & Statistics Department
	Housing tenure: shared residential unit	Census & Statistics Department
	Older singleton	Census & Statistics Department
Epidemiological	Standardised mortality rate	Census & Statistics Department
	Chronic diseases	Hospital Authority
	Living in residential care home	Census & Statistics Department
Geographical	Distance	Planning Department and Lands Department
Supply	Health professional supply	Hospital Authority
	Hospital beds	Hospital Authority

Table 2 – Variables included in the statistical model and data source

The model was built using data from 2011/12 to 2013/14. Since the major source of data for constructing the model variables was 2011 Population Census, which was a cross-sectional population-based survey conducted by C&SD every ten years, additional effort for projecting the annual changes in the population figures at TPU Group level would be required after 2011. In addition, just like the utilisation data, the supply variables would also need to be adjusted so that DS-related numbers were carved out to facilitate like-with-like comparison among Clusters. Using inpatient services as an example, the adjustment was made by utilising the proportion of BDO attributed to DS for each specialty in each hospital. While such methodology may not be able to derive the true capacity attributable to DS, it is nevertheless a fair approximation for the purpose of model building, given that there is no clearly delineated capacity information available for DS at the moment. Detailed explanation on the above technical adjustments on the variables can be found in Glossary Part F.

(B) Model Design

As mentioned, utilisation in HA was delineated into eight core services for model building. However, due to the heterogeneity of service models for Community Care and Day Hospital, and the lack of structured electronic data, these two services, which accounted for only 4% of Cluster recurrent expenditure on core hospital services, were excluded for statistical modelling.

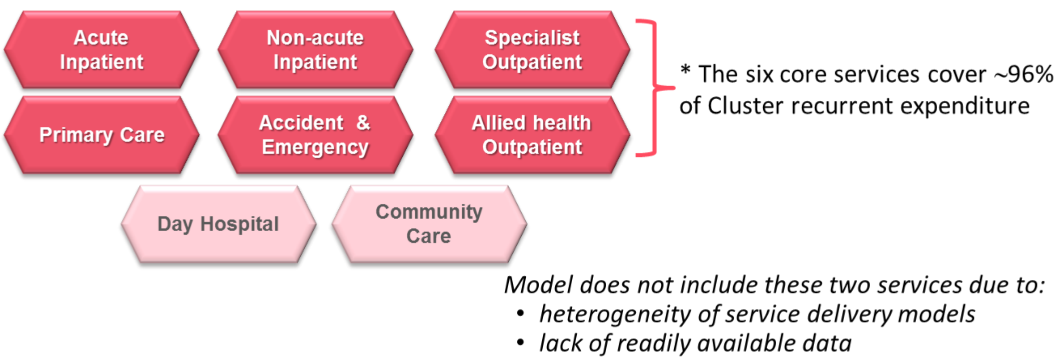


Figure 9 – Core services included in the statistical model

For the remaining six services, two types of models (i) Generalised linear model (GLM), or (ii) Two-level generalised linear mixed effect model (GLMM) have been considered to fit the utilisation outcomes for the six services (i.e., BDO for Acute and Non-acute IP and attendance for others).

(i) Generalised linear model (GLM):

$$g(y_{ij}) = \beta_0 + \sum \beta_{demo} x_{demo,ij} + \sum \beta_{socio} x_{socio,ij} + \sum \beta_{epi} x_{epi,ij} + \beta_{dist} x_{dist,ij} + \beta_{supply} x_{supply,j} + \beta_{year} Year$$

The g (.) is the link function in which a Poisson link was used. The y_{ij} denotes the utilisation outcome from the i^{th} TPU to the j^{th} hospital. A population offset is employed in the model. The model summarises the effects β_{demo}, β_{socio}, and β_{epi} for demographics ($x_{demo,ij}$), socioeconomic ($x_{socio,ij}$), and epidemiological ($x_{epi,ij}$) variables respectively. The coefficients β_{dist} and β_{supply} measure the effect for distance ($x_{dist,ij}$) from i^{th} TPU to j^{th} hospital and the supply ($x_{supply,j}$) provided by the hospital respectively.

(ii) Two-level generalised linear mixed effect model (GLMM):

First stage in TPU levels:

$$g(y_{ij}) = \beta_{0,j} + \sum \beta_{demo} x_{demo,ij} + \sum \beta_{socio} x_{socio,ij} + \sum \beta_{epi} x_{epi,ij} + \beta_{dist} x_{dist,ij} + \beta_{year} Year$$

Second stage in hospital levels:

$$\beta_{0,j} = \gamma_0 + \gamma_{supply} x_{supply,j} + u_{0,j}$$

The two-stage GLMM incorporates the effects from the first stage (TPU) and the second stage (hospital) respectively. The stage one model is similar to GLM with an intercept term ($\beta_{0,j}$) of the utilisation outcome in j^{th} hospital. In the stage two model, $\beta_{0,j}$ is the dependent variable. The coefficients γ_0 and γ_{supply} refer to an overall intercept and the supply factors respectively. The term $u_{0,j}$ refers to a random effect component for each of the hospitals which is able to capture the heterogeneity in utilisation across different hospitals. The model, either GLM or GLMM, that shows a better goodness of fit was chosen for estimation and projection.

(C) Developed Models

Goodness of Fit

The Pearson correlation coefficient (r) was used to assess the agreement between the observed utilisation data and the fitted/predicted results. The mean absolute percentage error (MAPE), calculated by taking the average of the absolute number of [(observed utilisation – fitted utilisation)/observed utilisation] for each of the hospitals were also used to assess the model fitness and validate the prediction performance.

Table 3 summarises the fitness statistics for two different models for the six services. Both models achieve >0.80 correlations between the observed and the fitted/predicted utilisation data for each of the services. The MAPEs of GLM are greater than that of two-level GLMM. All MAPEs of two-level GLMM are less than 1% in model building (ranging from <0.1% to 0.6%). Generally, two-level GLMM demonstrated a better prediction power on utilisation outcomes, and was therefore used for subsequent model projection. The coefficients of the variables using the two-level GLMM are illustrated below.

	Model building			
	GLM		**Two-level GLMM**	
Services	r	MAPE	r	MAPE
Acute IP	0.84	42.3%	0.85	<0.1%
Non-acute IP	0.77	50.1%	0.83	<0.1%
SOP	0.86	>100%	0.88	<0.1%
PHC	0.87	>100%	0.90	0.6%
A&E	0.89	16.0%	0.90	<0.1%
AHOP	0.87	>100%	0.90	<0.1%

Table 3 – r and MAPE for GLM and two-level GLMM (model building)

Models Built: Two-level GLMM Coefficients of Fixed Effects

Outcome measure:

y_{ij} = service utilisation at j^{th} hospital for patients residing in i^{th} TPU

1) Acute IP

TPU level:

$g(y_{ij}) = \beta_{0,ij}$ – 0.002 [Age<20] – 0.010 [Age >=65]
– 0.022 [% male] + 0.201 [% non-married]
– 0.106 [% non-Chinese] – 0.529 [Median income]
+ 0.029 [% unemployment] – 0.007 [% post-secondary education]
– 0.141 [% singleton] – 0.002 [% public rental housing]
– 0.013 [share residential unit] + 0.048 [SMR]
+ 0.069 [% chronic diseases] – 0.015 [% live in RCHE]
– 199.4 [weighted distance] + 0.031 [year]
+ log(population$_i$) + ε

Hospital level:

$\beta_{0,ij}$ = intercept + $u_{0,j}$ + 0.467 [number of acute beds]

2) Non-Acute IP

TPU level:

$g(y_{ij}) = \beta_{0,ij}$ + 0.003 [Age<20] + 0.053 [Age >=65]
+ 0.024 [% male] – 0.200 [% non-married]
+ 0.027 [% non-Chinese] – 0.909 [Median income]
+ 0.045 [% unemployment] + 0.019 [% post-secondary education]
– 0.144 [% singleton] + 0.003 [% public rental housing]
– 0.007 [share residential unit] + 0.095 [SMR]
+ 0.053 [% chronic diseases] + 0.068 [% live in RCHE]
– 159.3 [weighted distance] – 0.024 [year]
+ log(population$_i$) + ε

Hospital level:

$\beta_{0,ij}$ = intercept + $u_{0,j}$ + 0.362 [number of non-acute beds]

3) SOP

TPU level:

$$g(y_{ij}) = \beta_{0,ij} + 0.001\,[\text{Age<20}] - 0.024\,[\text{Age >=65}]$$
$$- 0.004\,[\text{\% male}] + 0.297\,[\text{\% non-married}]$$
$$- 0.173\,[\text{\% non-Chinese}] - 0.541\,[\text{Median income}]$$
$$+ 0.024\,[\text{\% unemployment}] - 0.0001\,[\text{\% post-secondary education}]$$
$$- 0.126\,[\text{\% singleton}] + 0.001\,[\text{\% public rental housing}]$$
$$- 0.020\,[\text{share residential unit}] + 0.106\,[\text{SMR}]$$
$$+ 0.023\,[\text{\% chronic diseases}] - 0.036\,[\text{\% live in RCHE}]$$
$$- 600.0\,[\text{weighted distance}] + 0.029\,[\text{year}]$$
$$+ \log(\text{population}_i) + \varepsilon$$

Hospital level:

$$\beta_{0,ij} = \text{intercept} + u_{0,j} + 0.483\,[\text{Doctor FTE}]$$

4) PHC

TPU level:

$$g(y_{ij}) = \beta_{0,ij} - 0.042\,[\text{Age<20}] - 0.037\,[\text{Age >=65}]$$
$$- 0.008\,[\text{\% male}] - 0.172\,[\text{\% non-married}]$$
$$- 0.180\,[\text{\% non-Chinese}] - 0.489\,[\text{Median income}]$$
$$+ 0.109\,[\text{\% unemployment}] - 0.013\,[\text{\% post-secondary education}]$$
$$- 0.043\,[\text{\% singleton}] + 0.004\,[\text{\% public rental housing}]$$
$$- 0.017\,[\text{share residential unit}] - 0.087\,[\text{SMR}]$$
$$+ 0.024\,[\text{\% chronic diseases}] - 0.078\,[\text{\% live in RCHE}]$$
$$- 1048.2\,[\text{weighted distance}] + 0.034\,[\text{year}]$$
$$+ \log(\text{population}_i) + \varepsilon$$

Hospital level:

$$\beta_{0,ij} = \text{intercept} + u_{0,j} + 0.605\,[\text{FM Doctor FTE}]$$

5) A&E

TPU level:

$g(y_{ij}) = \beta_{0,ij}$ – 0.015 [Age<20] – 0.028 [Age >=65]
+ 0.003 [% male] + 0.307 [% non-married]
– 0.075 [% non-Chinese] – 0.602 [Median income]
+ 0.017 [% unemployment] – 0.002 [% post-secondary education]
– 0.116 [% singleton] + 0.004 [% public rental housing]
– 0.006 [share residential unit] + 0.034 [SMR]
+ 0.038 [% chronic diseases] – 0.029 [% live in RCHE]
– 678.8 [weighted distance] + 0.001 [year]
+ log(population$_i$) + ε

Hospital level:

$\beta_{0,ij}$ = intercept + $u_{0,j}$ + 0.056 [A&E Doctor FTE]

6) AHOP

TPU level:

$g(y_{ij}) = \beta_{0,ij}$ + 0.003 [Age<20] – 0.037 [Age >=65]
– 0.022 [% male] + 0.620 [% non-married]
– 0.191 [% non-Chinese] – 0.561 [Median income]
+ 0.069 [% unemployment] – 0.002 [% post-secondary education]
– 0.151 [% singleton] + 0.002 [% public rental housing]
– 0.024 [share residential unit] + 0.137 [SMR]
+ 0.022 [% chronic diseases] – 0.042 [% live in RCHE]
– 638.4 [weighted distance] + 0.022 [year]
+ log(population$_i$) + ε

Hospital level:

$\beta_{0,ij}$ = intercept + $u_{0,j}$ + 0.633 [AH Prof. FTE]

All 16 factors were found to have a statistically significant effect on healthcare utilisation. Among the 16 factors, two were consistently found to be the most influential factors for the six service categories studied, namely, supply (e.g. number of beds, the doctor manpower strength, etc.) and distance (between the patient's residence and the location of the healthcare facilities where the patient sought care, whether within or across Clusters).

The other 14 factors represent the "needs" of the population. The extent of how these factors would impact utilisation differed among services. Table 4 illustrates the next three influential factors for each service category after supply and distance. While the top three factors are not identical among services, factors such as household income, housing tenure: shared residential unit, and age (elderly proportion) were found to be top influential factors in multiple models.

Core Services	**Top 3 influential factors after supply and distance**
Acute IP	Chronic diseases, household income, housing tenure: shared residential unit
Non-acute IP	Household income, age (elderly proportion), education level
SOP	Household income, housing tenure: shared residential unit, ethnicity (non-Chinese)
PHC	Household income, employment status, age (elderly proportion)
A&E	Household income, chronic diseases, age (elderly proportion)
AHOP	Household income, housing tenure: shared residential unit, age (elderly proportion)

Table 4 – Top three influential factors after supply and distance

Model Validation

Model validation is critical in any modelling process. To assess how the results of the models built using 2011/12 to 2013/14 data will generalise to an independent data set, a cross-validation process using out-of-sample data (i.e. 2014/15 and 2015/16 data) was employed.

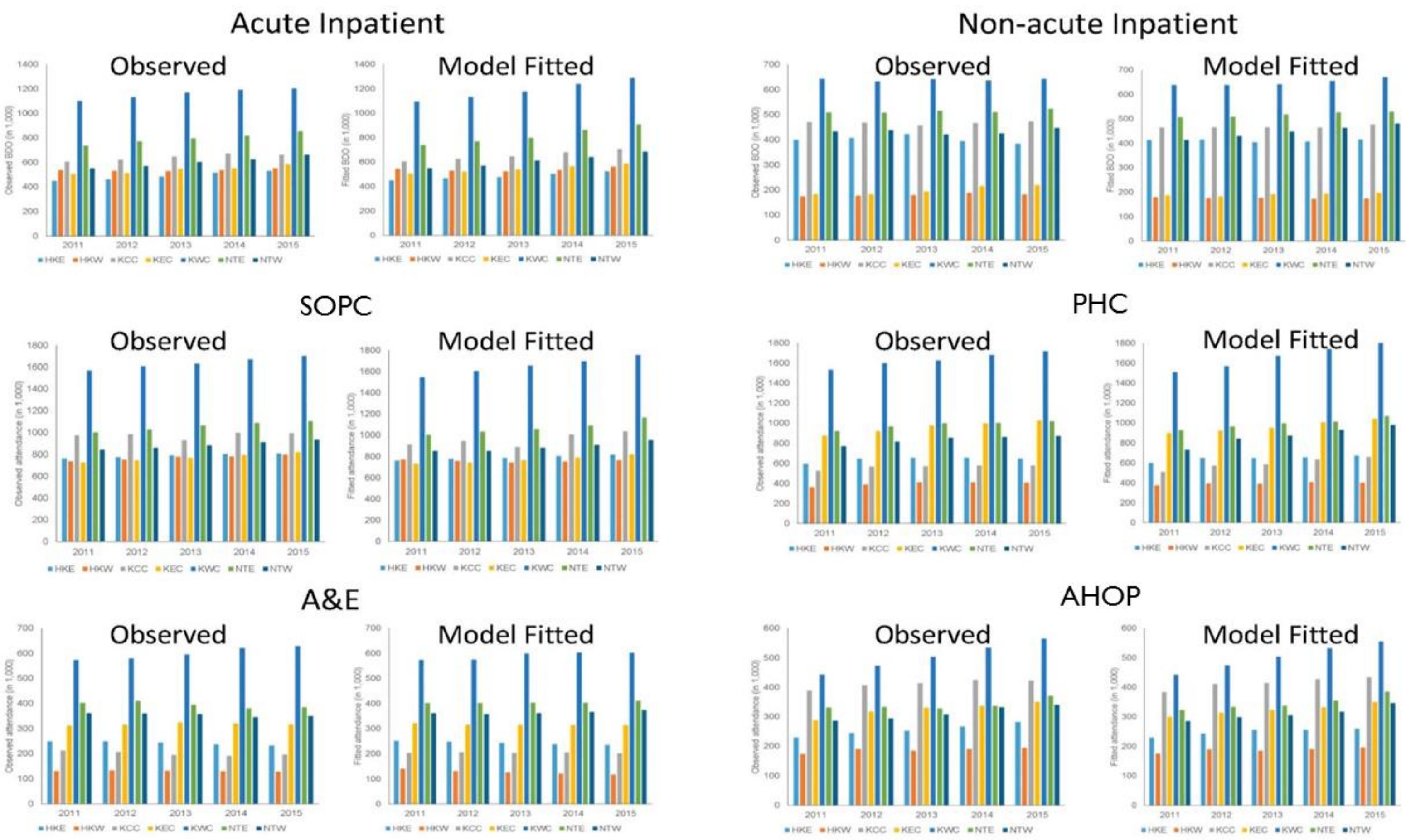
As mentioned above, the Pearson correlation coefficient (r) was used to assess the agreement between the observed utilisation data and the fitted / predicted results, while the MAPE for each of the hospitals are also used to assess the model fitness and validate the prediction performance. The best fitted model is selected based on a lower MAPE. Table 5 shows the r and MAPE statistics for the cross-validation for both the GLM and two-level GLMM. In addition, Figure 10 illustrates graphically the comparison between observed data and fitted results based on two-level GLMM.

As most of the needs factors could be highly correlated, variance inflation factors (VIF) was employed to check for multi-collinearity, i.e. variables with VIF>10 will be removed from the model.

	Model Validation			
	GLM		Two-level GLMM	
Services	*r*	MAPE	*r*	MAPE
Acute IP	0.84	49.7%	0.85	7.6%
Non-acute IP	0.76	39.9%	0.84	9.3%
SOP	0.86	>100%	0.89	10.7%
PHC	0.86	>100%	0.90	8.2%
A&E	0.87	21.3%	0.88	9.4%
AHOP	0.86	>100%	0.90	14.5%

Table 5 – r and MAPE for GLM and two-level GLMM (model validation)

In addition to the validation of model through utilisation data, the resources required calculated by the fitted model is validated against the actual resources utilised in different Clusters in 2014/15. The resources required based on the fitted model is calculated by summing up the product of utilisation (i.e. BDO for Acute IP and Non-acute IP and attendances for SOP, PHC, A&E and AHOP) and their respective HA average unit cost. The model-calculated resources in 2014/15, together with the actual amount of resources by Cluster, is summarised in Table 6. The differences in percentage share of HA overall cost between the model-calculated and actual resources are within 0.5% for all Clusters. Such agreement between the observed and modelled results also contributes to the validation on the model.



Remarks: 2011/12 to 2013/14 were model fitted results and 2014/15 to 2015/16 were model validated results

Figure 10 – Comparison between observed data and fitted results

2014/15	Model Fitted Utilisation in 1,000 BDO/attendance						Model-calculated Resources		Actual resources	
Cluster	Acute IP	Non-acute IP	SOP	PC	A&E	AHOP	Total ($Billion)	%share	Total ($Billion)	%share
HKEC	502.1	407.0	803.5	657.8	238.2	255.1	4.61	10.9%	4.73	11.4%
HKWC	534.7	172.4	750.5	406.7	120.6	190.1	3.98	9.4%	3.97	9.6%
KCC	679.7	464.8	1006.1	633.1	205.2	427.8	5.79	13.7%	5.62	13.5%
KEC	564.8	192.9	791.1	1007.7	314.4	332.5	4.68	11.1%	4.7	11.3%
KWC	1240.0	655.5	1698.9	1743.0	603.1	531.6	10.37	24.5%	10.03	24.1%
NTEC	862.0	527.0	1091.2	1013.9	403.2	354.1	7.15	16.9%	6.88	16.5%
NTWC	640.7	463.1	909.7	932.1	366.4	317.3	5.73	13.5%	5.67	13.6%
Total	5024.0	2882.7	7051.0	6394.3	2251.1	2408.5	42.30	100%	41.59	100%

Table 6 – Comparison between actual resources and resources fitted by model

Model Projection

Based on the validated model, the utilisation of the six services was projected using the available corresponding projected population characteristics in various TPUs. As the model was constructed on the TPU and hospital level, a scenario analysis simulating the post-cluster boundary refinement between KCC and KWC[13] could easily be achieved through revising the groupings of TPUs and institutions into KCC, as shown in Table 7.

[13] In response to the HA Review, a re-delineation of administrative arrangements' between KWC and KCC was implemented, which included the re-grouping of Wong Tai Sin district and Mong Kok area, involving Kwong Wah Hospital, TWGHs Wong Tai Sin Hospital and Our Lady of Maryknoll Hospital from KWC to KCC. Such implementation further enhanced the integration of services as well reducing cross-cluster consultations and strengthening the continuity of care for patients. Changes related to Cluster identity, transfer of functions as well as transfer of accountability were made on 1 December 2016, while cut-over from KWC to KCC with regard to non-clinical services (e.g. human resources, business support services, etc.) took place on 1 April 2017.

TPUs to be Grouped under KCC under Re-clustered Scenario
• 220, 221, 222, 227, 228, 229, 253, and 254 (Mongkok area) • 281, 282, 283, 284, 287, and 288 & 289 (Wong Tai Sin district)
Institutions to be Grouped under KCC under Re-clustered Scenario
• Kwong Wah Hospital (KWH) • TWGHs Wong Tai Sin Hospital • Our Lady of Maryknoll Hospital (OLM) • OLM: East Kowloon General Outpatient Clinic • KWH: Li Po Chun Health Centre General Outpatient Clinic • OLM: Robert Black Health Centre General Outpatient Clinic • OLM: Wang Tau Hom Jockey Club General Outpatient Clinic • OLM: Wu York Yu Health Centre General Outpatient Clinic

Table 7 – Re-grouping of TPU and institutions for re-clustered scenario

V. Proposed Model Application

(A) Guiding Principles for Model Application

In the application of the Refined Population-based Model, it is essential to examine how the objective of a population-based resource allocation is able to drive or enhance equity and efficiency (both in terms of allocative efficiency and technical efficiency). The very dominant effect of supply on utilisation needs to be addressed as well as the understanding of cross-cluster flow of patients arising from patients' health seeking behaviour.

(B) Conceptual Framework for Model Application

It is crucial to discuss how the model is applied to inform resource management in the context of prospective planning of facilities and services to enable the public equitable access to a comprehensive range and optimal mix of healthcare services and continuity of care in each Cluster. A conceptual framework linking the three key dimensions i.e. population healthcare needs, service planning and resource planning for model application is depicted in Figure 11. The framework shows the importance of relating resource allocation in the context of resource management, service planning, provision and utilisation based on the population healthcare needs to achieve resource efficiency and service effectiveness. The Refined Population-based Model provides the leverage for this framework that links "resource allocation, utilisation and management" and "services provision, utilisation and management" with "population health needs". Cluster population health needs will inform the resources needed to provide the healthcare services required. The determination of the optimal input-mix of resources will be an important determinant of "technical efficiency", whereas the appropriate output-mix of service that need to be provided will be a critical consideration for "allocative efficiency". Therefore, there is a need to study what input-mix is desirable and the types and output-mix of services appropriate to meet the health needs of the catchment population, identify the gaps and shortfalls in provision and feedback to inform resource facility and service planning. The determination of the optimal input-mix of resources and the appropriate output-mix of services would enable the next level of resource allocation from the Clusters to the hospitals which is necessary to enable equitable access to a comprehensive range of healthcare services.

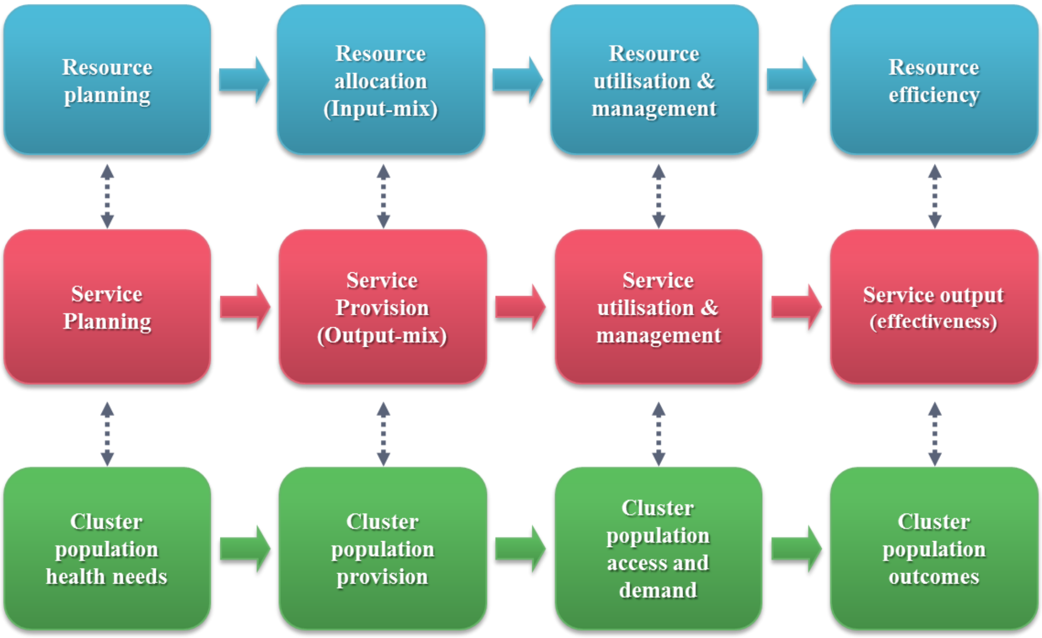


Figure 11 – Conceptual framework for model application

(C) Proposed Tools for Application

Per Recommendation 3 of the HA Review, the Refined Population-based Model needs to be implemented through HA's prevailing service and budget allocation process while avoiding unintentional and undesirable impact on the existing baseline services of individual Clusters. As such, the model cannot be directly applied as a funding formula but rather as a collection of analytical tools so as to make available business intelligence to inform HA's planning process – both to drive towards equity and to provide time trend analysis to demonstrate improvement over time, while avoid making abrupt disruptions to the existing system. This in turn will provide HA with a direction in making continuous and sustainable improvements on service planning and resource management under the population-based approach.

The Refined Population-based Model would provide analytical tools to generate business intelligence on Cluster resource against utilisation, as well as Clusters' ability in accommodating demand growth projected by the model, from both the hospital and TPU perspective. Specifically, four analytical tools are proposed, with a summary presented in Table 8 below and discussed sequentially in the next sub-sections. Numerical illustrations conducted by HA under the supervision of the CUHK consultancy team are set out in Chapter VIII in Part B of this report.

Tools	Description on application	Objectives
Tool 1	Did Cluster spend similar resources for similar core service utilisation?	Identify Clusters which need to catch up and explore catch up measures
Tool 2	Were there variances in the mix and configuration of services among different Clusters?	Identify optimal mix and configuration of service type to improve efficiency and enable Clusters to better use resources
Tool 3	Do Clusters have similar ability (regarding capacity elasticity) to accommodate demand growth as projected by the Refined Model?	Identify Clusters' need for building up capacity and inform short-term measures to accommodate expected growth in utilisation (through Annual Plans)
Tool 4	How can healthcare facility plans be aligned with population developments in the long term?	Identify Clusters' need for building up capacity to meeting population healthcare needs by TPU-based analysis and inform intermediate-term measures (through 5-year Strategic Plans)

Table 8 – Analytical tools under the Refined Population-based Model

Tool 1: Cluster Resource Analysis – Parity of Resources vs. Utilisation

The objective of Cluster resource analysis is to assess whether similar service utilisation of Clusters are supported by similar resources. After carving out the resource and activity of DS and making other adjustments to facilitate like-with-like comparison, Clusters' operating expenditure on core services can be compared against the inferred operating expenditure calculated by multiplying Cluster's core activities with HA average cost of each core service. This will help in identifying which Clusters' resources are below HA average with respect to their service output and provide insights as to which Clusters' would need to catch up.

Tool 2: Mix and Configuration of Services

As depicted in the conceptual framework for model application, there is a need to study the types and mix of services required to meet the health needs of the population. The study results would have implications for identifying the gaps and shortfalls in healthcare provision and informing facility and service planning. As a start, the utilisation among various core services should be compared, which would provide a current-state understanding on the various mix and configuration of service type among Clusters, so that better use of resources would be enabled among Clusters for improved efficiency.

Tool 3: Capacity Utilisation Analysis

While Tool 1 would analyse whether Clusters had been receiving similar resources for similar activity, another valuable tool would be to measure Clusters' capacity loading with respect to their ability to accommodate growth in demand. Capacity utilisation analysis (service utilisation divided by capacity) reflects the elasticity of Cluster capacity in accommodating further growth in utilisation as projected by the Refined Population-based Model in coming years, where Clusters with more constrained capacity (less elastic) would have a greater need for expansion. This piece of information is particularly useful in short-term facility and service planning.

To understand whether Clusters would face similar capacity utilisation pressure, a measure of capacity elasticity to accommodate growth in local healthcare needs i.e. parity regarding capacity vs. utilisation would be needed. For this purpose, the ratios of utilisation and capacity for each core service could be compared longitudinally and among Clusters (and to the HA average), so as to identify Clusters' need for building up capacity and inform short-term measures to accommodate expected growth in utilisation.

While the evaluation of relative elasticity through capacity utilisation is useful, one has to be mindful if the potential perverse incentive in focusing solely on one measure of capacity (e.g. number of acute beds for Acute IP). It is therefore recommended that additional metrics (e.g. length of stay, relative stay index, length of stay of linked episode, etc.) be supplemented when analysing capacity utilisation.

Utilisation is projected by the Refined Population-based Model taking into account the existing supply of each Cluster (this is called the hospital-based approach). This reflects the population's health seeking behaviour under the existing system constraint as well as the prevailing health-seeking behaviour of patients, and should not be used on its own to inform year-to-year annual planning. The analysis cannot evaluate whether the existing capacity in individual Clusters aligns with the needs of the local population, and must be used in conjunction with Tool 4, which is discussed below.

Tool 4: Hospital Utilisation vs. Local Population Needs

Tool 3 on "capacity utilisation" can be used to identify Clusters' need for building up capacity and inform short-term measures to accommodate expected growth in utilisation, and should be used in conjunction with Tool 4 for both short and intermediate term to identify Clusters' legitimate need for resources. For longer-term facility planning in HA, health service needs of the local population by TPU would need to be modelled by assuming there is no variance in the supply constraints among Clusters, so as to identify Clusters' legitimate need for building capacity to meeting population healthcare needs.

Hence, a TPU-based model was developed in addition to the original hospital-based model described above to model the healthcare need of the catchment areas of Clusters at the TPU level. The main difference between this TPU-based model and the hospital-based Model is the exclusion of the "distance" and "capacity" variables (Figure 12) in the model formulation.

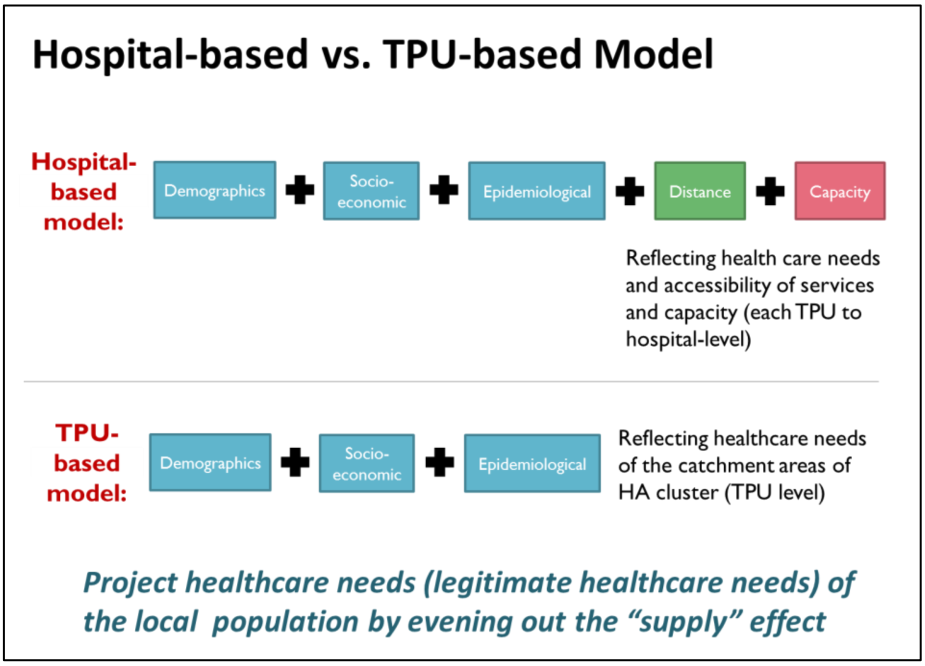


Figure 12 – Hospital-based model vs. TPU-based model

The r and MAPE statistics for model fitness for both model building and validation are respectively presented in Table 9. The list of two-level GLMM coefficients of fixed effects for TPU-based models is also presented below. The TPU-based models for all services are well-fitted with a high correlation and low value of MAPE. The validation performance of the models is satisfactory except the one for non-acute services having a marginal MAPE (22.3%).

	Two-level GLMM			
	Model building		Validation	
Services	*r*	MAPE	*r*	MAPE
Acute IP	>0.99	0.15%	>0.99	11.2%
Non-acute IP	>0.99	0.44%	>0.99	22.3%
SOP	>0.99	<0.10%	>0.99	6.8%
PHC	>0.99	<0.10%	>0.99	10.0%
A&E	>0.99	0.24%	0.97	10.9%
AHOP	>0.99	0.16%	>0.99	13.4%

Table 9 – r and MAPE for TPU-based models (model building)

Two-level GLMM Coefficients of Fixed Effects for TPU-based Models

Outcome measure:

y_{ij} = service utilisation at j^{th} hospital for patients residing in i^{th} TPU

1) Acute IP

TPU level:

$g(y_{ij}) = \beta_{0,ij}$ – 0.026 [Age<20] + 0.022 [Age >=65]
– 0.051 [% male] + 0.694 [% non-married]
– 0.037 [% non-Chinese] – 1.082 [Median income]
+ 0.018 [% unemployment] + 0.030 [% post-secondary education]
– 0.002 [% singleton] + 0.004 [% public rental housing]
– 0.007 [share residential unit] + 0.047 [SMR]
+ 0.100 [% chronic diseases] + 0.052 [% live in RCHE]
0 [weighted distance] + 0.011 [year]
+ log(population$_i$) + ε

Hospital level:

$\beta_{0,ij}$ = intercept + $u_{0,j}$ + 0 [number of acute beds]

2) Non-acute IP

TPU level:

$g(y_{ij}) = \beta_{0,ij}$ – 0.029 [Age<20] + 0.043 [Age >=65]
– 0.060 [% male] + 0.692 [% non-married]
– 0.046 [% non-Chinese] – 0.737 [Median income]
+ 0.059 [% unemployment] + 0.016 [% post-secondary education]
+ 0.007 [% singleton] + 0.007 [% public rental housing]
+ 0.001 [share residential unit] + 0.133 [SMR]
+ 0.111 [% chronic diseases] + 0.089 [% live in RCHE]
0 [weighted distance] – 0.029 [year]
+ log(population$_i$) + ε

Hospital level:

$\beta_{0,ij}$ = intercept + $u_{0,j}$ + 0 [number of non-acute beds]

3) SOP

TPU level:

$g(y_{ij}) = \beta_{0,ij}$ – 0.027 [Age<20] + 0.018 [Age >=65]
– 0.063 [% male] + 0.908 [% non-married]
– 0.162 [% non-Chinese] – 1.142 [Median income]
+ 0.007 [% unemployment] + 0.042 [% post-secondary education]
+ 0.001 [% singleton] + 0.009 [% public rental housing]
– 0.008 [share residential unit] + 0.122 [SMR]
+ 0.065 [% chronic diseases] + 0.008 [% live in RCHE]
0 [weighted distance] – 0.0001 [year]
+ log(population$_i$) + ε

Hospital level:

$\beta_{0,ij}$ = intercept + $u_{0,j}$ + 0 [Doctor FTE]

4) PHC

TPU level:

$g(y_{ij}) = \beta_{0,ij}$ – 0.029[Age<20] + 0.008 [Age >=65]
– 0.048 [% male] + 0.887 [% non-married]
+ 0.078 [% non-Chinese] – 1.407 [Median income]
+ 0.021 [% unemployment] + 0.026 [% post-secondary education]
– 0.015 [% singleton] + 0.012 [% public rental housing]
– 0.008 [share residential unit] + 0.101 [SMR]
+ 0.061 [% chronic diseases] + 0.001 [% live in RCHE]
0 [weighted distance] + 0.030 [year]
+ log(population$_i$) + ε

Hospital level:

$\beta_{0,ij}$ = intercept + $u_{0,j}$ + 0 [FM Doctor FTE]

5) A&E

TPU level:

$g(y_{ij}) = \beta_{0,ij}$ – 0.032 [Age<20] + 0.007 [Age >=65]
– 0.034 [% male] + 0.407 [% non-married]
– 0.106 [% non-Chinese] – 0.801 [Median income]
– 0.023 [% unemployment] + 0.022 [% post-secondary education]
– 0.005 [% singleton] + 0.007 [% public rental housing]
– 0.006 [share residential unit] + 0.048 [SMR]
+ 0.074 [% chronic diseases] + 0.030 [% live in RCHE]
0 [weighted distance] – 0.017 [year]
+ log(population$_i$) + ε

Hospital level:

$\beta_{0,ij}$ = intercept + $u_{0,j}$ + 0 [A&E Doctor FTE]

6) AHOP

TPU level:

$g(y_{ij}) = \beta_{0,ij}$ – 0.016 [Age<20] – 0.001 [Age >=65]
– 0.061 [% male] + 0.785 [% non-married]
– 0.185 [% non-Chinese] – 1.029 [Median income]
– 0.004 [% unemployment] + 0.044 [% post-secondary education]
+ 0.017 [% singleton] + 0.010 [% public rental housing]
– 0.006 [share residential unit] + 0.150 [SMR]
+ 0.071 [% chronic diseases] + 0.002 [% live in RCHE]
0 [weighted distance] + 0.034 [year]
+ log(population$_i$) + ε

Hospital level:

$\beta_{0,ij}$ = intercept + $u_{0,j}$ + 0 [AH Prof. FTE]

While the hospital-based model reflects healthcare needs and accessibility of services and capacity (at each TPU to hospital-level), the TPU-based model estimates the normative local healthcare needs of the population, irrespective of where they sought care (i.e. within Cluster or cross-cluster). The difference between the Cluster utilisation based on the hospital-based model and the estimated need of a Cluster's catchment population calculated by the TPU-based model would reflect a net inflow (if the hospital-based figure is larger than the TPU-based one) or net outflow (if the hospital-based figure is smaller than the TPU-based one) of utilisation. The TPU-based model addresses the historical legacy of inequity in the supply and provision of healthcare services and is the critical tool in the application of the Refined Population-based Model.

VI. Limitation

While the model was rigorously constructed based on sound scientific principles and methodologies, a model is an abstraction of reality and application should be considered in view of its inherent limitations. These limitations also make it necessary for the model to undergo periodic refinement in the future.

(A) Limitation on Data Availability and Accuracy

Costing of DS and Other Adjustments

A critical part in the development of the Refined Population-based Model is the costing of DS and other adjustments. As such, the results of the analysis under the Refined Population-based Model would need to be viewed in context of the limitation on the comprehensiveness and accuracy in identifying and costing of DS and other adjustments. Potential limitations of the costing methodology include:

- Bottom-up costing was adopted to cost selected DS (e.g. transplants, AIDS), which is based on the activities and their associated costs identified throughout the care pathway, leading to the difficulty in reconciling the calculated DS costs with the departmental cost. In addition, while bottom-up costing is generally regarded as more comprehensive and accurate, it should be noted that the costs of some component are derived based on unit costs calculated as an average cost per unit of output, which may over or underestimate the real cost of resource consumption.

- In view of the complexity and time constraint of the costing exercise, costing of certain DS for 2012/13, 2013/14 and 2015/16 were performed under a broad brush approach (e.g. uplifting 2014/15 costing result by APA composite rate for designated team and relevant growth rates for other costs to derive 2015/16 estimated cost). The accuracy of costing results depends on the validity of key assumptions made, such as no significant change in DS service scope, mode of service delivery, designated team and cost profile of services in the years concerned.

Please refer to the report "Costing Report of Designated Services: Year 2012/13 to 2015/16" for a detailed discussion on the limitations on costing DS.

Limited Availability of Clinical and Epidemiological Data

In developing the Refined Population-based Model, 38 potential factors were identified through literature review, and 16 of them were shortlisted based on their relevance in the local context and whether data is available for further quantitative assessment. It should be noted that there may be important factors, especially in the clinical and epidemiological aspects, that could not be incorporated in the model due to lack of quality data. For example, unlike some overseas jurisdictions which have comprehensive person-level morbidity database, such a database does not exist in Hong Kong. Nevertheless, it is reasonable to expect that data availability would be more complete in the future. In addition, as all statistical models, the model's predictive value will improve over time as more and better data become available.

Census Data Not Updated Annually

In addition, there is an inherent assumption that all data used for model development and application is accurate. However, this might not necessarily be the case. One prime example is how socioeconomic information could be incorporated in the model. Unlike population figures which C&SD would publish official projections, locality-specific socioeconomic data is only available for census years and thus any time-trend analysis conducted for the future will be conducted assuming no substantial change in the socioeconomic status of each community in Hong Kong. While this assumption may not be unreasonable, this example highlights the limitations of the model and how caution needs to be exercised when interpreting its results.

Time Lag of Data

It should be noted that the utilisation and costing data employed in this modelling exercise has up to two to three years of lag time with respect to the forthcoming annual planning cycle. For instance, for this first set of analysis informing the 2018/19 annual planning exercise, 2015/16 utilisation and costing data was the most recent information available for modelling.

(B) Limitation on Modelling

Complexity in Understanding Healthcare Needs

Population's healthcare needs are influenced by many factors, and the proposed model framework strives to address the complex interplay between population demographics, socioeconomic, and supply factors in shaping healthcare utilisation of individual Clusters.

This complexity alerts us of the uncertainty involved in predicting healthcare utilisation of individual Clusters as not all relevant factors can be studied or readily modifiable. In addition, although some of these factors could be incorporated into the model, their values (e.g. the socioeconomic status of a specific TPU) would evolve over time and thus the model will need to be updated at regular intervals to capture these changes.

Inherent Margin of Error of Statistical Model

As in modelling exercise, the results would need to be viewed in the context of the margin of error of the underlying model. As a result, it would not be possible, or appropriate, to aim at deriving a budget formula for internal resource allocation. Instead, the model will serve as one of the key references for service and facility planning in HA.

Model Covering Six Core Services Only

As mentioned, the Refined Population-based Model was developed for six core hospital services, with Day Hospital and Community Care not included due to the heterogeneity of service delivery model among Clusters as well as the lack of comprehensive electronic data for modelling. With the growing importance in chronic disease management, it will be important to include these two services in the model in the future, when service standardisation and alignment has been achieved and relevant structured data is available.

VII. Recommendations for Application and Future Developments

(A) Critical Factors in Application

The Refined Population-based Model incorporates factors influencing population healthcare needs (demographic, socioeconomic, epidemiological), accessibility (distance), capacity (supply), and addresses DS and cross-cluster movement of patients. It projects healthcare needs of localities (by TPU), instead of relying on crude inference from District Council Election Constituency Boundaries. Furthermore, the analysis of population healthcare needs (legitimate healthcare needs) by evening out (disregarding) "supply" effect enhances equity and efficiency and addresses the historical legacy of inequitable provision between Clusters. Not only will it inform resources and service planning, the model can also provide the leverage in a framework that links "resource allocation, utilisation and management" and "services provision, utilisation and management" with "population health needs" which will drive equity and efficiency in healthcare provision.

With the adjustment mechanisms of (1) population healthcare needs, (2) supply effect, and (3) cross-cluster effect, the model can be applied to inform short-term, intermediate-term and long-term services and resources planning (Figure 13). For example, in short term, Tool 3 on "capacity utilisation" can be used to identify Clusters' need for building up capacity and inform short-term measures to accommodate expected growth in utilisation, and should be used in conjunction with Tool 4 for both short and intermediate term to identify Clusters' legitimate need for resources and to build up capacity to meeting population healthcare needs by TPU-based analysis. As supply affects utilisation, when supply is increased in the underprovided Clusters in the intermediate and long term, the health-seeking behaviours of the Cluster populations will be affected and the cross-cluster flow will change. Models to study the effect on cross-cluster flow should be developed and further studied.

	Short and Intermediate term	Long term
Adjustment mechanisms	Capacity utilisation *(Tool 3)* TPU health needs *(Tool 4)* Service plan	TPU health need *(Tool 4)* Facilities and service plan
Supply effect	↓	↓ ↓
Cross cluster effect	⇣	⇣ ⇣

Figure 13 – Model application for service and resource planning

It has to be noted that the Refined Population-based Model alone is necessary but not sufficient to direct resources to where they are most needed. Population-based resource allocation needs to be an integral part of a holistic approach of strategic service and resource planning, provision, and management. The model would generate business intelligence and facilitate better understanding of healthcare needs and the most efficient mix of resource input to generate the optimal output-mix of healthcare services needed by the population. It is therefore crucial to examine how this can be applied in resource and service planning, provision, and management to enable equitable access to a comprehensive range of healthcare services for the local populations.

To supplement the Refined Population-based Model, more detailed study should be conducted to provide insights to identify issues relating to the mix or configuration of service types. Future Cluster resource analysis could be reviewed together with performance indicators to provide insight on the mix and configuration of service types. Specifically, there are several recommended next step for consideration as follows:

(B) Recommendations for Application

1. Application of Tool 3 on “capacity utilisation” for resource allocation needs to be applied concurrently with Tool 4 on “TPU needs-based population projection model” by evening out (disregarding) the “supply” effect to enhance equity and efficiency

2. Appropriateness of utilisation needs to be further examined to provide incentives for efficiency and prevent perverse incentives to inflate utilisation in applying Tool 3 on “capacity utilisation”

3. Future Cluster resource analysis needs to delve deeper to identify the optimal input-mix of resources and appropriate output-mix and configuration of service types (Tool 2) which can be applied to resource allocation from Clusters to hospitals and clinics to enable equitable access to healthcare services. Appropriate performance and monitoring measures need to be applied as well

4. Develop analytical tools for Clusters to assess efficiency in utilisation of resources and provision of services

5. Develop a model to study the pattern of cross-cluster flow and how this may be affected when supply and other variables are changed

(C) Recommendations for Future Development of the Model

1. Periodic recalibration of the model to assure the impacts of various factors remain update

2. Further refinement of the model with better data particularly for the effect of chronic diseases

3. Model should be updated regularly to assess impact of supply (first review in three years)

PART B: ANALYSIS UNDER THE REFINED POPULATION-BASED MODEL (HA)

VIII. Illustration of Analysis under the Refined Model

As recommended by CUHK consultancy team, the Refined Population-based Model would provide analytical tools to generate business intelligence on Cluster resource against utilisation, as well as Clusters' ability in accommodating demand growth projected by the model, from both the hospital and TPU perspectives. Noting the above and under the supervision of CUHK consultancy team, HA conducted the following set of analyses under the Refined Population-based Model. The four tools are recapped for ease of reference below:

Tools	Description on application	Objectives
Tool 1	Did Cluster spend similar resources for similar core service utilisation?	Identify Clusters which need to catch up and explore catch up measures
Tool 2	Were there variances in the mix and configuration of services among different Clusters?	Identify optimal mix and configuration of service type to improve efficiency and enable Clusters to better use resources
Tool 3	Do Clusters have similar ability (regarding capacity elasticity) to accommodate demand growth as projected by the Refined Model?	Identify Clusters' need for building up capacity and inform short-term measures to accommodate expected growth in utilisation (through Annual Plans)
Tool 4	How can healthcare facility plans be aligned with population developments in the long term?	Identify Clusters' need for building up capacity to meeting population healthcare needs by TPU-based analysis and inform intermediate-term measures (through 5-year Strategic Plans)

Table 10 – Recap of analytical tools under the Refined Population-based Model

(A) Illustration of Tool 1: Cluster Resource Analysis

The objective of Cluster resource analysis is to assess whether similar service utilisation of Clusters is supported by similar resources. After carving out the DS and making other adjustments to facilitate like-with-like comparison, Clusters' operating expenditure on core services can be compared against the inferred operating expenditure calculated by multiplying Cluster's core activities with HA average cost of each core service. This will help identifying which Clusters' resources are below HA average and need to catch up.

Result of such analysis using 2015/16 data is shown in Figure 14 below. It revealed inter-cluster variance to be within 0.5%, reflecting the fact that under the existing service planning and budgeting mechanism, Cluster expenditure generally corresponded to their respective scales of service provided.

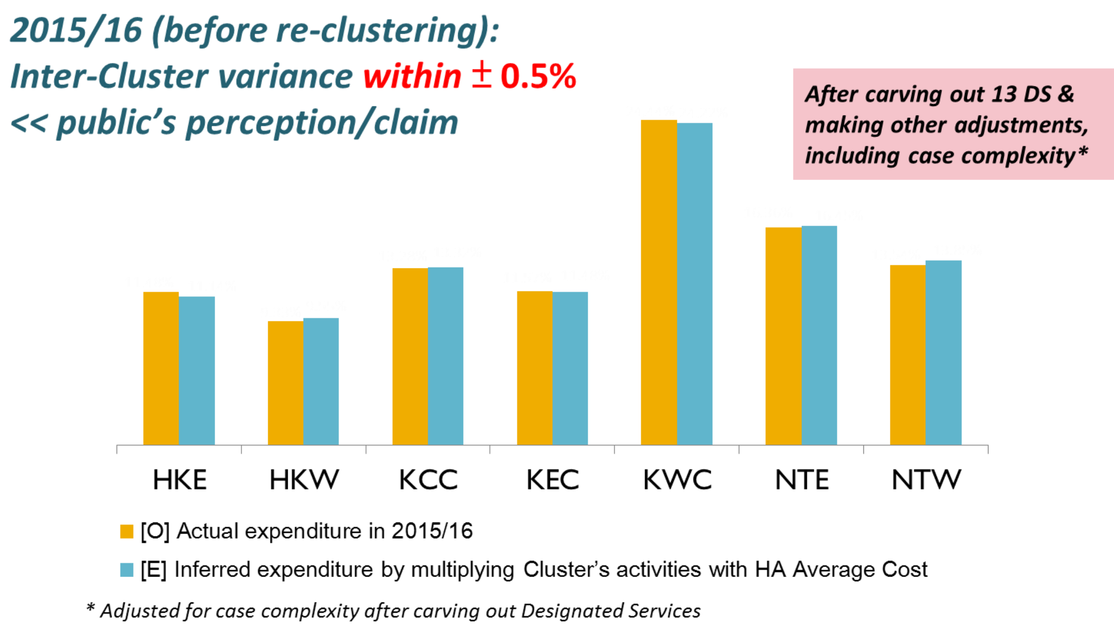


Figure 14 – Actual vs. inferred expenditure in 2015/16 of each Cluster

In order to analyse whether Clusters received resources that correspond to respective levels of service utilisation over the years, a time trend analysis was performed for years 2012/13 to 2015/16. As illustrated in Figure 15 below (with each data point representing one Cluster), the analysis shows that inter-cluster variance remains within ±0.5% throughout. Please refer to Glossary Part G for the detailed methodology and results of the Cluster resource analysis. It has to be noted that with the margin of error arising from HA's costing methodology, an absolute inference cannot be made with such a marginal difference in the derived inter-cluster variances (i.e., the variances among Clusters is insignificant when the margin of error is taken into account).

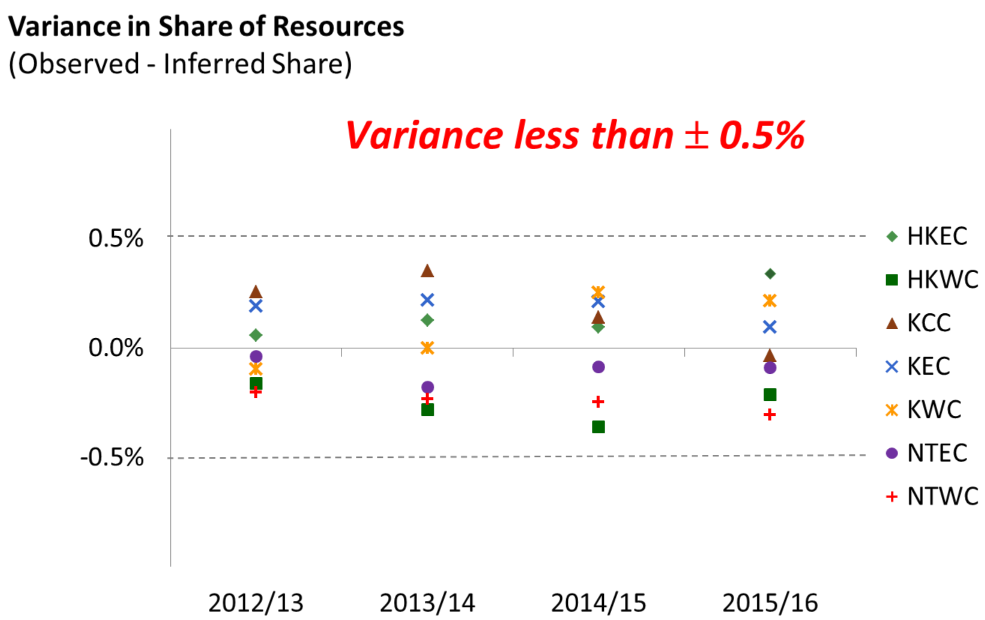


Figure 15 – Time-trend Cluster resource analysis

While this tool analyses whether Clusters had been receiving similar resources for similar activity, the scope of core services available in each Cluster is not taken in account. For example, the fact that Oncology service is not available in KEC at the moment (although planning of the service in KEC is already in the pipeline) and thus residents in the KEC catchment would need to patronize other Clusters for the service would not be reflected in this analysis. The scope of core services available, and the extent which populations can access core services in their localities, would be addressed in Tool 4 below.

(B) Illustration of Tool 2: Mix and Configuration of Services

As recommended by CUHK consultancy team, this tool aims to provide reference information on the various mix and configuration of service type among Clusters, so that better use of resources would be enabled among Clusters for improved efficiency.

While any pairwise comparison could be conducted between any two core services, Figure 16 – Figure 18 show the relationship between Acute and non-acute IP, Acute IP and SOP, and Acute IP and A&E respectively over the five-year study period between 2011/12 and 2015/16 as illustrations. Their relationship is illustrated by the ratio of utilisation (i.e. BDO or attendances) between two services.

One can observe that there was varied distribution of Acute IP and Non-acute IP between Clusters (Figure 16). As compared with other Clusters, HKEC had a relatively higher proportion of BDO in Non-acute IP, relative to that in Acute IP. One of the reasons could be the higher usage of rehabilitative services in HKEC. Similarly, Figure 17 illustrates the varied distribution between Acute IP and A&E among Clusters. Namely, HKWC had a relatively fewer attendances for A&E services relative to its BDO from Acute IP services, probably due to the existence of more elective cases in QMH. On the other hand, the distribution of Acute IP and SOP was similar across Clusters (Figure 18). It implies that SOP service is a continuum of Acute IP services, sharing the same group of patients.

The varied configuration of services among Clusters calls for further explanatory studies to understand the issues relating the mix and configuration of service types to efficiency. Relevant indicators are also needed to encourage better use resources among Clusters.

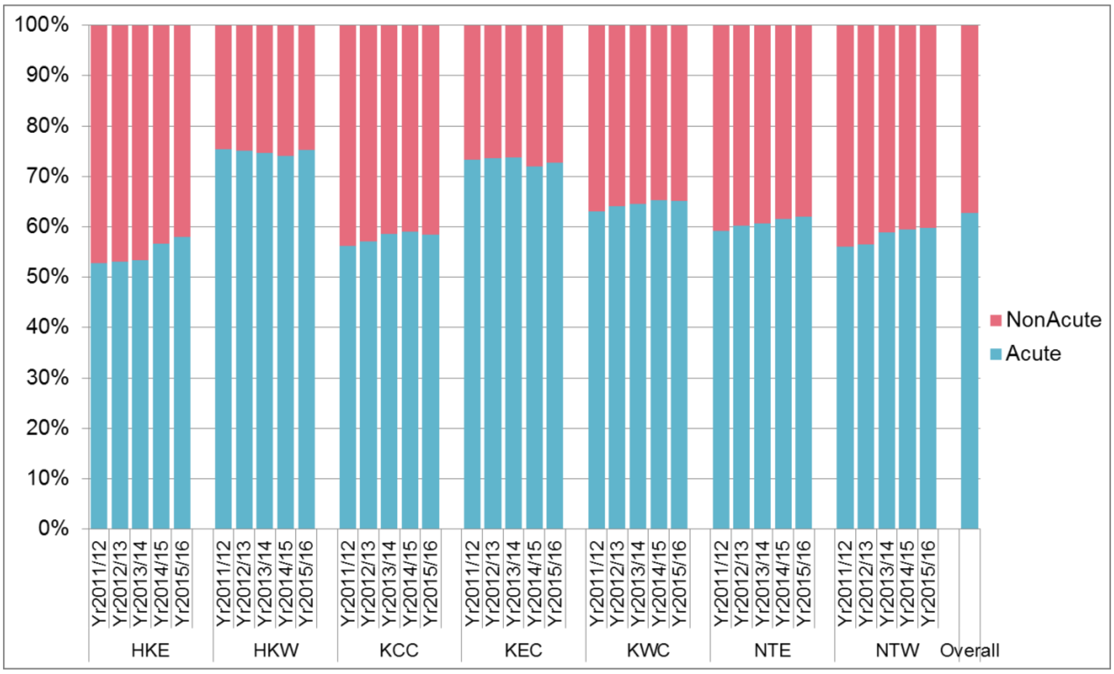


Figure 16 – Relationship between Acute and Non-acute IP services

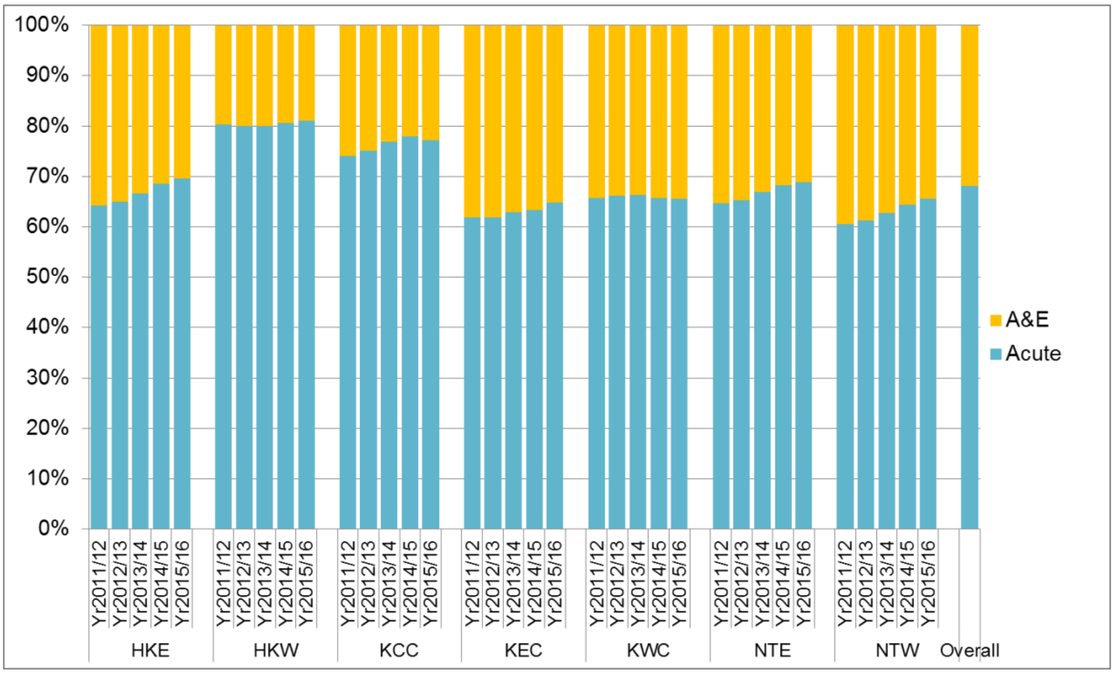


Figure 17 – Relationship between Acute IP and A&E

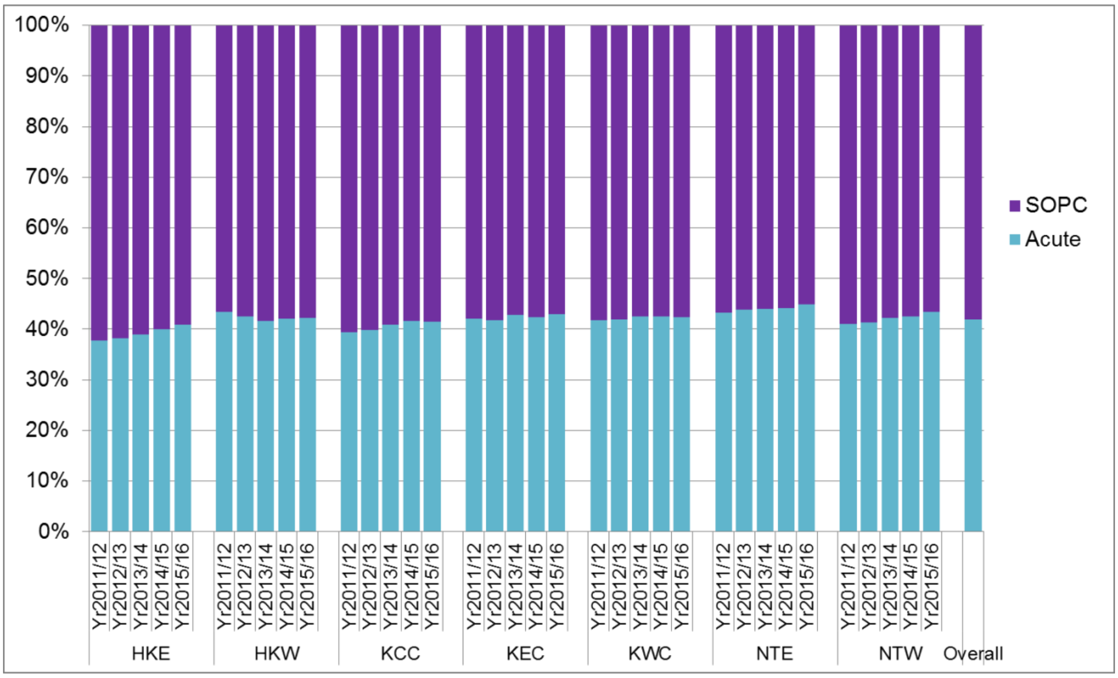


Figure 18 – Relationship between Acute IP and SOP

(C) Illustration of Tool 3: Capacity Utilisation Analysis

While Tool 1 has demonstrated that Clusters had been receiving similar resources for similar activity, Clusters' ability to accommodate demand growth may differ. This tool aims at measuring Clusters' capacity loading with respect to their ability to accommodate growth in demand.

To understand whether Clusters face similar capacity utilisation pressure, a measure of capacity elasticity to accommodate growth in local healthcare needs i.e. parity regarding capacity vs. utilisation would need to be developed. For this purpose, a ratio named "capacity utilisation" was calculated by dividing the utilisation figures by each unit of capacity among the seven Clusters. For example, regarding Acute IP, capacity utilisation is measured as the ratio of the number of BDO and the number of scheduled acute bed. This can be used a proxy of a Cluster's elasticity, or ability in accommodating additional demand, which could be analysed and compared among Clusters from multiple angles and time points. A larger value of capacity utilisation reflects a relatively lower ability to accommodate additional demand, which in turn may signal a need for additional support in short term.

Core Services	Utilisation Measure	Capacity Measure
Acute IP	BDO	Scheduled acute bed
Non-acute IP	BDO	Scheduled non-acute bed
SOP	Attendance	Doctor FTE
PHC	Attendance	FM Doctor FTE
A&E	Attendance	A&E Doctor FTE
AHOP	Attendance	AH Professional FTE

Table 11 – Utilisation and capacity measures for each core service

A detailed discussion on the selection of proxy as the capacity measure for each of the core services can be found in Glossary Part H.

To assess the relative capacity elasticity of each Cluster in a given time point, each Cluster's "capacity utilisation" can be compared or ranked with HA average (i.e. a cross-sectional analysis). The "capacity utilisation" can also be monitored over time to assess the change in elasticity over time for each Cluster (i.e. a longitudinal analysis).

Figure 19 shows an illustration of capacity utilisation for Acute IP services and other five services for year 2015/16 (actual) and 2016/17 – 2018/19 (projected data). As Cluster boundary refinement was implemented on 1 April 2017, the entire time-trend analysis was conducted simulating the re-clustered situation (even for 2015/16 and 2016/17) so that a like-with-like longitudinal analysis could be conducted.

Using Acute IP as an example (Figure 19), the capacity utilisation of various Clusters were projected to slightly increase from 2015/16 to 2017/18, with the relative positions of each Cluster being consistent over the years (i.e. NTWC, KCC, NTEC, KWC above HA average and KEC, HKEC and HKWC below). For 2018/19, the capacity utilisation was computed using capacity at the previous year's level (and also assuming the prevailing mode of operation). This represents the change in capacity utilisation due to population effect alone and the results would be a piece of useful reference information for the 2018/19 annual planning exercise.

While the evaluation of relative elasticity through capacity utilisation is useful, one has to be mindful if the potential perverse incentive in focusing solely on one measure of capacity (e.g. number of acute beds for Acute IP). It is therefore recommended that additional metrics (e.g. length of stay, relative stay index, length of stay of linked episode, etc.) be supplemented when analysing capacity utilisation.

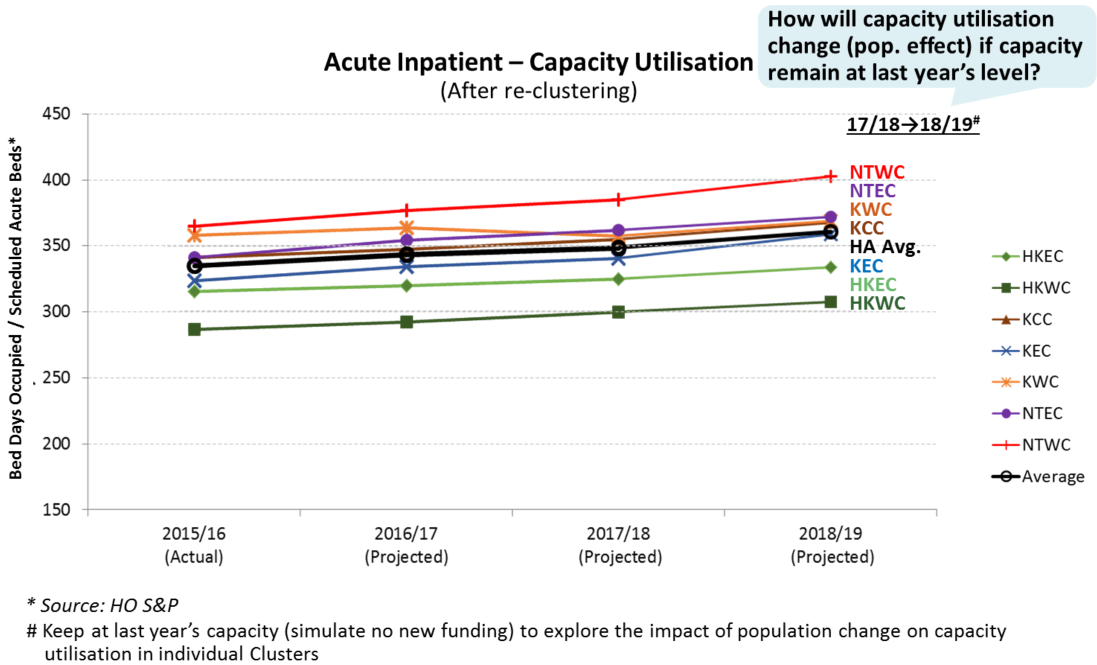


Figure 19 – Projected capacity utilisation for Acute IP

Similar analysis as the above was conducted for the other five core services as well. The results are presented in Annex C.

A summary of the results of the capacity utilisation analysis for 2018/19 is presented below in Table 12 to illustrate the relative capacity utilisation for each of the six core services. Relativity among the Clusters in terms of their ability to accommodate additional demand growth is shown, with a smaller number translating to a higher capacity utilisation. It has to be noted that while the capacity loading of HKWC seems to be lower when compared to the HA average, the service development focus of this Cluster would be on the provision of Designated Services, where on top of population size other factors like organ availability in transplantation services would play a key role their growth.

Cluster	Acute IP	Non-Acute IP	SOP	PHC	A&E	AHOP
HKEC	6	1	2	5	6	5
HKWC	7	7	7	7	7	7
KCC	4	2	4	6	3	1
KEC	5	6	3	1	2	2
KWC	3	5	1	4	5	6
NTEC	2	3	6	3	1	4
NTWC	1	4	5	2	4	3

Table 12 – Relativity of projected capacity utilisation in 2018/19 by service

The capacity utilisation (i.e. loading) by major care types calculated in this analysis provides an indication of the relative need for Clusters to enhance capacity, as it reflects the relative ability of individual Clusters in accommodating the current pattern of healthcare utilisation by the population taking into account its growth and cross-cluster patient movements.

Tool 3 can inform the identification of Clusters' need for building up capacity and inform short-term measures to accommodate expected growth in utilisation. However, since the utilisation projected would be based on population's health seeking behaviour under the existing system constraint, this analysis cannot evaluate whether the existing capacity in individual Clusters aligns with the needs of the local population. Such alignment between locality needs and capacity in Clusters will be studied using Tool 4 below.

(D) Illustration of Tool 4: Hospital Utilisation vs. Local Population Needs

Health service needs of the local population by TPU could be modelled so as to identify Clusters' legitimate need for building capacity to meeting population healthcare needs. As such, CUHK consultancy team has also built a TPU-based model to evaluate the healthcare need of the catchment areas of Clusters at the TPU level. Details of the TPU-based model can be found in Chapter V above.

While the hospital-based model reflects healthcare needs and accessibility of services and capacity (at each TPU to hospital-level), the TPU-based model estimates the actual healthcare needs of the population, irrespective of where they sought care (i.e. within Cluster or cross-cluster). The difference between the Cluster utilisation based on the hospital-based model and the estimated need of a Cluster's catchment population calculated by the TPU-based model would reflect an inflow (if the hospital-based figure is larger than the TPU-based one) or outflow (if the hospital-based figure is smaller than the TPU-based one) of utilisation.

In an attempt to analyse the mismatch between hospital utilisation and local population need, Figure 20 illustrates the share of projected expenditure (estimated using projected utilisation of each of the six core services and their respective HA average unit cost) by two perspectives: (i) based on utilisation in hospitals in 2017/18 (in orange) and (ii) based on utilisation by local population in 2017/18 and 2020/21 (in light and dark green respectively). Figures under the orange bars were derived from the hospital-based models while figures under the green bars were calculated using the aforementioned TPU-based model, assuming there is no inter-cluster variance in supply constraints. The individual analysis conducted for each of the six core services could be found in Annex C.

Comparing the figures from the two models would generate intelligence on which Cluster is projected to have a net inflow (orange > green) or outflow (green > orange). For example, KCC is projected to have a net inflow of patients, which intuitively links to its central location in Hong Kong together with patient convenience/choice. On the other hand, one of the Clusters projected to have a net outflow is KEC, which may at least partly be explained by capacity and accessibility issues (e.g. KEC not have oncology services so residents need to travel to other Clusters, namely KCC, for the service). However, population is not restricted to Clusters as the public healthcare system is not registration-based. The level of cross-cluster movement of patients depends on a lot of factors including daytime mobility, ease of transportation, patients' preferences, etc. Due to the geographical proximity among the Clusters in Kowloon, the health-seeking behaviour of their residents is fluid and thus absolute inference on their inflow/outflow is difficult to be made.

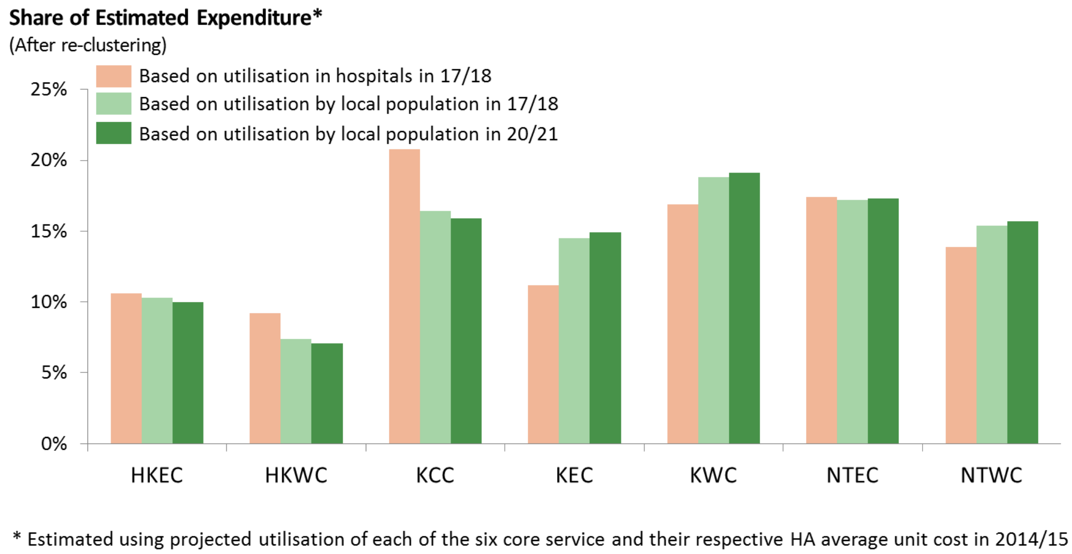


Figure 20 – Projected share based on utilisation in hospitals vs. local population

Such comparison between the share of estimated expenditure based on utilisation in hospitals and local population provides insights to how HA should develop facility plans to dovetail with population and city developments in Hong Kong. Scalability of Clusters' infrastructure would be one of the considerations in longer-term facility planning.

The findings of this analysis correspond well with the 10-year hospital development plan announced by the government in 2016 (list of developments shown in Annex E), where a significant amount of resources will be injected to the aforementioned Clusters with projected net patient outflow (e.g. expansion of United Christian Hospital, redevelopment of Prince of Wales Hospital, and extension of Operation Theatre (OT) Block of Tuen Mun Hospital), so as to incrementally enhance populations' local access to service.

IX. Implementation

Resource management cannot be isolated from the overall planning activities regarding capacity of service provision including facilities, technology and service delivery (the optimal mix of type, level, configuration and volume) as well as capability such as financial and human resources. With resource allocation linked to a Cluster's existing scale of operation and infrastructure, having the Refined Population-based Model alone is necessary but not sufficient to direct resources to where they are most needed. Instead, as an integral part of a holistic approach for service planning and resource management, the model will serve to facilitate better understanding of healthcare needs and contribute to service planning by generating business intelligence under the existing service and budget planning mechanism of HA.

(A) Model Providing Business Intelligence for Planning

The essence of the subject matter is to address resource management from the population's perspective. Sharing the same objective basis as the population-based approach for government funding review adopted since 2000, the Refined Population-based Model is valuable in meeting this objective by extending the population concept to resource analysis at Cluster level. In addition, the Refined Population-based Model projects the healthcare needs down to localities (by TPU), and this would allow a better understanding of the health seeking behaviour of the population.

Under the prevailing planning mechanism, HA uses population projection figures published by the Government's C&SD as well as a set of detailed breakdowns by geographical areas from Planning Department to project demand growth in terms of the different categories of services provided by HA. This serves as a common basis for service, facility and workforce planning within the HA in longer term. The Refined Population-based Model would not replace the existing planning projection tools but could complement each other by taking into account factors other than demographics (e.g. social-economic and epidemiological factors), DS and other adjustments.

As population is not restricted to Clusters (the public healthcare system in not registration-based) and in view of the long implementation lead times for building up capacity (changes should not disrupt existing services as recommended by the HA Review) and also the inherit limitations of the statistical model, the Refined Population-based Model can identify challenges such as capacity (often facility constraint) but could not serve as a funding formula for direct budget allocation. Instead, the model can be applied in the short and intermediate term in adjustment mechanism to inform resource service needs for underprovided Clusters. It should be used for resource analysis to generate business intelligence and inform service planning in short and longer terms.

(B) Way Forward

System changes are expected to be gradual and incremental, considering the long implementation lead times for building up capacity and inertia in health-seeking behaviour. As such, instead of updating the Refined Population-based Model and conducting resource analysis annually, it would be more practical to monitor the trend and analyse at regular intervals such as dovetailing with HA's five-yearly development cycle under its Strategic Plan.

While the Refined Population-based Model enables analyses from multiple perspectives and time points that aim to identify the relative needs of Clusters in aligning with population development, there are other equally important factors for determining the pace of development which need to be comprehensively considered. The analysis under the Refined Model would inform HA's planning through existing planning mechanism starting from the 2018/19 cycle onwards.[14]

[14] Per direction from the HA Board at its Administrative & Operational Meeting held on 27 April 2017.

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Glossary Part A: Literature Review on Public Healthcare Funding

A review of international literature was conducted as groundwork of the development of the Refined Population-based Model. The following is a brief summary of the information available in the literature on the various public healthcare funding approaches as well as the international experience in employing the population-based model.

According to the World Health Organisation (WHO) (WHO, 2008), flow of public funds in health services is often complex, with funding flow between Government, central healthcare agencies, local agencies / service providers, and citizen / patients. In the context of this web of funding flow, a key requirement for any health system is to ensure that the available public funds are directed to local organisations in line with population healthcare needs and health system objectives. The determination of the magnitude of funds directed from a central healthcare agency towards localities is challenging due to:

- Technical difficulty in determining where limited public funds are best spent
- Difficulty in aligning funding mechanism with health system objectives
- Acuteness of political ramifications of any geographical funding choices
- Difficulty in monitoring the effectiveness and efficiency of local spending

As discussed by Rice and Smith (2001), determination of funds towards local healthcare agencies have been an important focus for securing important healthcare objectives, such as enhancing equity. To this end, a central feature is the requirement to facilitate a prospective budget that reflects some concepts of fairness.

Healthcare Resource Allocation Approaches

Different methods exist and are adopted internationally for the allocation of available healthcare funding from a central healthcare agency to local organisations (WHO, 2008). One crude approach would be based on political patronage. Although no jurisdiction would openly admit it, there is evidence to suggest that such patronage exists to an extent in some allocation systems. Another rather crude methodology is to allocate funding according to historical precedent. The main attraction is that it minimises disruption to existing health services and avoids large year-to-year variance in funding to each local organisation. However, sole reliance on this method would let any existing unfairness and inefficiency perpetuate. Allocating funds according to bids submitted by localities is another methodology. It is commendable in the sense that it ensures public funds are spent in line with local needs and that corporate policies could be incorporated in the resource allocation through the bid selection process. However, the high transaction costs, in terms of central scrutiny and bid preparation by local agencies, have made it virtually impossible for health systems to solely rely on this methodology. Unsuccessful localities may also perceive that the allocations have been made according to patronage, rather than the quality of the bids. In addition, financial allocation could be expenditure-based, where allocation is made according to how much localities actually spent in the previous year. However, it encourages spending in excess of efficient levels, and in principle it contradicts good public finance.

Allocation by mathematical formula / model is another approach in determining local financial allocations. In formula funding, mathematical rules that determine the magnitude of the funding received by local organisations are specified in advance. Depending on the need of the system, the rules could be very simple or very complex. Two broad approaches exist in formula funding. The first is activity-based, where local agencies are funded on the basis of some measure of local activity. This methodology is particular useful if an unambiguous indicator of patient need could be established. However, development of this indicator can be tricky and controversial, with one example being the difficulty in taking into account differences in case complexity. Activity-based funding can be vulnerable to unwarranted service utilisation and gaming of local organisations, as funding is based on activity data as recorded by the localities themselves.

Capitation funding, on the other hand, reimburses local authorities according to the expected level of local activity, mainly based on the size and structure of a locality's population, while adjusting for other factors that impact need and expenditure, so that the expected level of local service expenditure could be inferred. This type of capitation funding is referred to population-based funding, as it is mainly based on population counts. It circumvents the perverse incentive mentioned for activity-based case payments, but its effectiveness hinges on how the variations of characteristics in the populations could be accounted for, and how a pace-of-change strategy could be implemented to mitigate the potentially high year-to-year fluctuation in resources available to localities.

According to WHO (2008) and Penno, Gauld and Audus (2013), two methods of allocating resources to people are available, via either individual-level data or small area-level data. Employment of individual-level data is seemed to be more desirable, as the accuracy of the need estimation of the model will be much better. However, a significant challenge of implementing an individual-based methodology is the availability of a comprehensive database that keeps track of all important health utilisation, expenditure, diagnosis, census, and other socioeconomic variables for all individuals covered by a health system. Because of this limitation with individual based data, most systems have resorted to using more aggregate data (with the relative availability of area level census and socioeconomic data). Under this approach, aggregate measures of the characteristics of a system's population are combined to create an index, which seeks to indicate the aggregate spending needs of the associated population.

To summarise, the strengths and weaknesses of the various public healthcare funding methodologies are tabulated below.

Methodology	Description	Strengths	Weaknesses
Political patronage	Rewards localities according to their political support in the past, or their importance in the future	• Eliminates administrative costs in developing or refining allocation models	• Leads to unfairness to certain localities • Arouses controversy as methodology is not transparent • Evokes public dissatisfaction as service providers cannot be held accountable • Lacks focus on quality and efficiency
Historical	Allocates funding according to historical precedent, sometimes adjusted by inflation and/or efficiency changes	• Minimizes disruption to existing services • Avoids large year-to-year funding variation for local organisations	• Allows existing unfairness to perpetuate • Leaves the Government with no power in introducing new policies or services • Lacks focus on quality and efficiency
Bid-based	Allocates resources by scrutinizing uncapped budget submissions made by localities, funding activities that are line with overarching national strategies	• Links resource allocation to local performance • Ensures corporate policies are followed • Ensures public funds are spent in the most cost-effective way	• Incurs high transaction costs, in terms of central scrutiny and preparation of bids by local agencies • May result in large geographical inequalities • May lead to perceived unfairness, as political patronage may be perceived by less successful localities
Expenditure-based	Allocates funding according to how much localities actually spend, forming an element of many systems of matching grants from central Government to local administrations	• Encourages spending when localities would otherwise spend below efficient levels	• Contradicts principles of good public finance • Encourages spending in excess of efficient level

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Methodology	Description	Strengths	Weaknesses
Activity-based	Reimburses localities according to some measure of the expected expenditure on a service user	• Makes funding more transparent • Promotes accountability and binds stakeholders to distributional rules • Reimburses local agencies fairly in line with the number of service users • Encourages efficiency improvements so as to reduce unit costs • Takes into account case complexity in the reimbursement	• Leads to controversy as development of an unbiased and accurate indicator of need is tricky • Arouses scepticism as a homogeneous patient classification system is difficult to be developed • Creates unwarranted service utilisation as funding is based on recorded activity • Encourages over-treatment in order to secure a high case payment • Subjects to insurance risks and incentivizes risk selection • Subjects to gaming as localities' utilisation information is difficult to verify
Population-based	Reimburses local authorities according to the expected level of local activity, mainly based on the size and structure of a locality's population, while adjusting for other factors that impact need and expenditure	• Strives for equitable funding which is responsive to the demand • Facilitates general public's support as principle behind the methodology is easy to articulate • Utilizes an objective and transparent methodology • Promotes accountability • Removes the incentive for supplier induced demand • Reduces reliance on output data provided by local providers • Promotes prospective planning	• Subjects to danger of oversimplification, as variations of need is difficult to be accounted for by population characteristics alone • May induce potential favourable risk selection • Requires sufficient utilisation, cost, and socioeconomic data • May require a damping mechanism as high year-to-year fluctuations in funding for localities may result

Source: (WHO, 2008), (Rice & Smith, 2001), (Penno et al. 2013).

Glossary A: Table 1 – Strengths & weaknesses of different funding methodologies

Common Themes in Population-based Resource Allocation Models

Rather than relying on arbitrary methods on funding calculation or historical precedents in funding, more and more health systems in the developed world have sought to place greater emphasis on the use of systematic funding models (WHO, 2000; Smith, 2008a; Smith, 2008b, WHO, 2008). In addition, according to Penno et al. (2013), pressure to maintain equitable funding which is responsive to the demand placed on different health plans has triggered each health system to develop population-based funding model. This section provides an overview of the population-based resource allocation approaches that are employed internationally.

A high-level comparative analysis on the international application of population-based funding model was conducted via a review of information available in the public domain, e.g. scientific journals, working papers, Government reports, Government websites, etc. To make the analysis meaningful and applicable to the local context in Hong Kong, the eleven health systems selected are all high-income, predominantly publicly-financed, and use a population-based model to facilitate resource allocation. They include: Belgium, England, Germany, Scotland, the Netherlands, New Zealand, the state of New South Wales in Australia, the provinces of Alberta, British Columbia and Ontario in Canada, and the city of Stockholm, Sweden.

All population-based models are found to be consistent in their overall framework in the calculation of healthcare resource need. Their approach largely follows the three common steps as suggested by Penno et al. (2013):

(a) Identifying factors which predict differential need amongst populations

(b) Adjusting for cost factors outside of needs

(c) Quantifying ‘unmet’ need and engaging in normative correction for the ‘unmet’ need

(a) Identifying Need

Each model starts by identifying factors that explain differences in demand. Demography is the single most often used factor across the systems. Age and sex groups are used in this regard with obvious reasons. In addition to these two most basic characteristics, the impact of socioeconomic factors is universally reflected. In addition to population characteristics, some jurisdictions have also incorporated measures of disease status in the models.

(b) Adjusting for Cost Factors Outside of Needs

It is common for health systems to make adjustments for excess costs incurred on top of the relative need of population. As costs of supplying healthcare can vary substantially in different geographical regions, or by providing services of different level of specialisation, compensatory measures are incorporated in funding models. Adjustments for overseas patients and inter-jurisdiction movement are also often found in the funding models.

(c) Quantifying Unmet Need

The reliance on past utilisation data in the population-based act to promote equality of access based on demand. However, it risks reinforcing health disparities in groups that systematically under-utilise health services relative to their healthcare needs. Since unmet need is concealed by prevailing utilisation patterns, most funding models would engage in some form of normative comparisons between sub-populations.

Population-based Resource Allocation Models around the World

Although population-based funding models have been employed by a large number of health systems, the development of a formula that estimates needs well is still a major challenge. In particular, the selection of needs factors for risk adjustment is a complex and controversial process for the following six reasons (Rice & Smith, 1999):

(a) Unavailability of data;

(b) Sparse empirical evidence on appropriate needs factor;

(c) Difficulty in establishing the extent to which a particular factor is independent of other needs factors;

(d) Difficulty in separating legitimate needs factors from other policy and supply influences on utilisation;

(e) Difficulty in identifying healthcare costs associated with a proven needs factor, and

(f) Possibility for budget recipients to influence the choice of needs factors to favour their area through the political process.

According to WHO (2008), there are a number of critical factors in the selection of needs adjustment factors in a population-based funding model. Namely, they have to be:

(a) Feasible, with low administrative cost;

(b) Consistently, reliably, verifiably and universally recorded;

(c) Free from perverse incentives or gaming;

(d) Not vulnerable to manipulation or fraud;

(e) Consistent with confidentiality requirements, and

(f) Plausibly determinative of service needs.

Although technology has made data collection, repository and access a lot easier compared to a decade ago, the above criteria have severely limited the choice of variables, as in most systems few data exist that conform to all of the above.

A summary of the various elements of the population-based resource allocation model for the nine health systems are provided below. For ease of reference, the elements are grouped according to the three main planning themes as described in the previous section: (a) identifying need, (b) adjusting for cost factors of needs, and (c) quantifying unmet need.

Health system	Main financing source	Identifying need							Adjusting for cost factors outside of needs		Quantifying unmet need	
		Age	Sex	Socioeconomic	Ethnicity	Geography	Clinical	Epidemiological	Cost of supply	Capitation correction	Policy based	Epidemiological based
Alberta (Canada)† [a]	Tax-based	<1,1-4,5-9,… 90+		Welfare, subsidy	Aboriginal		Diagnosis Groups		Research, education	Inter-regional flow		
Belgium [b]	Compulsory health insurance	Proportion of people aged between 40-99	M/F	Disability, income, employment status, Civil servant, eligibility of social exemption		Urbanisation (population density/ housing quality)		Mortality Chronic illness	Medical supply (GPs, specialists, pharmacists, dentists & physical therapists)			
British Columbia (Canada) [c]	Tax-based	5-yr bands	M/F	Welfare and disabled, premium assistance	Aboriginal	Remoteness	Casemix Groups		Specialty service	Inter-regional flow		
England [d]	Tax-based	<1,1-4,5-9,… 85+	M/F	Semi-routine occupation	Minority ethnic groups	Distance to outpatient, ONS pop. to GP , number of OTs		Standardized mortality ratio	Market Forces Factor, Emergency Ambulance Cost Adjustment			(Also reflected via SMR)
Germany [e]	Statutory health insurance	Single-year age groups from <1 to 90+	M/F	Income, disability(Recipient of an invalidity pension), entitlement for sickness allowances						Registration in a certified Disease Management Programme		
Netherlands [f]	Social health insurance	0,1-4,5-9,… 90+	M/F	Income, immigrants, entitlement for compulsory sickness fund membership (e.g. disability)		Urbanisation	Pharmacy and Diagnosis Cost Groups	Standardized death probability		Retrospective adjustments		

† Methodology as at 1999.; switched to an activity-based funding approach starting in 2007

Source:

[a] (Plain, 1999).
[b] (Schokkaert & Van de Voorde, 2000).
[c] (Kolbuch, 2001), (Office of the Auditor General of British Columbia, 2014).
[d] (Asthana & Gibson, 2008), (Diderichsen, Varde, & Whitehead, 2003), (London Health Board, 2013), (Leeds, 2011), (NHS England, 2013a), (NHS England, 2013b), (NHS, 2014).
[e] (Buchner & Wasem, 2003), (van de Ven, 2007).
[f] (Lamers, Van Vliet, & van de Ven, 2003), (van de Ven, 2007).

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Health system	Main financing source	Identifying need							Adjusting for cost factors outside of needs		Quantifying unmet need	
		Age	Sex	Socioeconomic	Ethnicity	Geography	Clinical	Epidemiological	Cost of supply	Capitation correction	Policy based	Epidemiological based
New South Wales (Australia) [g]	Tax-based	5-yr bands	M/F	Index of occupation and education	Aboriginal and Torres Strait Islanders	Accessibility index		Standardised mortality ratio	Teaching, research, specialty services, dispersion costs, small hospital, public/private	Interstate flow	Indigenous and homeless population	
New Zealand [h]	Tax-based	5-yr bands	M/F	Index of deprivation	Maori, Pacific, Other				Rural adjuster	Overseas adjuster	Ethnicity, index of deprivation, excess ambulatory sensitive hospitalisation rate	
Ontario (Canada)* [i]	Tax-based	1-17, 18-59, 60-79, 80+	M/F	Income		Rurality, small hospital	Clinical Groups		Unit costs by supply	Market Share		
Scotland [j]	Tax-based	5-yr bands	M/F	Mental health, housing related		Urban/rural		Standardised mortality, limiting long term illness rate	Unavoidable costs			Rate of circulatory disease
Stockholm (Sweden) *[k]	Tax-based	5 & 10-yr bands		Marital status, housing, education, employment		Urbanisation	Costly diagnosis groups					

* Employs an individual-based capitation formula, rather than an area-level formula

Source:

[g] (Sydney: NSW Department of Health, 2005) (Vega, O'Shea, Murrin, & Staines, 2014).

[h] (Penno, Audas, & Gauld, 2012), (Vega et al., 2014), (Wellington: Ministry of Health, 2016).

[i] (Ontario: Ministry of Health and Long-Term Care, 2011), (Sutherland, Repin, & Crump, 2012).

[j] (Vega et al., 2014).

[k] (Diderichsen, Varde, & Whitehead, 2003), (Vega et al., 2014).

Glossary A: Table 2 – Overview of population-based resource allocation models

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Glossary Part B: Review of Recurrent Government Subvention to HA

The major source of funding for Hospital Authority (HA) comes from the Government, in the forms of recurrent and various capital subventions, each serving a different scope and purpose. Apart from Government Subvention, HA also generates income from its activities, albeit to a much smaller extent, such as from services provided to patients and interest of money deposit. Both Government Subvention and HA income are used for supporting HA's operations.

There are established mechanisms for the annual review between HA and the Government on each of the different Votes of Government Subvention. For example, during the annual Resource Allocation Exercise (RAE), HA would submit to the Food and Health Bureau (FHB) a shortlist of new / enhanced initiative options together with a medium term financial projection to bid for recurrent Government Subvention under One-Line-Vote, and shortlists of equipment and Information Technology (IT) project options to bid for funding under the Capital Block Vote (CBV) and Information Technology Block Vote (ITBV) respectively. There are also designated funds assigned to HA for spending over an extended period of time, such as the one-off grant of $13Bn earmarked for facility improvement works. While HA will manage such funds including interest generation, accounting treatment and planning cashflow for meeting the expenditure required, prior approval from the Government is still needed for individual expenditure items under the master project plan, which will be reviewed from time to time.

Each year, the Government determines the exact level of subvention to HA basing on a basket of considerations, including (i) the baseline subvention granted to HA in the preceding year and the cashflow projection by HA needed to sustain the existing workforce and levels of services (primarily a reflection of the historical development), (ii) financial implication of service initiatives for meeting the population's growing demands for new public healthcare services (subject to population effect, manpower supply, and bidding to the Government's Resource Allocation Exercise), (iii) a reality check on the healthcare funding need by using the population-based model, which was lately expanded from demand-driven projection to also include supply-driven projection, and (iv) other considerations like the prevailing Government fiscal policy.

To set the scene for understanding the public hospital system's need for additional operational expenditure in the coming years, financial projection (2018/19 to 2022/23) was conducted under a two-pronged approach, namely, population-based approach (demand-driven) and capacity-based approach (supply-driven). Analysis on HA's operational expenditure from 2018/19 to 2022/23 (primarily cashflow condition) provides the context for deliberating "recurrent Government subvention" to HA and facilitates Government's review of HA's composite RAE bidding list (reflecting budget condition).

Population-based Approach

Projection under the population-based approach[15] has been adopted since 2001/02 as one of the key considerations for the Government to determine its recurrent subvention to HA. The method shared similarity to the United Kingdom Treasury's Wanless projection method (Wanless, 2002). The transition is not a complete switch to formula funding but a shift of emphasis in examining the relationship between population and public healthcare, particularly in projecting changes in healthcare demand in relation to population projection, and in using that as a basis for assessing changes in funding need.

[15] The population-based approach, as agreed with the Government, was presented to LegCo Panel on Health Services (Paper No. CB(2)200/00-01(05) on "Funding Arrangements for the Hospital Authority" on 13.11.2000).

In addition to projecting the financial requirement from the **evolving healthcare needs arising from the changes in population size and demographics**[16], an estimate on financial requirement on the **evolving care practices and treatment modules in relation to medical advancement** would also be made with reference to the past trend of service utilisation rate and cost of service provision[17].

Capacity-based Approach

Projection by a capacity-based approach assesses HA's ability to use resources by considering the key system capacity constraints, particularly the manpower and facilities situation, according to HA's prevailing modes of operation, cost drivers changes and manpower availability, etc. A conceptual framework is presented in the following figure.

A multi-layer scenario analysis was conducted to simulate how public hospital services would fare under different scenarios, namely:

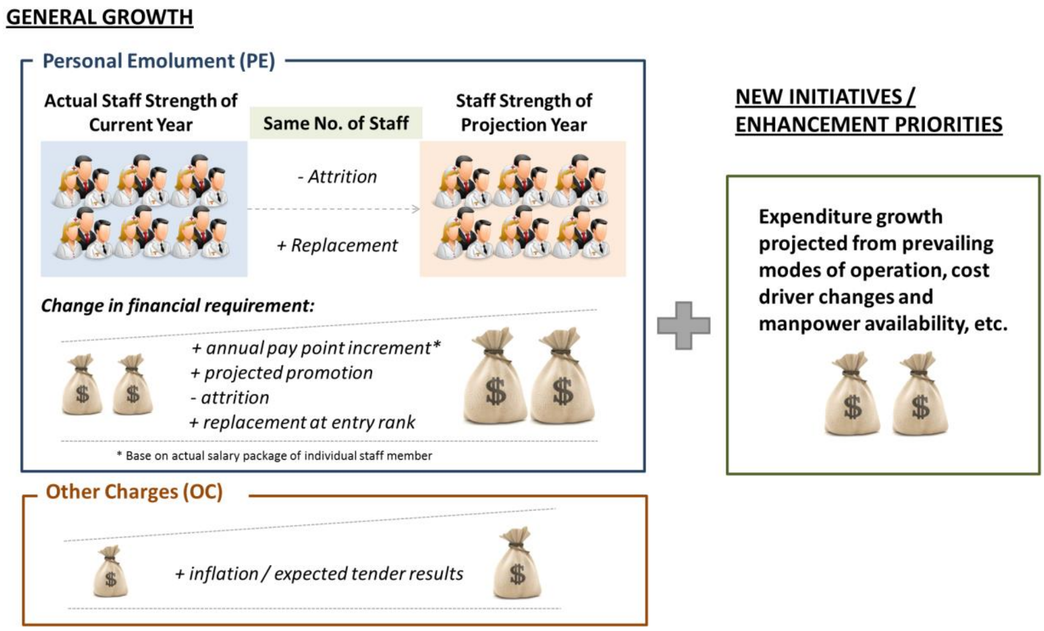
(i) base case for maintaining past year's (i.e. existing) workforce and service capacity,

(ii) introducing new / enhanced initiatives in the coming financial year (i.e. the year under the annual planning exercise) on top of the base case, and

(iii) introducing new / enhanced initiatives for up to 5 years on top of the base case.

[16] Under the existing projection approach, the key factors considered are sex and age profile.

[17] In 2013, HA provided, upon FHB's request, a long-term financial projection till 2041/42 (Long-term Fiscal Planning exercise) which became part of the Government's overall projection on its expenditure. As stated in "Report of the Working Group on Long-Term Fiscal Planning (Phase One)", the financial requirement arising from evolving care practices and treatment modules in relation to medical advancement was projected based on data in 2007/08 to 2012/13. The same growth rate previously compiled and submitted to FHB was adopted in this projection exercise as the healthcare environment has remained more or less stable.



Glossary B: Figure 1 – Conceptual framework of base case projection

With regard to the base case which accounts for over 90% of the total annual expenditure requirement (labelled as “general growth” in the figure above), the key assumption is the existing workforce will be maintained and service capacity will remain unchanged from the current level. Specifically, actual staff strength at current year end (i.e. 31 March) would be adopted as the starting point to roll forward till the end of the projection period, taking into account the actual salary package of individual staff member (with annual increment of pay point if applicable), projected promotion, as well as the projected attrition and new intake for attrition replacement at entry rank. On the other hand, Other Charges (OC) would be categorised by nature and the projection would incorporate different price adjustment factors such as inflation and latest / expected tender results.

Summary

The existing levels of services and potential growth from both the population (demand-side) and system (supply-side) perspectives set the scene for upper and lower bound projections of HA expenditure. The spread between the two projections gives an indication on the adequacy of the public hospital system and the need for extra measures on top of the usual planning strategy.

Theoretically, the magnitude of the difference gives an indication of unmet need and the extent of how HA’s capacity is being over-stretched. This demand-supply gap is likely to show up as worsening of waiting time and overloading of service provision, which may end up in access block under surges in service demand.

In addition to the lower bound requirement projected by the capacity-based approach, the eventual spending will be correspondingly higher subject to the extent of Government-policy initiatives and other special measures approved for alleviating the prevailing demand-supply gap. In summary, the financial projection provides a contextual background for understanding service growth, and HA’s need for recurrent Government subvention in the coming few years on top of the income generated.

Glossary Part C: Initial List of Designated Services

Background information on the initial list of 13 Designated Services are given below.

AIDS Service

Cases for AIDS are being managed by service networking between HA and integrated treatment centre of Centre of Health Protection (CHP). In HA, comprehensive AIDS services provided by Princess Margaret Hospital and Queen Elizabeth Hospital included inpatients and outpatients service, partners screening, nurse counselling, compliance assessment, post-exposure prophylaxis and counselling for needle stick injury, etc.

Blood Transfusion Service

Blood Transfusion Service is responsible for ensuring that sufficient supplies of safe and high-quality blood and blood components are available for local transfusion therapy patients. One of the service's most-important tasks is to motivate the community to make regular blood donations. The blood donations are then tested for blood groups and mandatory infection markers before they are processed into various blood products. Finally, these blood and blood products are distributed to public and private hospitals for clinical transfusion, which make them available to patients.

Bone Marrow (Allogeneic) Transplantation

Bone Marrow (allogeneic) Transplantation services were provided by Queen Marry Hospital and Prince of Wales Hospital. The diseased bone marrow would be removed and replaced by a healthy one. The scope of services included entire transplantation activities of all clinical care paths involved (such as transplant coordinator office, workup for potential recipients/donors, follow up in subsequent years, etc.) and other supporting services/overheads (Pathology and Radiology services, etc.) incurred. New Territories East Cluster only provides paediatric services. In view that some of these paediatrics services would be translocated to the Hong Kong Children's Hospital, it was not included in IRA analysis for the time being.

Cardiothoracic Surgery (including Heart and Lung Transplantation)

In HA, a comprehensive ranges cardiothoracic surgical services were supported by these 3 centres namely Queen Marry Hospital, Prince of Wales Hospital (with a Thoracic Surgery satellite site in New Territories West Cluster) and Queen Elizabeth Hospital including adult cardiac surgery, paediatric cardiac surgery, thoracic surgery, intrathoracic (i.e. heart and lung) organ transplantation with advanced mechanical circulatory support.

Developmental Disabilities Unit

Developmental Disabilities Unit at Caritas Medical Centre is the sole centre that provides medical, educational and rehabilitation services to children with severe developmental disabilities and complex medical needs in Hong Kong in a home-like environment.

Forensic Psychiatry

Department of Forensic Psychiatry of Castle Peak Hospital of New Territories West Cluster provides territory-wide mental health services to people who have both a mental disorder and a history of criminal offence (or who present a serious risk of such behaviour). The department works closely with the Correctional Services Department and other law-enforcing agencies to provide clinical assessment and treatment to individuals with serious mental illness presenting in the criminal justice system in Hong Kong.

Infectious Disease Centre

The Infectious Disease Centre at Princess Margaret Hospital was founded as an aftermath of the outbreak of SARS in 2003. The Infectious Disease Centre is the tertiary referral centre for mapping infectious diseases in Hong Kong.

Liver Transplantation

Liver transplantations services were only provided by Queen Marry Hospital. The diseased liver would be removed and replaced by a healthy one. The scope of services included entire transplantation activities of all clinical care paths involved (such as transplant coordinator office, workup for potential recipients/donors, follow up in subsequent years, etc.) and other supporting services/overheads (Pathology and Radiology services, etc.) incurred.

Severe Mentally Handicapped

Siu Lam Hospital is the only hospital in Hong Kong serving patients with severe intellectual disability aged 16 or above. It provides comprehensive rehabilitative and infirmary services exclusively to adult patients with severe intellectual disability in Hong Kong.

Toxicology

Toxicology service comprises four clinical units: the Hong Kong Poison Information Centre (United Christian Hospital), the Prince of Wales Hospital Poison Treatment Centre, the Toxicology Reference Laboratory (Princess Margret Hospital) and the Chief Pharmacist's Office (HA Head Office), with support provided by the Infection, Emergency & Contingency Department (HA HO).

Teaching and Research Component in Teaching Hospitals

According to Section 24 of the Hospital Authority Ordinance (Chapter 113), "Teaching Hospital means the Prince of Wales Hospital or the Queen Mary Hospital where such hospital is a public hospital" and; also the main clinical education and research centres in Hong Kong. It was a common understanding that Teaching and Research (T&R) Component in the Teaching Hospital has all along been recognised to incur additional cost to the Teaching Hospitals. Although it is not strictly within the definition of DS, it is necessary to understand the impact of T&R and should be addressed along with DS in the Refined Population-based Model as far as practical.

Glossary Part D: Variables Considered for Modelling

During the variable evaluation process, a total of 38 potential variables were identified and categorised into seven dimensions, including (i) demographic, (ii) socioeconomic, (iii) epidemiological, (iv) clinical, (v) geographic, (vi) unmet needs and (vii) other variables.

Demographic (n = 5)
Age
Sex
Ethnicity
Marital status
Indigenous

Socioeconomic (n = 11)
Household income
Education level
Employment status
Social welfare
Deprivation index
Type of housing
Housing tenure: sub-divided unit
Homelessness
Insurance
Old singleton
Dependents with carer

Epidemiological (n = 8)
Standardised mortality rate
Morbidity index
Standardised illness ratio
Fertility
Low birth weight
Self-rated health status / index
Number of chronic diseases/ disability
Living in residential care home

Clinical (n = 5)
Clinical risk groups
Costly diagnosis group
Diagnostic cost groups/ hierarchical condition categories
Physiological measures
Ambulatory sensitive hospitalisation rate

Geographic (n = 3)
Urbanisation
Distance
Remoteness

Unmet needs (n = 1)
The excess unmet needs (e.g. difference between least deprived and most deprived group)

Other variables (n =5)
Market force factor
Health professional supply
Hospital beds
Private sector utilisation
Previous expenditure

Glossary D: Figure 1 – List of potential variables in statistical model

These 38 identified variables were further deliberated on their relevance in the local context and data availability for model testing. For the development of the Refined Population-based Model, the identified variables would be subject to statistical testing, which examine their effect and extent on healthcare utilisation. A description of each variable, their application in other capitation payment systems, and a high-level assessment on whether subsequent work is warranted to analyse in the context Hong Kong is provided in this section.

Demographic Variables

Age and Sex

Healthcare needs, and thus resource utilisation, vary with population size and demographics. In general, resource utilisation for healthcare needs is proportionately related to the underlying population size. Elderly and infant tend to utilise relatively more resources than the rest of the population for their healthcare needs.

The population-based model first requires a verifiable count of population, disaggregated where necessary into demographic groups. Out of this disaggregation of fundamentals, age and gender are the most common and important predictors of expected healthcare spending that are readily available from official data sources.

Ethnicity and Indigenous Groups

In spite of significant advances in the diagnosis and treatment of most chronic diseases, there is evidence that racial and ethnic minorities tend to receive lower quality of care than non-minorities and that, patients of minority ethnicity experience greater morbidity and mortality from various chronic diseases than non-minorities (Egede, 2006). The Institute of Medicine (IOM) report on unequal treatment concluded “racial and ethnic disparities in healthcare exist and, because they are associated with worse outcomes in many cases, are unacceptable.” (Smedley, Stith & Nelson, 2003)

Ethnicity is adjusted for in population-based models in jurisdictions where aboriginal / indigenous groups are prevalent. Examples include the province of British Columbia in Canada (Kolbuch, 2001) (adjusting for Aboriginal, which accounts for around 5% of population in the province (Fraser Region Aboriginal Early Childhood Development, n.d.), New South Wales of Australia (New South Wales Department of Health, 2005) (adjusting for Aboriginal and Torres Strait

Islanders – about 3% of population (Australian Indigenous HealthInfoNet, n.d.), and New Zealand (Ministry of Health, 2004) (adjusting for Maori, Pacific, etc. – about 22% of population (Statistics New Zealand, 2013).
Unlike the aforementioned jurisdictions, although about 6% of Hong Kong's population is made up of ethnic groups other than Chinese (Indonesian, Filipino, etc.) (Hong Kong Census and Statistics Department, 2011), there are reports of specific ethnic consideration (mainly Nepalese, Pakistani and other South Asian) on health access in some localities, which needs to be further investigated. Also, it is noted that there are certain districts / Clusters might have higher proportion of ethnic groups. Their impact and burden on the HA services warrant further investigation for justifying the inclusion of an ethnicity variable in the Refined Population-based Model.

On the contrary, Hong Kong does not have a distinct aboriginal / indigenous population group, where their culture and history are highly distinct from the rest of the population. As such, an ethnicity variable of indigenous / aboriginal peoples may not be necessary in the Hong Kong setting.

Marital Status

Previous literature also revealed that there are differences in the utilisation of health services by marital status. As a main proxy measure on familial support and care, divorced and widowed persons are found to have a higher utilisation of health services, when compared to married people after controlling for age and sex (Joung, van der Meer & Mackenbach, 1995). Therefore, this variable is included in the model of resource allocation for hospital services in Stockholm of Sweden (Andersson, Varde & Diderichsen, 2000).

Currently, C&SD provides the breakdown of marital status into five major categories, namely "Never Married", "Married", "Widowed" "Divorced" and "Legally separated".

Socioeconomic Variables

An ideal situation in geographical resource allocation is that the ratio of resource per unit of need is identical for all sub-units of the population (Donabedian, 1973). This optimal allocation of scarce resources would not only maximise health benefits as those at higher needs will benefit more from effective intervention, but it will also enhance equity as health outcomes are expected to be identical for all sub-units of a population.

To achieve the above, area-specific healthcare needs have to be measured by available health, socioeconomic, and demographic information. Local research (Wong et al., 2009) conducted in Hong Kong in 1999 has shown that there is indeed a correlation between socioeconomic variables with mortality and hospital admission. For example, one-person households, unemployment and low household income (<HK$2,000) were associated positively with mortality and hospital admission, while high educational attainment (university degree or above) and managerial occupation was associated negatively with both.

Income and Social Welfare

Income alone, or in concert with other variables is a significant contributor to health and, consequently, health inequalities. Research indicates that there is a significant difference in disease prevalence and in years of life lost between the highest-income quintile and each income quintile lower than that of the highest (Public Health Agency of Canada, 2008; Swartz, 2009). In addition, special healthcare needs may be prevalent among people in social welfare system, especially for children (Ringsisen, Casanueva, Urato et al., 2008; Hung, Hahn, Buka et al., 2015).

Income is one of the variables used in the Netherlands and Ontario (Canada) models. In particular, average income (Ministry of Health Welfare and Sport,

2008) and the quintile of neighbourhood income per person (Ministry of Health and Long-Term Care, 2012) are used respectively.

On the other hand, the level of utilisation on social welfare is being used as an adjustment factor in the population-based model for the province of British Columbia in Canada. Namely, the regional distribution in the number of residents classified as Welfare and Disabled is used (Kolbuch, 2001).

In Hong Kong, a social security system is in place to provide the basic and special needs to the members of the community who are in need of financial or material assistance. The non-contributory social security system administered by the Social Welfare Department comprises the Comprehensive Social Security Assistance (CSSA) Scheme, Social Security Allowance Scheme, Criminal and Law Enforcement Injuries Compensation Scheme, Traffic Accident Victims Assistance Scheme and Emergency Relief.

Recipients of CSSA will be waived from payment of their public healthcare expenses. To assist the three vulnerable groups in the community, i.e. the low income group, chronically ill patients and elderly patients who have little income or assets, but who are not CSSA recipients, a medical fee waiver mechanism is in place to provide effective protection from undue financial burden to them.

Initial analysis conducted internally by HA using PHC utilisation, counts of CSSA recipients (Hong Kong Legislative Council, 2016), and population information in 2014 has indicated that patients who were CSSA recipients had a higher service utilisation rate than those who are not.

With people with lower income / supported by social welfare having potentially higher healthcare needs, and that these people may be unevenly distributed in Hong Kong, it may be worthwhile to explore whether level of household income and level of support by social welfare should be incorporated into the Refined Population-based Model in HA .

Education

Education level is an important predictor of healthy life and self-care behaviour that affect healthcare utilisation. In an earlier work on individuals with diabetes in Ontario of Canada (Alguwaihes & Shah, 2009), those with high educational attainment were more likely to have had an ophthalmologic examination and were more likely to report having a specialist as their most responsible provider of care, rather than a family doctor. In the context of resource allocation, educational level is also considered as one of the adjustment factors for primary and hospital care in the State of New South Wales of Australia and in Stockholm of Sweden.

In terms of data availability, educational level is consistently recorded in population censuses of Hong Kong. As a consequence, it is suggested to include this variable for further investigation in understanding how educational level would affect healthcare service demand in Hong Kong, and whether the geographical distribution of people with different educational level would impact the resource utilisation by Clusters.

Employment Status

For decades, the influence of employment on individual and family health has been controversial. On one hand, employment provides citizens with economic opportunities, which can improve individual and family health. However, working environment can also significantly impact physical and mental health through type of work and working conditions. In addition, stress related to employment in the form of job strain, satisfaction, and perception of physical risk and issues of job security is a significant health concern. The amount of workplace-related injury, disability and death would be dependent on the nature of industries.

For example in Canada, 630,000 Canadians experienced at least one activity-limiting occupational injury in 2003. Blue collar workers (sales and service, transport, equipment operation, primary industry and manufacturing) experience over four times the injury rates experienced by white collar workers (business, administrative, management, and occupations in health, science, social science and arts). Men (5.2%) experience more work-related injuries than women (2.2%). Although the type of occupation is the key to determination of risk, higher-income men (over $60,000) and women (over $40,000) were less likely to experience injury compared to those men and women at lower income levels (Public Health Agency of Canada, 2008).

Employment has been incorporated into the population-based model in England and New South Wales (Australia). The distribution of 16-74 population with semi-routine occupation is taken into account in England (NHS England Strategic Finance, 2014), while a socioeconomic index named EDOCC (level of education achieved and occupational status) (New South Wales Department of Health, 2005) is incorporated into the New South Wales model.

In this connection, it would be worthwhile to understand how employment status would affect healthcare service demand in Hong Kong, and whether the geographical distribution of people with different occupations would impact the resource utilisation by Clusters.

Deprivation Index

To better understand the condition of relative socioeconomic deprivation in each small-area district, some western countries have developed their own index of deprivation from census data for assessing healthcare needs, health services planning and resource allocation. For example, New Zealand Ministry of Health (NZMoH) adopted the 2013 New Zealand Index of Socioeconomic Deprivation (NZDep) in its 2015 Population-based Funding Formula Review.

However, there remains no official index of deprivation available in the context of Hong Kong. To address the influence of socioeconomic variations of each small-area district on healthcare utilisation, it is suggested that the model should include one or more socioeconomic variables and the following sub-sections discuss major socioeconomic variables in more detail.

Type of Housing

In addition to income, education and employment status, housing condition is also a main predictor of socioeconomic status that affects healthcare utilisation and resource allocation. For example, type of housing is one of the adjustment factors in the estimation of expenditure of sickness funds of social insurance in Belgium (Schokkart & Van de Voorde, 2000) while housing tenure is adopted for hospital service in Stockholm of Sweden (Andersson, Varde & Diderichsen, 2000). Furthermore, in New South Wales of Australia, an additional of 150% resources is allocated to areas with more homeless person (New South Wales Department of Health, 2005).

In view of data availability, both type of housing and housing tenure are consistently collected in population censuses. Therefore, it is suggested that both of them should be further investigated in exploring their statistical association with healthcare utilisation for resource allocation.

Housing Tenure: Sub-divided Unit

As firstly described by Peter Townsend in his deprivation index, household overcrowding is one of the four constituting factors of material deprivation (Townsend, Phillimore & Beattie, 1998). This factor was mentioned by the WHO that heightens health risks, including pneumonia, tuberculosis and many allergies (World Health Organisation, n.d.a), and consequently healthcare utilisation. In Hong Kong, sub-divided unit (also known as sub-divided flats) is a common type of rental housing, which a housing quarter is subdivided into two or more individual rooms. As most of these units are not properly renovated, the safety and hygiene condition of these housing are usually undesirable that may affect their healthcare utilisation pattern, when compared to others (Buildings Department, Hong Kong, n.d.).

With regard to data availability, the number of domestic households and the number of quarters occupied by domestic households are consistently recorded in population censuses. Also, the C&SD conducted a Thematic Household Survey (THS) to investigate the housing conditions of sub-divided units in Hong Kong in 2015 (Census and Statistics Department, Hong Kong, 2016). Therefore, it is suggested that this factor should be further investigated in exploring their statistical association with healthcare utilisation for resource allocation.

Homelessness

Published studies suggested that homelessness is a possible factor of affecting health need and healthcare utilisation within the population. In the US, evidence showed that homeless people are exposed to higher risk of both acute and chronic medical illness and excess mortality while more than half of them have a history of mental illness and substance use (Baggett, O'Connell, Singer et al., 2010). They also experience poor access to timely health services, leading to delayed clinical presentation, increased reliance on emergency department and higher rates of hospitalisation (Baggett, O'Connell, Singer et al., 2010).

In Hong Kong, however, this factor is unlikely to be available from population censuses and other accredited sources. It is thus suggested that this potential variable should not be considered in the Refined Population-based Model until this barrier is resolved.

Insurance

Within the terminology of the National Health Accounts, financing sources are distributed through financing agents, which are intermediary institutions that collect financial resources and use them to purchase health goods and services.

Common financing agents that apply to most developed countries include the Government taxation system, social security systems, private insurance, non-profit institutions and direct out of pocket expenses (Actuarial Society of Hong Kong, 2006).

In Hong Kong, estimates by C&SD on provision of medical benefits by employers / companies and coverage of medical insurance purchased by individuals and hospitalisation (Hong Kong Census and Statistics Department, , 2013) (e.g. the rate of persons enjoying medical insurance by age and sex, the rate of inpatients' hospital charges covered by insurance for each type of hospital) can be used to assess the take up rate of private health insurance in each Cluster and its impact on the Clusters' healthcare needs. It would be worthwhile to study whether this potential variable should be incorporated into the Refined Population-based Model.

Older Singleton

According to UK-NHS, older persons are vulnerable to loneliness and social isolation, which can lead to a serious effect on health (National Health Service, n.d.). In the United Kingdom, areas with older singletons (i.e. aged 75+ living alone) are allocated additional resources for mental health and acute care services (Sutton et al., 2002).

In Hong Kong, the living arrangement pattern of residents is consistently recorded in population censuses. Although the age threshold of defining an older person remains unclear and controversial, it would be worthwhile to further examine whether this variable should be incorporated into the Refined Population-based Model in HA.

Dependents with Carer

Similar to older singleton, evidence showed that the availability of caregivers may affect the demand for health services. In UK-NHS, proportion of dependents with no/a single carer is considered as an adjustment variable for mental health and maternity care in the resource allocation model (Sutton et al., 2002).

In Hong Kong, the definition of "career" is not clearly defined in population census and it is unlikely to collect this variable at the population level from official or unofficial sources. It is thus suggested that this potential variable should not be considered in the Refined Population-based Model until this barrier is resolved.

Epidemiological Variables

Epidemiology may be defined as the study of the distribution of health and disease in groups of people and the study of the variables that influence this distribution. Descriptive epidemiology provides information on the pattern of diseases, on "who has what and how much of it" information that is essential for healthcare planning and rational allocation of resources (Wassertheil-Smoller & Smoller, 2015).

Standardised Mortality and Illness ratio

As well-known epidemiological adjustment factors in determining resource allocation, both mortality and morbidity measures such as standardised mortality (illness) ratio, (the ratio of observed deaths [or persons with long-standing illness] in the study group to expected deaths [or persons with long-standing illness] in the general population (Everitt & Skrondal, 2014)), and/or burden of chronic diseases (such as the limiting long term illness rate) are used in the England (NHS England, 2013), Netherlands (Ministry of Health Welfare and

Sport, 2008), New South Wales (Australia) (New South Wales Department of Health, 2005), and Scotland (NHS Scotland Resource Allocation Committee, 2007) models.

In the context of Hong Kong, it is suggested that mortality remains one of the most prominent factors in determining allocation of health resources to each hospital Cluster. In addition, there is a well-established registration system to capture all known births and deaths occurred. Hence, it is not difficult to compute the standardised mortality ratio (SMR) for each small-area district. In view of the above, it would be highly beneficial to undertake further study to see whether and how SMR should be incorporated into the Refined Population-based Model is warranted.

On the contrary, the applicability of standardised illness ratio in Hong Kong remains controversial. Firstly, according to an earlier work conducted by Ayis, Gooberman-Hill & Ebrahim (2003), the term "long-standing illness" was constructed by six major domains: socio-demographic, physical environment, social environment, social support, psychological and disease conditions in the United Kingdom (Ayis, Gooberman-Hill & Ebrahim, 2003). Yet, there remains no evidence to substantiate this relationship in the local context. Also, this information is not consistently recorded and it is unlikely to collect this variable at the population level through official or unofficial sources. It is thus suggested that this potential variable should not be considered in the Refined Population-based Model until this barrier is resolved.

Morbidity Index and Number of Chronic Diseases / Disability

In facilitating comparisons of non-fatal health outcome across small-area districts or jurisdictions, the National Health Service of England developed a morbidity index adopted a morbidity index, which consists of morbidity of nervous system, circulatory system, musculoskeletal system and psycho-social morbidity in the measurement, for funding acute care, maternity care, drug prescription, inpatient mental healthcare (Sutton et al., 2002).

Similar to the limitations of standardised illness ratio, there remains no universally accepted morbidity index in the context of Hong Kong. It is thus suggested that this potential variable should not be considered in the Refined Population-based Model until this barrier is resolved. On the contrary, as it would be worthwhile to incorporate the prevalence of selected (or number of) chronic diseases, as a proxy measure of population health, into the model through the data reported by the HA's clinical database.

Fertility

In comparing with other adjustment factors for general health services, it is well known that fertility rate (i.e. probability of bearing a child among childbearing-age women) would be a more reliable and appropriate indicator to predict utilisation of obstetrics services. Currently, this indicator is included into the resource distribution formula for funding obstetrics care in the State of New South Wales of Australia (New South Wales Department of Health, 2005).

In Hong Kong, there is a well-established registration system to capture all known births occurred. Therefore it would be highly beneficial to undertake further study to see whether and how fertility rate should be incorporated into the Refined Population-based Model for obstetrics care is warranted.

Low Birth Weight

According to the WHO, low birth weight (LBW: a birth weight of a liveborn infant of less than 2,500 g) is one of the major causes of neonatal deaths worldwide and this factor is known to be associated with greater utilisation and resources for paediatric care services (World Health Organisation, n.d.b). In England, the proportion of LBW babies born in an area is considered as an adjustment factor in their capitation formula (Sutton et al., 2002).

In Hong Kong, there is a well-established registration system to capture all known births (including birth weight and related information) occurred. Therefore it would be highly beneficial to undertake further study to see whether and how LBW should be incorporated into the Refined Population-based Model for paediatric care is warranted.

Self-rated Health Status / Index

Previous literature generally agrees that measures of self-rated health are robust risk predictors for patient outcomes as mortality and healthcare utilisation. They have the advantage of being less expensive and less burdensome to collect, and could be conceivably collected at the point of care with relative ease (Yu & Dick, 2010). Thus, this variable has been used as an adjustment factor on resource allocation by the National Health Service of England for drug prescription of patients with ischaemic heart disease. Recently, this variable was suggested to be incorporated into the capitation formula for children in the States (Lamers, Vliet & Ven, 2003) and for private health insurance plans in the Netherlands (Desalvo et al., 2005).

In Hong Kong, despite information of self-rated health has been inconsistently collected from C&SD's Thematic Household Survey, it is not feasible to incorporate this variable into the Refined Population-based Model as any forms of geographical breakdown of the dataset is not possible. It is thus suggested that this potential variable should not be considered until this barrier is resolved.

Elderly Living in Residential Care Home

There may be significant difference in health status and needs of the elderly population living in old age homes vs. elderly residing in domestic households.

Research indicates higher emergency admission rates and hospital death rates among people from nursing and residential care homes (Godden & Pollock, 2001). On a similar note, there is an increased risk of admission for falls and injuries for people living in institutions (falls by nursing home residents in the United States are twice the rate for persons dwelling in the community (Ray, 1997)).

Adjustment on elderly residing in institutions is developed for the population-based model in the province of New South Wales in Australia, where an index based on private/non-private dwelling living arrangements for the elderly is used to adjust the Rehabilitation and Extended Service component of the funding model. Actually, an adjustment based on age-adjusted rates for people living alone is also incorporated (New South Wales Department of Health, 2005).

For Hong Kong, the Thematic Household Survey Report Number 21 (2005) published by the C&SD (Hong Kong Census and Statistics Department, 2005) shows that 53,900 (95.7%) of all institutional elderly reported to have chronic diseases in 2004, whereas 706,200 older persons (71.6%) of all the elderly residing in domestic households reported to have chronic diseases. Although, the population of institutional elderly was not in high proportion in total elderly population, they are likely to be frail and have limitations in activity of daily living and a significant proportion of unplanned hospital readmission. A study on the significance of differences on healthcare needs of elderly residing in institutions which may be unevenly distributed vs. private dwellings may be warranted.

Clinical Variables

Clinical factors generally are used to explain the difference in health cost due to **complexity and comorbidity of diseases**. Utilisation of healthcare service in terms of simple activities count may not exactly reflect the relative healthcare resources need. From a clinical prospectus, severity of illness, risk of mortality and potentially preventable events may affect the level of resources use **(3M**

Health Information System, n.d.). For the purpose of accurately report the utilisation of each Cluster, case complexity should be adjusted to ensure the utilisation is compared on an equal footing. Though clinical variables are vulnerable to manipulation so that it would not be included in the statistical modelling, clinical variables will be useful for model application at later stage.

<u>Clinical Risk Groups and Physiological Measures</u>

Huges et al (2004) proposed that the Clinical Risk Groups (CRGs) payment, where each diagnostic group should be adjusted for both chronic diseases and severity levels in the Centres for Medicare & Medicaid Services (CMS) resource allocation (Hughes et al., 2004). In the Netherlands, Lamers et al (2003) suggested that some physiological measures, such as blood glucose level, blood pressure, respiratory function and cardiac function should be incorporated into the resource allocation mechanism for health services **(Lamers, Vliet & Ven, 2003)**, despite its feasibility remains highly questionable.

<u>Costly Diagnostic Groups and Diagnostic Cost Groups / Hierarchical Condition Categories</u>

Adjustment for case complexity is applied in a number of population-based models around the world. For example, the CMS adopted the Diagnostic Cost Groups (DCGs) -Hierarchical Condition Categories (HCCs), which identifies an individual's complexity or seriousness based on risk-adjusted score, which is derived from their clinical diagnoses and socio-demographic (e.g., age/sex group, Medicaid status, disability status) information (3M Health Information Systems, n.d.), for Medicare capitation payments in the United States (Kautter et al., 2014). To predict spending for comparable beneficiaries who enrol in the Medicare Advantage programme (Part C), the DCG/HCC model regresses the expected cost in the fee-for-service setting on those explanatory variables (Shafrin, 2011). Coefficients obtained from regression analysis represent the marginal (additional) cost of the condition or demographic factor (Shafrin, 2011).

Lastly, hierarchies were imposed on the condition categories, assuring that more advanced and costly forms of a condition are reflected in a higher coefficient (Shafrin, 2011).

A similar risk-adjustment mechanism is adopted in Stockholm of Sweden, where they used Costly Diagnosis Groups (CDGs) for funding hospital services. In the Netherlands, prior use of durable medical equipment (DME) is considered as one of the adjusting variables in computing expenditure of sickness funds of social insurance (Andersson, Varde & Diderichsen, 2000). Apart from those mentioned, some form of diagnosis groups or casemix groups are used in jurisdictions such as British Columbia (Canada) (Kolbuch, 2001), Netherlands(Ministry of Health Welfare and Sport, 2008), and Ontario (Canada) (Ministry of Health and Long-Term Care, 2012).

In Hong Kong, Diagnosis Related Groups (DRG) has been used in describing Acute IP activities in HA. Such information has mainly been used internally for utilisation review and quality assurance. With regard to the Refined Population-based Model in HA, the benefit of incorporating such useful information is questionable. Any difference in case complexity is more likely to be related to historical supply and unlikely to be related to genuine differences in healthcare needs given the considerable sizes of the catchment populations of the seven Clusters. Furthermore, DRG is more likely to be perverse incentive and is vulnerable to manipulation, which may adversely affect the ultimate fairness in resource allocation. Incorporating casemix would unnecessarily complicate the model. It is thus suggested that this potential variable should not be considered in the Refined Population-based Model. However, it could be used to examine resource management in the application of the model.

Ambulatory Sensitive Hospitalisation Rate

Instead of case-mix, the New Zealand Ministry of Health recently considers to incorporate the ambulatory sensitive hospitalisation (ASH) rate into the resource allocation. Based on the formula, the ASH rate refers to the number of people who appear in hospital with conditions that could have been prevented or treated in out-of-hospital settings such as primary healthcare (Ministry of Health, 2016). The excess ASH of certain population represents part of healthcare needs have not been met in PHC setting and thus an adjustment of resource allocation for health services should be needed in modifying the situation.

However, incorporation of ASH rate as an adjustment factor for unmet needs in PHC is controversial, as stated by New Zealand Ministry of Health (Ministry of health, 2016). In addition to the strong correlation between social deprivation and ASH, ASHs can also be caused by poor quality of PHC. While it is difficult to distinguish service under-performers from true unmet needs in PHC, using ASH rate as an adjuster shall be cautioned. In the case of New Zealand, benchmarking against ASH rates for unmet need adjuster is considered as a less preferred option.

ASH rate could reflect PHC adequacy. **The admissions of the Ambulatory Care Sensitive Conditions (ACSCs) are believed to be preventable in most cases if adequate primary/ ambulatory care are provided.** A Hong Kong-specific ACSCs were developed to serve as indicators of avoidable hospitalisations taking into account local context and system constraints (Yeoh, Yam, Yam et al, 2016). Though ASH might not be included in the statistical modelling, it might be useful for model application.

Geographic Variables

Geography can play an important role in influencing both an individual's health status and their access to health services. Discussion of some identified variables, including urbanisation, distance, and remoteness, are included as follows.

Urbanisation and Rural Adjustment

Rural adjustments are sometimes made to cover the unavoidable costs in providing services for rural areas, as the population of these communities is widely dispersed. In New Zealand, this has resulted in an adjustment for the unavoidable differences in costs that a locality faces in providing services to rural communities and for the diseconomies of scale involved in maintaining a reasonable level of access to hospital services for rural communities (Ministry of Health, 2004). Similar adjustments exist in the England, Netherlands, Belgium and Stockholm City (Rice & Smith, 2001).

However, this adjustment factor might not be applicable to Hong Kong. 100% of population in Hong Kong has been residing in urban area since early-1990s (United Nations, 2014).

Distance

To quantify the accessibility of care, distance from healthcare facilities is often incorporated as a geographical factor for the healthcare needs of the population. In general, shorter distance from healthcare facilities implies a higher accessibility for the population. However, the relationship between accessibility and healthcare needs could be complex. An area with a lower accessibility does not necessarily mean that there is a lower healthcare need or reduced utilisation of all types of care services. For example, there might be greater needs for inpatient admission in remote and rural areas due to reduced access to general and SOP care in some settings.

The use of distance shall be reviewed together with the context of the health system. For the weighted capitation formula used in England, distances to both outpatient providers and admitted inpatient providers are included as supply factors to estimate the healthcare needs of the population (Leeds: Financial Planning and Allocations Division. 2011). Such dual inclusion could take account of the complex interplay between different types of care services and their associated accessibility.

In Hong Kong, the distance variable shall be interpreted in a different way, as compared with that used in country-level model. As mentioned above, remoteness and rural adjustment is almost negligible due to densely populated and urbanised development of Hong Kong. Geographically speaking, there is a relatively good coverage of the majority of services, offered by HA, for the population residing in any parts of Hong Kong. Such geographical settings allow long distance travel for healthcare services, especially with the highly efficient transportation system and road networks. In this context, distance to healthcare facilities should be incorporated in the Refined Population-based Model for the adjustment of the differential healthcare utilisation patterns among population residing at different districts or locations, rather for the needs of the population.

Remoteness

No matter in developing or developed countries, access is the major issue in rural health around the world. Even in the countries where the majority of the population lives in rural areas, the resources are concentrated in the cities. All countries have difficulties with transport and communication in rural and remote areas, and they all face the challenge of shortages of doctors and other health professionals for these areas. Many rural people are often caught in the poverty, ill health, low productivity and downward spiral, especially in developing countries (Strasser, 2003).

The province of British Columbia utilises a remoteness adjustment to account for the higher cost for delivering care in remote or rural areas due to travel, isolation and/or climate conditions, where remoteness is qualified by the distance from a major centre/acute care facility. In New South Wales (Australia) (New South Wales Department of Health, 2005), Accessibility and Remoteness Index of Australia is also used for adjustment for remote area of former Far West area.

However, this may not be applicable to Hong Kong, due to its relatively-small geographical area and highly-convenient transportation network. However, the relationship between healthcare utilisation and accessibility, measured by the distance between residence and healthcare facilities, needs to be considered to examine the effect on population in Cluster where healthcare services and facilities have been relatively under supply historically.

Unmet Needs

Unmet need can be defined as the inadequate availability of healthcare services deemed necessary to address a particular health problem (Marshall, Wong, Haggerty et al., 2010). Unmet need is often used in monitoring the accessibility of healthcare.

Unmet need is sometimes incorporated in population-based models to mitigate the risk of reinforcing health disparities in groups that systematically under-utilise health services relative to their healthcare needs. Since unmet need is concealed by the prevailing utilisation patterns, it would be necessary for the model to explicitly adjust for unmet needs if they exist. This adjustment could be policy-based, where ‘policy-weighted’ adjustment is made for aboriginals and homeless populations in New South Wales (Australia) (New South Wales Department of Health, 2005). In New Zealand a predetermined proportion of the global budget would be distributed according to the proportion of Maori, Pacific and deprived populations resident in each district (Ministry of Health, 2004).

Another approach has been employed by jurisdictions such as Scotland, where unmet need is quantified through extensive investigations and researchers found good evidence to justify an adjustment to the circulatory disease component of the acute index (NHS Scotland Resource Allocation Committee, 2007).

Despite its importance on influencing health need, it is not feasible to incorporate this variable into the Refined Population-based Model as there remains no universally accepted measure on this variable in the context of Hong Kong. It is thus suggested that this potential variable should not be considered in the Refined Population-based Model until this barrier is resolved.

Other Variables

Market Forces Factors

In the weighted capitation formula of England, market forces factor is included for adjusting the unavoidable cost differences between areas due to their geographical location alone (Leeds: Financial Planning and Allocations Division. 2011). For instances, it typically costs more to run a hospital in city centres, as compared with other areas, due to higher costs for staff, building and land.

Unlike the situation in England, these geographical factors are unlikely to affect the operation costs of a hospital or healthcare facility in Hong Kong. Geographic difference in the cost for employing staff in various districts is unapparent, due to the small land size and efficient transportation system of Hong Kong. Expenses on buildings and land are also not an issue, as establishment of a public hospital or healthcare facility is planned and managed by the Government, instead of through market competition.

Supply of Health Professional and Hospital Beds

The interplay between healthcare supply and demand is generally complex and dynamic. Higher availability of a healthcare service, due to larger supply of health professional and hospital beds, might be an incentive to attract more patients, who would probably expect a shorter waiting time and stronger health team for managing their ill conditions. Health institutions with higher service availability might require more resources to cover these expenditures. In practice, it is extremely difficult to distinguish supply-induced and need-based healthcare utilisation. Whether giving a higher weighting of resources for hospitals or clinics, which could offer more services, is always a controversial issue, especially in a population need-based resource allocation model. In the Hong Kong context, historical imbalance of supply of healthcare needs to be critically considered and adjustments need to address this in the model.

Private Sector Utilisation

Not all of the healthcare needs of the population are met by the public sector. Hong Kong has a dual-track healthcare system by which the public and private healthcare sectors complement each other. The public sector is the predominant provider of secondary and tertiary healthcare services. Around 88% of inpatient services (in terms of number of bed days) are provided by public hospitals. Apart from hospital services, the public sector also provides medical treatment and rehabilitation services to patients through specialist clinics and outreaching services.

The public healthcare system provides the Hong Kong population with equitable access to healthcare service at highly subsidised rates. The private sector complements the public healthcare system by offering choice to those who can afford and are willing to pay for healthcare services with personalised choices and better amenities. It provides a variety of choices of healthcare services, including PHC (about 70% of outpatient services in terms of attendance) as well as specialist and hospital care (Steering Committee, 2015; Food and Health Bureau, 2014). There were around 13,000 registered doctors in Hong Kong at 2014, about 60% of them worked in the private sector. There is clearly a distinct division of labour between the two sectors (Chan, 2011).

Overseas experience could be drawn using New Zealand's model, where the Adjacent DRG-specific "private hospital substitutable activity" and "public/private patient mix in public hospitals" are adjusted for (Ministry of Health, 2004).

In Hong Kong, statistics on public/private health expenditure, and throughputs (inpatient discharges and deaths) in medical institutions with hospital beds by area (HK Island, Kowloon, NT) in both public and private sectors are released by the Government (Hong Kong Food and Health Bureau, 2012; Hong Kong Census and Statistics Department, 2015) and can be used to assess the impacts of the use of private healthcare services on healthcare utilisation / resource needs in Hong Kong. However, due to limited readily available data (e.g. distribution of private clinics across Clusters, cross-cluster utilisation of private services), a number of hypothetical assumptions and ballpark estimations would be needed to assess impacts on regional/Clusters' healthcare services in term of dollars and throughputs if the use of private services (provided by both private clinics and hospitals) is to be incorporated into the Refined Population-based Model.

There are concerns raised at the Cluster Management Meetings that private sector utilisation would have impact on the overall health services utilisation. Further deliberation is needed to further consider whether this factor should be in the statistical modelling.

Previous Expenditure

Risk-adjusted capitation rates are calculated for their population with the use of their previous expenditure on healthcare in some health systems, such as the United States (Yu & Dick, 2010) and the Netherlands (Lamers, Van Vliet & van de Ven, 2003). Taking the Dutch system as example, risk adjusted subsidies calculated from basic needs variables are combined with "historical" costs. Historical costs are average cost, in terms of sickness funds in Dutch system, in an area of previous three years.

Nevertheless, the health systems, which use previous expenditure as a factor in the estimation of healthcare funding, are linked with social or private health insurance. For the health system in Hong Kong, neither social nor private insurance is the major source of healthcare financing. Therefore, this factor is unlikely to be applicable to the context of Hong Kong.

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Glossary Part E: Descriptions of Variables Selected for Model Building

The variables used for each factor and their definitions are listed below:

Demographics

Age	*Age < 20 years [Age<20]*: *Age >= 65 years [Age>=65]*:	Proportion of population aged below 20 years in each TPU Group Proportion of population aged 65 years and over in each TPU Group
Gender	*Male [% Male]*:	Proportion of male population in each TPU Group
Ethnicity	*Non-Chinese [% Non-Chinese]*:	Proportion of population of ethnicity other than Chinese in each TPU Group
Marital Status	*Non-married [% Non-married]*:	Proportion of population aged 15 and over being never married in each TPU Group. Under this definition, the non-married population did not include those who were widowed, divorced or separated.

Socioeconomic

Household income	*Median household income [Median Income]*:	Median monthly domestic household income of economically active domestic households in each TPU Group. Economically active household refers to a domestic household with at least one member, excluding foreign domestic helpers, being economically active.
Educational Level	*Post-secondary education [% Post-secondary education]*:	Proportion of non-student population aged 20 and over having attained post-secondary education in each TPU Group
Employment status	*Unemployment [% Unemployment]*:	Proportion of labour force not in working population in each TPU Group. Labour force refers to economically active population, comprising the employed (working population) and the unemployed. Working population refers to persons aged 15 and over who should have formal job attachment or be engaged in performing work for pay or profit during the seven days before the Census. Working population includes employees, employers, self-employed persons and unpaid family workers.
Type of housing	*Public rental housing [% Public rental housing]*:	Proportion of population living in public rental housing in each TPU Group

Housing tenure: Shared residential unit	*Shared residential unit*:	Average number of domestic households per 1000 units of quarters occupied by domestic households in each TPU Group
Older singleton	*Older singleton [% singleton]:*	Proportion of population aged 65 and over living domestic households, which the household size is one, in each TPU Group

Epidemiological

Standardised mortality rate	*Standardised mortality rate [SMR]:*	Standardised mortality rate is a ratio between observed number of deaths in Hong Kong between 2010 and 2012 to the number of expected deaths, based on the age- and sex-specific mortality of rates of the entire Hong Kong population over the 3-year period and the age and sex distribution of population in each TPU Group in 2011
Chronic disease:	*% Chronic disease:*	Proportion of population aged 60 and over, who were admitted to the specialty of Medicine with any of the following 15 pre-defined chronic conditions in each TPU group: (i) nutritional deficiencies (ii) malignant neoplasms (iii) diabetes mellitus (iv) epilepsy (v) dementia, other degenerative and hereditary central nervous system disorders (vi) Parkinson disease (vii) ischaemic heart disease (viii) heart failure (ix) cerebrovascular disease (x) chronic obstructive pulmonary disease (xi) Bronchiectasis (xii) cirrhosis of liver (xiii) gastrointestinal haemorrhage (xiv) chronic renal failure (xv) chronic ulcer of skin
Living in residential care home	*% Living in residential care home [% live in RCHE]:*	Proportion of population aged 65 and over living in non-domestic households. An assumption that the majority of persons at this age group in non-domestic households was living in residential care homes for the elderly was made.

Geographical

Distance	*Weighted distance:*	A distance weighted for the geographic proximity to health service for population in each TPU Group. It is calculated by dividing the Euclidean distance between the geographic centroid of TPU Group and the location of hospital or clinic by the summation of Euclidean distance between the geographic centroid of TPU Group and all hospitals or clinics providing the same type of health service.

Supply

No. Of hospital beds	*No. of scheduled acute beds [no. of acute beds]*	Number of scheduled acute beds in each hospital on 31st March of each year, adjusted for the proportion of DS (for the Acute IP Model)
	No. of scheduled non-acute beds [no. of acute beds]	Number of scheduled non-acute beds in each hospital on 31st March of each year, adjusted for the proportion of DS (for the Non-acute IP Model)
Health professional supply	*FTE strength of doctors [Doctor FTE]*	Full-time equivalent doctors, excluding those in (i) A&E, (ii) Anaesthesia, (iii) FM & OPD/Staff Clinics/GOPC, (iv) Others – e.g. Hospital Mgt/HO, (v) Pathology, and (vi) Radiology at each institution. Adjustment was made for excluding manpower used for DS (for the SOP model)
	FTE strength of doctors in FM [FM Doctor FTE]	Full-time equivalent doctors in FM & OPD/Staff Clinics/GOPC/SOPD specialty at each institution (for the PHC Model)
	FTE strength of doctors in A&E [A&E Doctor FTE]	Full-time equivalent doctors in A&E specialty at each hospital (for the A&E model)
	FTE strength of Allied Health professionals [AH Prof. FTE]	Full-time equivalent staff, including (i) clinical psychologist, (ii) dietitian, (iii) medical social workers, (iv) occupational therapist, (v) optometrist, (vi) orthoptist, (vii) physiotherapist, (ix) podiatrist, (x) prosthetist and orthoptist, (xi) scientific officer (medical) (audiology), (xii) social workers, and (xiii) speech therapist, at each hospital (for the AHOP model)

Others

Year	Financial year of HA, which starts from 1st April of each year and ends at 31st March in the next year.
Population	Population refers to the Hong Kong resident population, covering both usual residents and mobile residents, in each TPU Group at the reference moment of 2011 Population Census. Report of Projections of Population Distribution 2013-2021 is used to obtain the population distribution between census years, while Report of Projections of Population Distribution 2015-2024 is used to project the population distribution in the coming years.

Glossary Part F: Technical Adjustments on Variables

Projection of Population Variables

Reports of Projections of Population Distribution issued by Planning Department were able to provide the observed population size of each TPU Group between 2011 and 2014, as well as projected population size at the same spatial unit by 2020. However, the annual changes of population figures between 2011 and 2020 by age groups could only be available at district level. The proportions of population aged below 20 (children) and population aged 65 and over (elderly) were estimated by the following mathematical expressions.

$$Proportion\ of\ children\ _t^{TPU}$$
$$= Proportion\ of\ children_{t-1}^{TPU} \times \frac{Proportion\ of\ children_t^{District}}{Proportion\ of\ children_{t-1}^{District}} \times \frac{Proportion\ of\ population_{t-1}^{District}}{Proportion\ of\ population_t^{District}}$$

$$Proportion\ of\ elderly\ _t^{TPU}$$
$$= Proportion\ of\ elderly_{t-1}^{TPU} \times \frac{Proportion\ of\ elderly_t^{District}}{Proportion\ of\ elderly_{t-1}^{District}} \times \frac{Proportion\ of\ population_{t-1}^{District}}{Proportion\ of\ population_t^{District}}$$

Each formula above involves three components. The first component is the proportion of children or elderly in the previous year (i.e. $Proportion\ of\ children_{t-1}^{TPU}$ or $Proportion\ of\ elderly_{t-1}^{TPU}$). The second component represents the rate of change of children or elderly, following that for their respective District, while the third component was included for adjustment for the difference of the population size of TPU Group within the same District.

While there is a lack of information about the projected figures of other population variables at TPU Group level, variables other than the age group proportion were assumed to remain unchanged over the study period.

Adjustment on Supply Factors

For inpatient services, the number of scheduled bed was adjusted to carve out DS. The adjustment was made by calculating the proportion of BDO attributed to DS for each specialty *s* in each hospital *h* using the following formula:

$$\text{Number of scheduled bed}_{Core\ \ service,s,h}$$
$$= \text{ Total number of scheduled bed}_{s,h} \times (\,1 - \frac{\text{Bed days occupied}_{Designated\ service,s,h}}{\text{Bed days occupied}_{All\ service,s,h}}\,)$$

Likewise, the number of FTE staff in outpatient settings was adjusted to exclude DS for modelling, as well as to handle the limitation that manpower data was only available at hospital level. The adjustment was similarly made by calculating the proportion of attendances attributed to DS in hospital h, which *n* clinics (c_1 c_2,…, c_n) *were under its management,* using the following formula:

$$\text{Number of FTE staff in clinic}_{\,ci\ Core\ service}$$
$$= \text{ Total number of FTE}_{\,h} \times (\,1 - \frac{\text{attendances}_{Designated\ service,h}}{\text{attendaces}_{All\ service,h}}\,) \times \frac{\text{attendances at } c_i}{\sum_{i=1}^{n} \text{attendances at } c_i}$$

Glossary Part G: Cluster Resource Analysis for 2012/13 to 2015/16

Expenditure Covered by the Analysis

HA expenditure comprises operating expenditure and capital expenditure. Operating expenditure refers to the expenditure to run HA's day-to-day hospital services. It covers manpower, drug, consumables and daily maintenance of equipment and facilities, etc. but is separated from capital expenditure (e.g. for capital works projects, major equipment acquisition, corporate-wide Information Technology development)

Since the subject of interest is equity of healthcare expenditure, it is important to perform the following steps on HA expenditure which can enable data cleansing so as to generate a suitable dataset for the Cluster resource analysis, as well as building the Refined Population-based Model.

Step 1: Exclude capital expenditure

HA’s capital expenditure is incurred for designated uses and are centrally planned under a separate mechanism for corporate-wide standards. Capital expenditure does not directly relate to day-to-day running of core hospital services and it varies years from years due to the following reasons:

i) Facilities maintenance and improvement works projects
   Capital expenditure on facilities maintenance and improvement work projects varies between Clusters due to long planning cycles and different phases for improving the infrastructure to meet service needs.

ii) Medical equipment

The different in the phasing of replacement cycle for medical equipment results in variation of capital expenditure incurred for medical equipment among Clusters.

iii) IT System Development

The IT system development in HA are mainly centrally administered. The corresponding expenditure is separately funded and is not directly relevant to Clusters' day-to-day operation.

Hence, capital expenditures should be excluded from analysis to facilitate like-with-like comparison of resource used for core hospital services between Clusters.

Step 2: Carving out Designed Services

It is common for public healthcare systems to organise highly specialised services (labelled as Designated Services (DS)) and operations in designated locations so as to benefit from concentration of expertise (not only of healthcare professionals but also technology setup and facility design, etc.) and economies of scale. This is particularly relevant in Hong Kong in view of the size of its population and territory.

As DS are provided in designated institutions for the entire population of Hong Kong, they serve populations beyond their Cluster boundary and thus are outside of the scope of the Clustering concept and in turn the Refined Model to facilitate resource allocation. After deliberation at the Internal Resource Allocation Model Development Steering Committee (IRAMD SC) and with the external consultant, it was decided that DS should be carved out from the Refined Model such that the remaining core hospital and clinic services are more comparable in terms of scope, nature, and the target population (i.e. within the Cluster's catchment locations) intended to serve, which in turn would minimise any potential bias that may result from the varying provision of DS in different Clusters. For more information on the detailed definition of DS, their costing methodologies and corresponding results, please refer to the report "Costing of Designated Services 2012/13 to 2015/16".

Step 3: Performing Other Adjustments to Facilitate Like-with-like Comparison

In order to facilitate like-with-like comparison of the resources used for the provision of core hospital services, the following adjustments have also been performed apart from excluding the resources and activities of DS:-

(a) Expenditure not related to Day-to-day Public Services

Resources unrelated to day-today public services are not attributable to the provision of core hospital services, in which should be excluded from Clusters' recurrent resource:

(i) Private services

Private services are not public services and are not common across Clusters. Thus, the corresponding costs and activities should be carved out from the analysis. Costs of private services are not readily available. For 2012/13, private service income (extracted from general ledger) was used as a proxy to reflect the costs of private services. For other relevant years (i.e. 2013/14 – 2015/16), to avoid the distortion arising from 2013 fee revision, the unit cost of services was based on 2012/13 information and applied to the private patient activities to come up with the estimation of cost of private services in each year.

(ii) Alternative Source of Income (ASOI) related expenditure

Since 1991, HA has been initiating different kinds of new activities which have generated additional income. In 1999, it was agreed with Government that such income could be classified as ASOI. As ASOI is not related to core hospital services, those related expenditures (extracted from general ledger) should be excluded from the analysis.

(iii) Services to outsiders

Resources and activities for services provided to outsiders (i.e. Department of Health, Universities, Labour Department, Correctional Services Department and private hospitals) are not related to core hospital services. To compile Annual Costing information, hospitals have been reporting this information to Head Office. This information would be excluded from Clusters' resources for like-with-like comparison.

(iv) Hospital commissioning

Expenditures related to hospital redevelopment, expansion and development are project-based spending and not related to core hospital services. Such costs should not be counted for as Clusters' resources. Such information is also reported by hospitals during Annual Costing exercise.

(b) Expenditure Borne by Patients

Self-financing drug items (SFI Drugs) and expenditures related to non-standard Positron Emission Tomography (PET) services provided by the Queen Elizabeth Hospital (QEH) and the Pamela Youde Nethersole Eastern Hospital (PYNEH)_, are borne by patients. The cost information can be extracted from general ledger and would be excluded from Clusters' resources. Privately Purchased Medical Items (PPMI) are purchased by hospitals on behalf of patients and do not treated as hospital expenditure.

(c) Expenditure related to Policy Directed Initiatives

In order to assure like-with-like comparison of expenditure attributable to the provision of core hospital services, resources relating to policy directed initiatives should be excluded from Clusters' resources.

Expenditures (extracted from general ledger) relating to clinical Public-Private Partnership (PPP) Programme, designated/enhanced services to Civil Service Eligible Persons, community health call centre (located at Ruttonjee Hospital and Kwai Chung Hospital) are adjusted. For clinical PPP programme, as the services rolled out to some districts only, resources and activities of clinical PPP should be carved out of Clusters' resources at this stage. This adjustment could be further reviewed with future development.

Resources relating to support for public crisis (i.e. lead in drinking water incident), nursing schools and special accommodation ward (located at PYNEH and Ruttonjee Hospital) are also excluded from the analysis. This costing information is reported by hospitals during the Annual Costing exercise.

(d) Technical Adjustments

(i) Electricity

Electricity is charged at different rates by two local electricity providers covering the Hong Kong Island, Kowloon and the New Territories. In order to minimise the distortion arising from different electricity tariff, the lowest unit cost of electricity among Clusters (estimated by Clusters' total electricity cost divided by total consumption unit) is chosen as the base unit cost to adjust the electricity tariff. In particular, the adjusted electricity tariff of each Cluster is computed by multiplying the base unit cost with the respective number of electricity unit consumed and the difference will be excluded from Clusters' operating expenditure to facilitate like-with-like comparison.

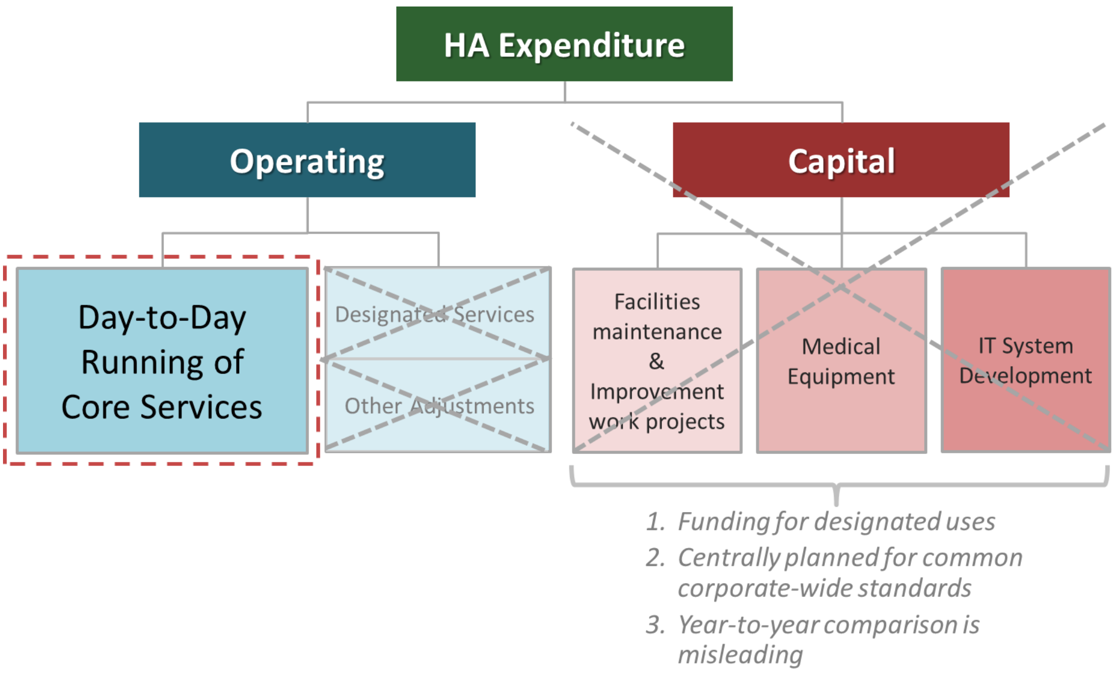
(ii) Inter-cluster services

Clusters would provide/receive services to/from other Clusters. Inter-cluster services include staff services, centralised laundry services[18], food provision, radiology examination and laboratory tests. To match cost with activity, inter-cluster services are reported and mutually agreed by involving hospitals during the Annual Costing exercise. For the purpose of analysis, this information agreed by respective hospitals has been adopted in this costing exercise.

(iii) Resources centrally administrated by Head Office

Expenditure centrally administrated by Head Office that is necessary for the provision of core hospital services should be allocated to Clusters to reflect the resources required. Adjustment for Public-Private Partnership Project of Food Services (PPP food) has been made in respective years.

After performing the above steps for data cleansing, the resources to be analysed are illustrated below:



Glossary G: Figure 1 – Expenditure covered by the analysis

[18] In the 7th IRAMD SC meeting held in February 2016, members opined that centralised laundry, should be handled as a model adjustment, namely in the form of inter-cluster services, rather than treating it as a DS

The diagram showing the Profile of Clusters' Recurrent Resource for 2012/13 to 2015/16 (in terms of percentage) is also illustrated as Glossary G: Figure 3.

Deriving Actual Resources of Cluster for the Eight Core Hospital Services

After carving out resources of DS and other adjustments mentioned above from the Cluster recurrent resources to facilitate like-with-like comparison, the resource would be further grouped into the following eight core hospital services (which represents around 99% of HA's total service cost throughout 2012/13 to 2015/16) for the purpose of Cluster resource analysis:

Primary Care includes General Outpatient Clinic, Family Medicine Specialist Clinic, Integrated Mental Health Program, Risk Factor Assessment and Management Programme

Glossary G: Figure 2 – Core hospital services in HA

The relativity of the eight core hospital services under Specialty Costing would be used as a proxy to split the Recurrent Fund into resources for eight core hospital services as mentioned above. Please refer to Glossary G: Table 1 – Glossary G: Table 4 for Resources of Core Hospital Services for 2012/13 to 2015/16, respectively.

Deriving Inferred Resources of Cluster for the Eight Core Hospital Services

In order to identify Clusters with resources below HA average, Inferred Resources is defined as the resources required for providing eight core hospital services based on HA average unit cost. For Acute IP service, the average unit cost also incorporated adjustments for case complexity (Casemix adjustment). The following steps are taken to derive the Inferred Resources of Clusters for the provision of core hospital services.

- HA average unit cost of each service is computed as dividing HA total resources of each service (after carving out DS and other adjustments) by respective adjusted activities for DS and other adjustments (where relevant) of each services.

- Please refer to Glossary G: Table 5 for Unit Cost of Core Hospital Services (after carving out DS and other adjustments) for 2012/13 to 2015/16.

- The Inferred Resources of each service is derived by multiplying Cluster's adjusted activities and respective HA average unit cost.

- For Acute IP service, case complexity is adjusted by assigning Acute IP episodes to DRG based on demographic data (such as age and sex) and clinical data (such as diagnoses and procedures). Each DRG is weighted according to the resource consumption data such as length of stay and the magnitude of the performed operations. The more complex the case, the higher the weight as a result.

Calculating Percentage of Share of Resources

Based on the steps mentioned above, Actual Resources and Inferred Resources of each Cluster are calculated.

Observed Share of Resources is hereby defined as the percentage of Cluster's Actual Resources to total Cluster recurrent resources (after carving out resource of DS and other adjustments); whilst Inferred Share of Resources is defined as the percentage of Inferred Resources of Cluster to total Cluster recurrent resources for the provision of core hospital services.

Calculating Variance in Share of Resources (%)

To analyse whether Cluster deployed resources more than HA average for the provision of core hospital services, Observed Share of Resources should be compared with Inferred Share of Resources. For comparison purpose, "Variance in Share of Resources (%)" is defined as Observed Share of Resources less Inferred Share of Resources. Positive sign in Variance (%) indicated that the Cluster deployed relatively more resources than HA Average, and vice versa.

Please also refer to Glossary G: Table 6 – Glossary G: Table 9 for Calculation of Variance in Share of Resources (%) for 2012/13 to 2015/16 respectively.

$Million	Calculation of Core Hospital Service Resources for 2012/13							
	HKEC	HKWC	KCC	KEC	KWC	NTEC	NTWC	Total
Cluster recurrent resources	4,748	5,192	5,933	4,335	9,510	7,032	5,469	42,219
Less: Resources of DS	-	1,136	521	20	247	605	341	2,870
Less: Other adjustments:-								
Expenditure not related to day-to-day public services								
- ASOI related expenditure	29	46	17	6	44	31	24	197
- Private services	8	174	16	-	2	76	-	276
- Services provided to outsiders (i.e. Department of Health, Universities, Labour Department, Correctional Services Department and private hospitals)	33	-	22	15	6	15	22	113
- Hospital commissioning (UCH, NLTH)	-	-	-	3	47	-	-	50
Expenditure borne by patients	125	264	183	60	146	179	96	1,053
Expenditure related to policy directed initiatives								
- Clinical PPP programme	3	-	-	-	-	3	4	10
- Designated / enhanced services to Civil Service Eligible Persons	9	1	44	-	-	35	-	89
- Special accommodation wards	38	-	-	-	-	-	-	38
- Nursing schools	7	9	24	4	7	13	17	81
Technical adjustments								
- Electricity	45	38	6	10	18	-	6	123
- Inter-cluster services	32	17	(23)	(15)	(54)	(27)	70	-
- Resources centrally administrated by HO	-	-	(12)	-	-	-	(15)	(27)
Total other adjustments	329	549	277	83	216	325	224	2,003
Resources of Core Hospital Services	4,419	3,507	5,135	4,232	9,047	6,102	4,904	37,346

Glossary G: Table 1 – Resources of core hospital services for 2012/13

$Million	Calculation of Core Hospital Service Resources for 2013/14							
	HKEC	HKWC	KCC	KEC	KWC	NTEC	NTWC	Total
Cluster recurrent resources	5,040	5,554	6,342	4,695	10,265	7,466	5,869	45,231
Less: Resources of DS	-	1,191	563	23	274	618	360	3,029
Less: Other adjustments:-								
Expenditure not related to day-to-day public services								
- ASOI related expenditure	32	46	19	6	42	33	24	202
- Private services	6	193	14	-	3	62	-	278
- Services provided to outsiders (i.e. Department of Health, Universities, Labour Department, Correctional Services Department and private hospitals)	40	1	26	14	6	14	24	125
- Hospital commissioning (UCH, NLTH, TSWH)	-	-	-	3	58	-	3	64
Expenditure borne by patients	145	311	214	69	168	198	108	1,213
Expenditure related to policy directed initiatives								
- Clinical PPP programme	3	-	-	-	-	4	4	11
- Designated / enhanced services to Civil Service Eligible Persons	10	3	48	-	-	35	-	96
- Special accommodation wards	40	-	-	-	-	-	-	40
- Nursing schools	6	9	17	3	10	13	14	72
Technical adjustments								
- Electricity	43	41	7	9	25	-	8	133
- Inter-cluster services	23	18	(21)	(14)	(49)	(28)	71	-
- Resources centrally administrated by HO	-	-	(16)	-	-	-	(17)	(33)
Total other adjustments	348	622	308	90	263	331	239	2,201
Resources of Core Hospital Services	4,692	3,741	5,471	4,582	9,728	6,517	5,270	40,001

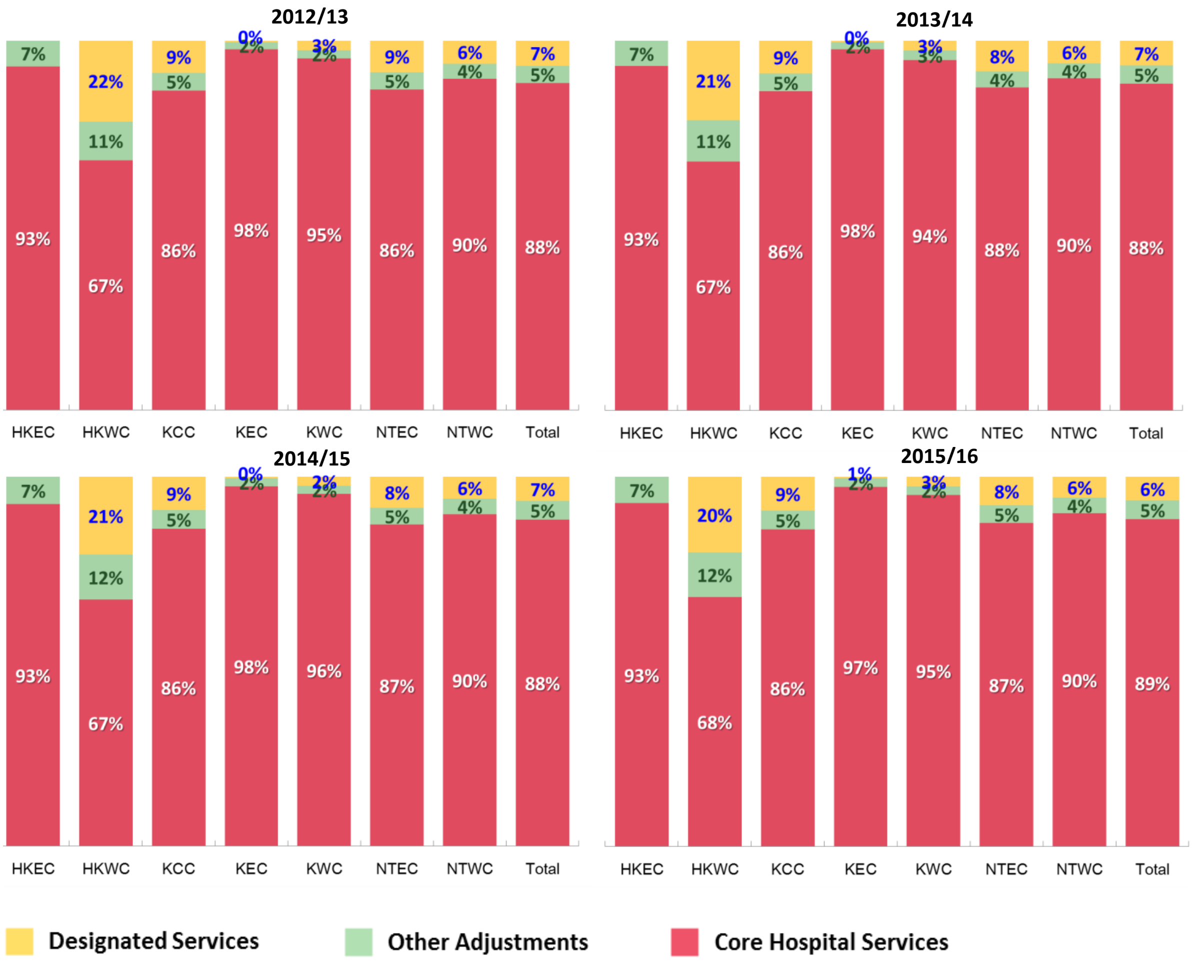
Glossary G: Table 2 – Resources of core hospital services for 2013/14

$Million	Calculation of Core Hospital Service Resources for 2014/15							
	HKEC	HKWC	KCC	KEC	KWC	NTEC	NTWC	Total
Cluster recurrent resources	5,412	5,933	6,803	5,168	11,187	8,034	6,408	48,945
Less: Resources of DS	-	1,253	614	26	279	673	383	3,228
Less: Other adjustments:-								
Expenditure not related to day-to-day public services								
- **ASOI related expenditure**	32	45	19	8	43	34	26	207
- **Private services**	5	220	20	-	3	66	-	314
- **Services provided to outsiders (i.e. Department of Health, Universities, Labour Department, Correctional Services Department and private hospitals)**	47	1	26	16	7	18	27	142
- **Hospital commissioning (UCH, TSWH)**	-	-	-	4	-	-	3	7
Expenditure borne by patients	164	380	242	81	185	226	124	1,402
Expenditure related to policy directed initiatives								
- **Clinical PPP programme**	-	-	-	-	-	-	4	4
- **Designated / enhanced services to Civil Service Eligible Persons**	10	3	51	-	-	36	-	100
- **Special accommodation wards**	45	-	-	-	-	-	-	45
- **Community health call centre**	34	-	-	-	21	-	-	55
- **Nursing schools**	4	10	20	3	12	14	15	78
Technical adjustments								
- **Electricity**	41	41	6	9	28	-	7	132
- **Inter-cluster services**	21	20	(26)	(14)	(52)	(27)	78	-
- **Resources centrally administrated by HO**	-	-	(17)	-	-	-	(19)	(36)
Total other adjustments	403	720	341	107	247	367	265	2,450
Resources of Core Hospital Services	5,009	3,960	5,848	5,035	10,661	6,994	5,760	43,267

Glossary G: Table 3 – Resources of core hospital services for 2014/15

$Million	Calculation of Core Hospital Service Resources for 2015/16							
	HKEC	HKWC	KCC	KEC	KWC	NTEC	NTWC	Total
Cluster recurrent resources	5,775	6,457	7,235	5,561	12,011	8,742	7,026	52,807
Less: Resources of DS	-	1,324	667	29	315	680	397	3,412
Less: Other adjustments:-								
Expenditure not related to day-to-day public services								
- **ASOI related expenditure**	32	45	23	10	47	36	24	217
- **Private services**	4	211	18	-	1	58	-	292
- **Services provided to outsiders (i.e. Department of Health, Universities, Labour Department, Correctional Services Department and private hospitals)**	47	2	26	16	11	35	32	169
- **Hospital commissioning (UCH, TSWH)**	-	-	-	5	-	-	24	29
Expenditure borne by patients	176	435	265	94	206	253	137	1,566
Expenditure related to policy directed initiatives								
- **Clinical PPP programme**	1	-	-	2	1	-	6	10
- **Designated / enhanced services to Civil Service Eligible Persons**	11	3	54	-	-	39	-	107
- **Special accommodation wards**	44	-	-	-	-	-	-	44
- **Community health call centre**	38	-	-	-	28	-	-	66
- **Nursing schools**	-	11	21	3	14	32	17	98
- **Support to public crisis**	-	-	-	-	1	-	-	1
Technical adjustments								
- **Electricity**	43	45	8	11	28	-	7	142
- **Inter-cluster services**	17	32	(27)	(17)	(58)	(32)	85	-
- **Resources centrally administrated by HO**	(1)	(11)	(28)	(1)	(6)	(5)	(33)	(85)
Total other adjustments	412	773	360	123	273	416	299	2,656
Resources of Core Hospital Services	5,363	4,360	6,208	5,409	11,423	7,646	6,330	46,739

Glossary G: Table 4 – Resources of core hospital services for 2015/16



Glossary G: Figure 3 – Profile of Clusters' recurrent resources

($)	HA Average Unit Cost			
	2012/13	2013/14	2014/15	2015/16
Acute IP	3,990	4,146	4,396	4,650
Non-acute IP	1,863	1,952	2,080	2,163
SOP	1,105	1,133	1,188	1,251
PHC	342	367	391	417
A&E	848	934	1,022	1,102
AHOP	334	348	362	377
Day Hospital	1,252	1,318	1,366	1,434
Community Care	534	555	597	652

Glossary G: Table 5 – HA average unit cost by core service

	Calculation of Variance in Share of Resources for 2012/13							
	HKEC	HKWC	KCC	KEC	KWC	NTEC	NTWC	Total
Actual Resources ($Million)	4,419	3,507	5,135	4,232	9,047	6,102	4,904	37,346
Observed Share of Resources (%) [O]	11.83%	9.39%	13.75%	11.33%	24.23%	16.34%	13.13%	100%
Inferred Resources* ($Million)	4,397	3,568	5,039	4,161	9,083	6,117	4,980	37,346
Inferred Share of Resources (%) [E]	11.77%	9.55%	13.49%	11.14%	24.32%	16.38%	13.33%	100%
Variance in Share of Resource (%) [O] – [E]	0.06%	(0.16%)	0.26%	0.19%	(0.10%)	(0.04%)	(0.20%)	

** Inferred Resources: Acute IP adjusted for case complexity*

Glossary G: Table 6 – Calculation of variance in share of resources for 2012/13

	Calculation of Variance in Share of Resources for 2013/14							
	HKEC	HKWC	KCC	KEC	KWC	NTEC	NTWC	Total
Actual Resources ($Million)	4,692	3,741	5,471	4,582	9,728	6,517	5,270	40,001
Observed Share of Resources (%) [O]	11.73%	9.35%	13.68%	11.45%	24.32%	16.29%	13.18%	100%
Inferred Resources* ($Million)	4,641	3,854	5,331	4,494	9,729	6,588	5,364	40,001
Inferred Share of Resources (%) [E]	11.60%	9.64%	13.33%	11.24%	24.32%	16.47%	13.41%	100%
Variance in Share of Resource (%) [O] – [E]	0.13%	(0.28%)	0.35%	0.22%	(0.00%)	(0.18%)	(0.23%)	

** Inferred Resources: Acute IP adjusted for case complexity*

Glossary G: Table 7 – Calculation of variance in share of resources for 2013/14

	Calculation of Variance in Share of Resources for 2014/15							
	HKEC	HKWC	KCC	KEC	KWC	NTEC	NTWC	Total
Actual Resources ($Million)	5,009	3,960	5,848	5,035	10,661	6,994	5,760	43,267
Observed Share of Resources (%) [O]	11.58%	9.15%	13.52%	11.64%	24.64%	16.16%	13.31%	100%
Inferred Resources* ($Million)	4,968	4,117	5,788	4,944	10,552	7,031	5,867	43,267
Inferred Share of Resources (%) [E]	11.48%	9.52%	13.38%	11.43%	24.39%	16.25%	13.56%	100%
Variance in Share of Resource (%) [O] – [E]	0.09%	(0.36%)	0.14%	0.21%	0.25%	(0.09%)	(0.25%)	

** Inferred Resources: Acute IP adjusted for case complexity*

Glossary G: Table 8 – Calculation of variance in share of resources for 2014/15

	Calculation of Variance in Share of Resources for 2015/16							
	HKEC	HKWC	KCC	KEC	KWC	NTEC	NTWC	Total
Actual Resources ($Million)	5,363	4,360	6,208	5,409	11,423	7,646	6,330	46,739
Observed Share of Resources (%) [O]	11.48%	9.33%	13.28%	11.57%	24.44%	16.36%	13.54%	100%
Inferred Resources* ($Million)	5,205	4,461	6,225	5,365	11,322	7,687	6,474	46,739
Inferred Share of Resources (%) [E]	11.14%	9.55%	13.32%	11.48%	24.22%	16.45%	13.85%	100%
Variance in Share of Resource (%) [O] – [E]	0.34%	(0.22%)	(0.04%)	0.09%	0.22%	(0.09%)	(0.31%)	

** Inferred Resources: Acute IP adjusted for case complexity*

Glossary G: Table 9 – Calculation of variance in share of resources for 2015/16

Glossary Part H: Capacity Utilisation Calculation

By comparing the service utilisation projected by the Refined Population-based Model and the service capacity in each Cluster, a measure of elasticity or their ability to accommodate additional demand could be worked out:

$$Capacity\ Utilisation\ = \frac{Utilisation}{Service\ Capacity}$$

Proxy for Service Capacity

As the utilisation would be projected by the Refined Population-based Model, utilisation would be measured in terms of Bed Days Occupied (BDO) for inpatient services and number of attendance for outpatient services. On the other hand, as the measurement of service capacity could be multi-dimensional, a suitable supply factor should be chosen for each service category to be the proxy of capacity.

Core Service	Proxy for Service Capacity	Data Source
Acute Inpatient (Acute IP)	No. of scheduled acute beds	Head Office Strategy & Planning (HO S&P)
Non-acute Inpatient (Non-acute IP)	No. of scheduled non-acute beds	
Specialist Outpatient (SOP)	FTE strength of doctors related to specialties with SOP activity (i.e., excluding Accident & Emergency, Family Medicine, Intensive Care Unit, Management/Head Office, Pathology and Radiology)	Head Office Human Resources (HO HR)
Primary Care (PHC)	FTE strength of doctors under Family Medicine & GOPC doctors	
Accident and Emergency (A&E)	FTE strength of doctors under A&E including SHS	
Allied Health Outpatient (AHOP)	FTE strength of allied health professionals in streams that correlate with the service throughput of AHOP	

Glossary H: Table 1 – Proxies for service capacity

While such proxy should be a surrogate for the actual ability of Clusters to provide service, data availability issues would also need to be taken into account. Glossary H: Table 1 shows the proxies used for service capacity for the six core services for 2015/16 and 2016/17.

Acute and Non-acute IP

As the most straight-forward and internationally recognised proxy for capacity of inpatient services in hospitals, the number of acute and non-acute beds were chosen as surrogates for capacity for Acute and Non-acute IP respectively. In particular, the number of “scheduled beds”, defined as beds with manpower and other necessary resources allocated to them for service provision, was chosen over the “bed complement” (HA’s official planned bed capacity as presented on the Controller Officers’ Report) as the number of “scheduled beds” would better reflect the true capacity of hospitals. The number of acute and non-acute scheduled beds broken down by hospital was collected from the HO S&P.

SOP

Unlike inpatient services where the number of beds could act as a reasonable proxy for capacity, no equivalent entity exists for outpatient services. With capacities measures like the number of quota and sessions being vulnerable for manipulation, it was decided that the amount of manpower available, in terms of FTE strength of doctors in each hospital, for the service be utilised for the purpose of this analysis.

To arrive at a better surrogate, doctors in specialties that do not have service throughput in SOP were excluded. Such specialities include Accident and Emergency, Family Medicine, Intensive Care Unit, Management/Head Office, Pathology and Radiology. The FTE strength information was collected from HO HR.

PHC

Similar to SOP, the amount of manpower available in each hospital for PHC service was selected a proxy for service capacity. Specifically, the FTE strength of doctors in specialty Family Medicine (FM) was employed. One limitation of using the total FTE strength in FM was that not all FM doctors would be providing PHC outpatient services (e.g. trainees, doctors seconded outside of HA, etc.). Nevertheless, the total number was deemed to be a reasonable proxy for the purpose of this analysis. The FTE strength information was collected from HO HR.

A&E

The FTE strength of doctors in specialty “A&E” in each hospital was employed as capacity of A&E. Recognising the popularity of utilising the special honorarium scheme (SHS) in meeting service demand in A&E, the amount of SHS, converted to the number of FTE through application of average salary of a resident, was also included. The FTE strength as well as related SHS information was collected from HO HR.

AHOP

The FTE strength of allied health professionals in each hospital was employed as a proxy for service capacity for AHOP service. Similar to SOP, FTE of AH streams that correlate with the service throughput of AHOP would be included (listed below).

Allied Health Streams	Included
Audiology Technician	
Clinical Psychologist	✓
Dental Technician	
Dietitian	✓
Medical Laboratory Technologist	
Medical Social Workers	✓
Mould Laboratory Technician	
Occupational Therapist	✓
Optometrist	✓
Orthoptist	✓
Physicist	
Physiotherapist	✓
Podiatrist	✓
Prosthetist & Orthotist	✓
Radiographer (Diagnostic)	
Radiographer (Therapeutic)	
Scientific Officer (Medical) (Audiology)	✓
Scientific Officer (Medical) (Pathology)	
Scientific Officer (Medical) (Radiology)	
Scientific Officer (Medical) (Radiotherapy)	
Social Workers	✓
Speech Therapist	✓

Glossary H: Table 2 – The list of FTE strength information for AHOP service

Estimating Capacity for 2017/18

With the analysis conducted in financial year 2017/18, actual data for 2017/18 for the aforementioned capacity proxies is not yet available. As such, relevant planning information was incorporated (with details below) to estimate the additional amount of capacity in 2017/18.

Core Service	Basis for Estimating 2017/18 Additional Capacity over 2016/17 Level	Data Source
Acute IP	Bed opening plan 2017/18	HO Strategy & Planning (HO S&P)
Non-acute IP	Bed opening plan 2017/18	
SOP	Additional FTE per 2017/18 approved Annual Plan proposals	Annual Planning System
PHC	Additional FTE per 2017/18 approved Annual Plan proposals	
A&E	Additional FTE per 2017/18 approved Annual Plan proposals	
AHOP	Additional FTE per 2017/18 approved Annual Plan proposals	

Glossary H: Table 3 – Proxies used to estimate additional capacity in 2017/18

Annex A: Governance of Model Development

The terms of reference and membership of the Internal Resource Allocation Model Development Steering Committee and Working Group are set out below.

Internal Resource Allocation Model Development Steering Committee

Terms of Reference

1. To steer and provide direction to the Internal Resource Allocation (IRA) Model Development Working Group on the IRA Model and methodological approach for analysis

2. To review and endorse the IRA analysis findings

3. To guide Clusters to formulate catch-up plans for submission of resource bids through established mechanisms

4. To provide views and suggestions to Service and Budget Planning Committee on existing resources allocation across Clusters (including budget and manpower) and the trend of IRA over time

Membership

Convener:	Director (Finance)	
Co-conveners:	Director (Cluster Services) Director (Strategy & Planning)	
Members:	Clusters	Cluster Chief Executives or representatives
	Strategy & Planning Division	Chief Manager (Strategy, Service Planning & Knowledge Management)
	Finance Division	Chief Manager (Budget Planning & Management)
	IRAMD WG Convener	Chief Manager (Financial Planning & Revenue Management)

Internal Resource Allocation Model Development Working Group

Terms of Reference

1. To deliberate on the development of HA's Internal Resource Allocation (IRA) Model based on direction from IRAMD SC (IRAMD SC)

2. To provide necessary data, compile IRA analysis, and set up subgroups to review on the basis and calculation of the model parameters

3. To report progress and results to the IRAMD SC

Membership

Convener:	Finance Division	Chief Manager (Financial Planning & Revenue Management)
Members:	Clusters	Finance Representatives IRA Focal Points
	Strategy & Planning Division	Chief Manager (Statistics & Workforce Planning)
	Finance Division	Chief Manager (Financial Advisory Services & Development)
	Quality & Safety Division	Chief Manager (Clinical Effectiveness & Technology Management) Chief Manager (Quality & Standards)
	Cluster Services Division	Chief Manager (Cluster Performance)

Annex B: List of Stakeholder Engagement Activities

Key Stakeholders	Platforms	Date
Food and Health Bureau	Meeting with Secretary of Food and Health	26 Jan 2017 27 Jun 2017
HA Board and Committees	Administrative and Operational Meeting (AOM)	25 Jun 2015 13 Oct 2016 27 Apr 2017
	Executive Committee (EC)	1 Aug 2016 5 Sep 2016 10 Apr 2017
	Finance Committee (FC)	13 Oct 2015 8 Mar 2016 12 Jul 2016 13 Sep 2016 11 Apr 2017
	Service & Budget Planning Committee (SBPC)	20 Mar 2015
	Medical Services Development Committee (MSDC)	3 Oct 2016 10 Apr 2017
	Medical Policy Group (MPG)	11 Oct 2016
	Regional Advisory Committees (RAC)	8 Dec 2016 12 Dec 2016 19 Dec 2016
	Committee on Teaching Hospitals (THC)	10 Feb 2017
	Task Force on Implementation of HA Review Recommendations	20 Aug 2015 8 Sep 2015
	HA Board Workshop	27 Aug 2015
HA Senior Management	Director's Meeting	14 Jan 2015 2 Mar 2016 24 Aug 2016 1 Feb 2017 5 Apr 2017
	Progress Updates with CE, Directors and Divisional Heads	21 Sep 2016 30 Mar 2017 5 May 2017
	Strategic partners in HO (Strategy & Planning and Cluster Services Division)	9 Sep 2016

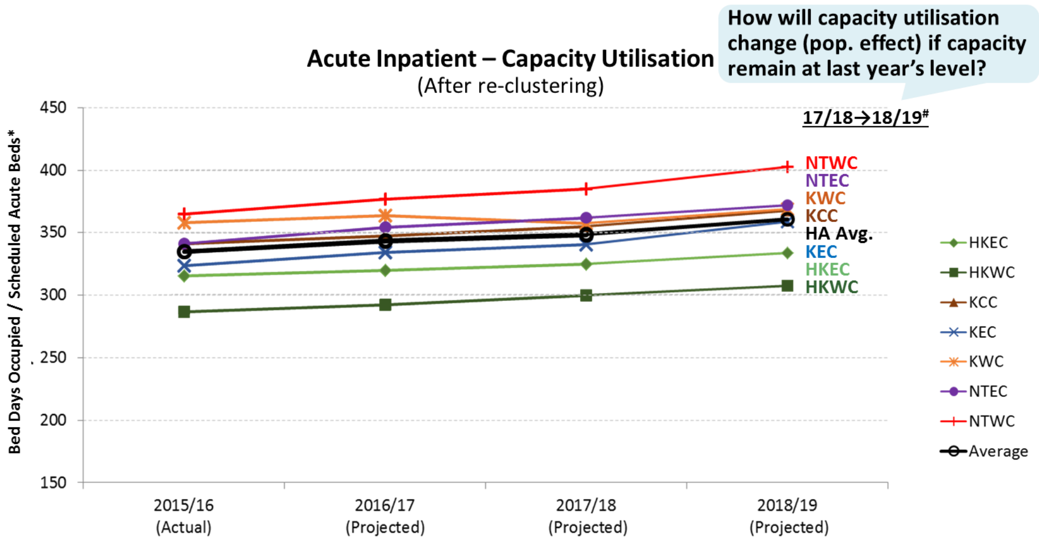
Key Stakeholders	Platforms	Date
Cluster Management & Clinicians	Cluster Sharing Forum with Cluster Management & Clinicians	Aug – Sep 2015 May – Jul 2016 Jan – Mar 2016 Nov 2016 Apr 2017
	Hospital Visits by Consultant and Project Team	Jul - Oct 2016
Project Governance	Internal Resource Allocation Model Development Steering Committee	27 Feb 2015 6 May 2015 23 Jun 2015 30 Sep 2015 10 Dec 2015 15 Jan 2016 20 Apr 2016 18 Aug 2016 28 Nov 2016 16 Mar 2017
	Internal Resource Allocation Model Development Working Group	21 Apr 2015 9 Oct 2015 30 Nov 2015 8 Jan 2016 10 Jun 2016 10 Aug 2016 17 Nov 2016 24 Feb 2017
Public & Community	Briefing to Legislative Council Members	7 Oct 2016
	Media Briefing	14 Oct 2016
	Patient Groups	Oct – Nov 2016

Annex B: Table 1 – List of stakeholder engagement activities

Annex C: Capacity Utilisation Analysis

The results of the time-trend analysis on capacity utilisation for the six core services are set out below.

Acute Inpatient (Acute IP)

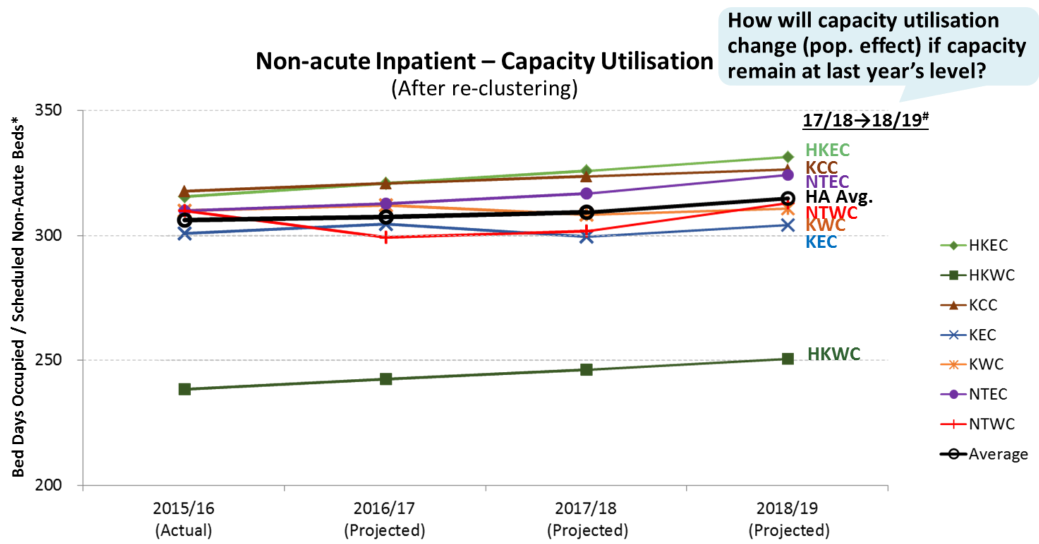


** Source: HO S&P*

\# Keep at last year's capacity (simulate no new funding) to explore the impact of population change on capacity utilisation in individual Clusters

Annex C: Figure 1 – Projected capacity utilisation for Acute IP

Non-acute Inpatient (Non-acute IP)

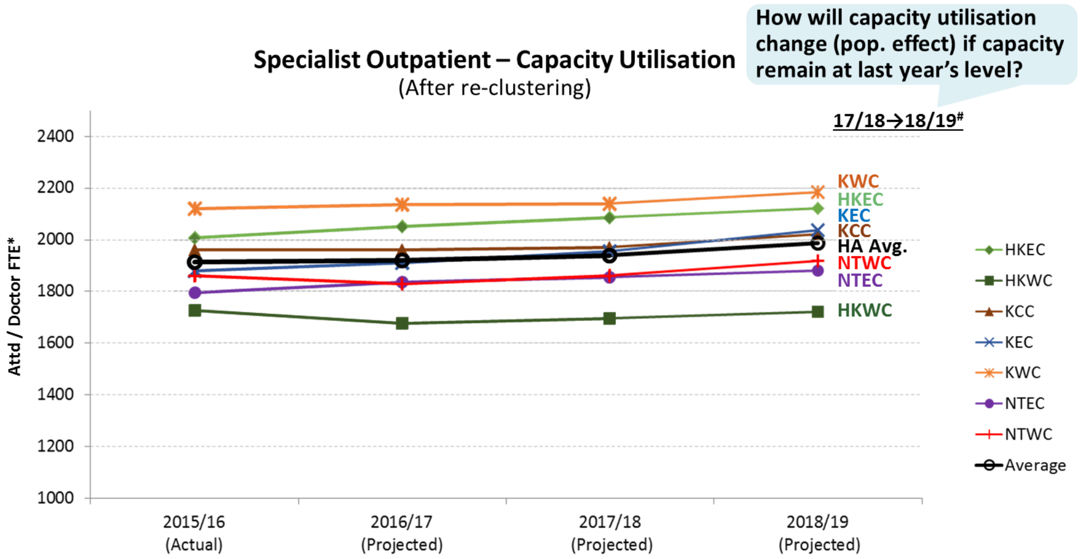


** Source: HO S&P*

\# Keep at last year's capacity (simulate no new funding) to explore the impact of population change on capacity utilisation in individual Clusters

Annex C: Figure 2 – Projected capacity utilisation for Non-acute IP

Specialist Outpatient (SOP)

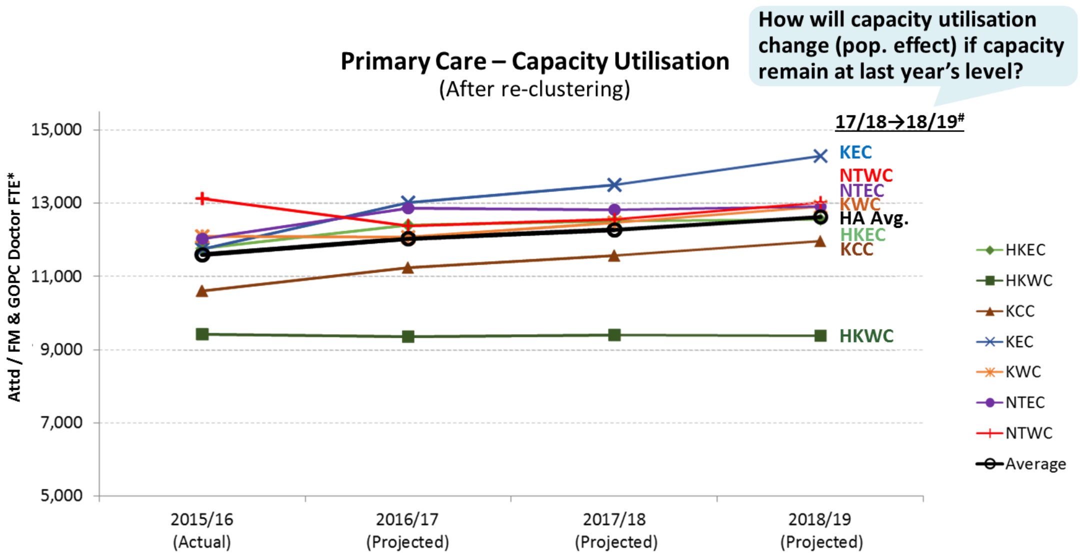


* *FTE strength of doctors excluding specialties A&E, Family Medicine, ICU, Hospital Management / HAHO, Pathology, and Radiology (Source: HO HR)*

Keep at last year's capacity (simulate no new funding) to explore the impact of population change on capacity utilisation in individual Clusters

Annex C: Figure 3 – Projected capacity utilisation for SOP

Primary Care (PHC)

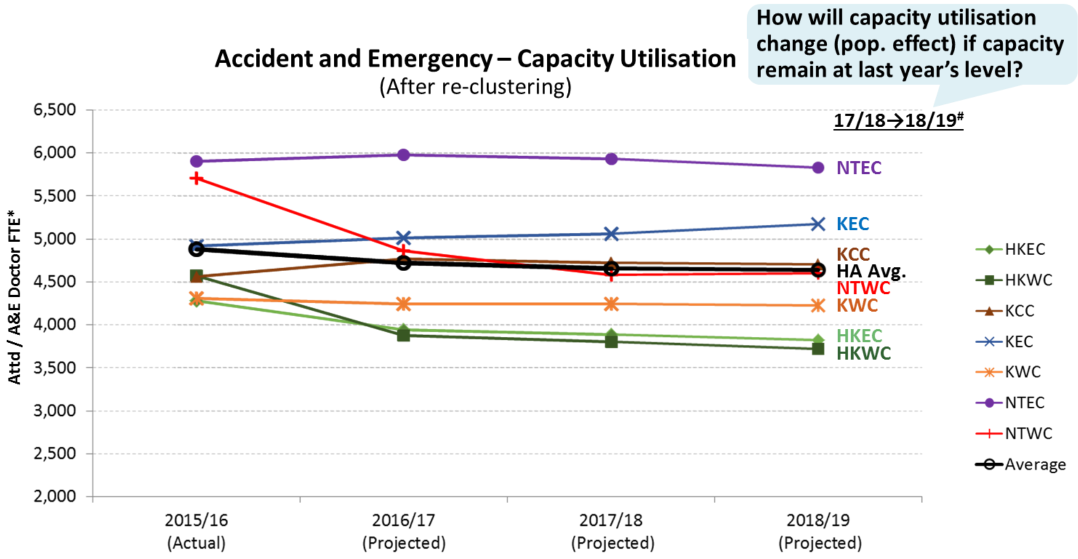


* *FTE strength of doctors under Family Medicine & GOPC (Source: HO HR)*

Keep at last year's capacity (simulate no new funding) to explore the impact of population change on capacity utilisation in individual Clusters

Annex C: Figure 4 – Projected capacity utilisation for PHC

Accident and Emergency (A&E)

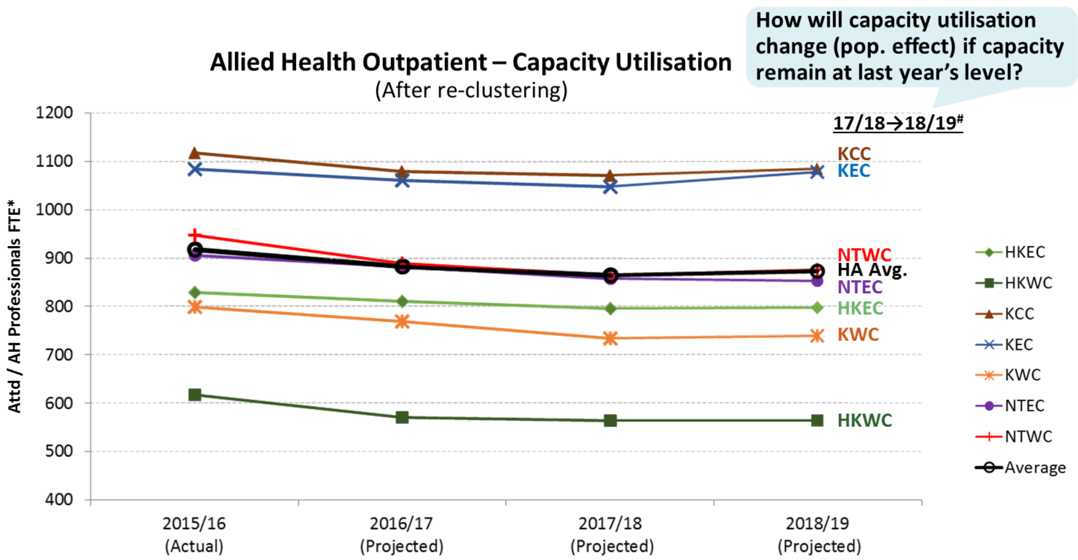


* *FTE strength of doctors under A&E including SHS (converted to FTE by NAMS of Resident) (Source: HO HR)*

\# Keep at last year's capacity (simulate no new funding) to explore the impact of population change on capacity utilisation in individual Clusters

Annex C: Figure 5 – Projected capacity utilisation for A&E

Allied Health Outpatient (AHOP)



* *FTE strength of Allied Health Professionals in streams that correlate with service throughput of AHOP (Source: HO HR)*

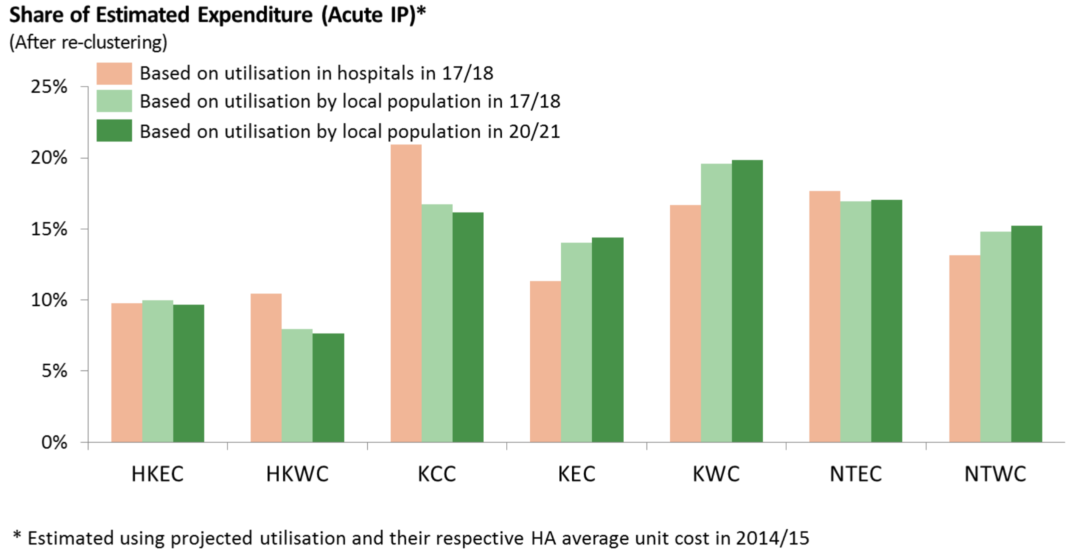
\# Keep at last year's capacity (simulate no new funding) to explore the impact of population change on capacity utilisation in individual Clusters

Annex C: Figure 6 – Projected capacity utilisation for AHOP

Annex D: Hospital-based vs. TPU-based Models

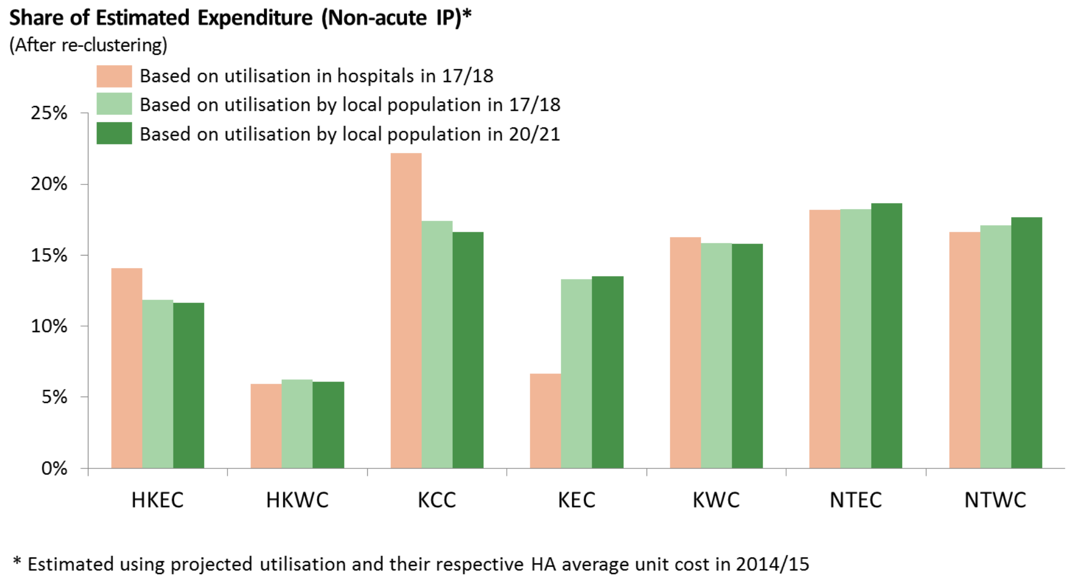
The results of Hospital-based model (2017/18) vs. TPU-based model (2017/18 and 2020/21) for the six core services (using data after re-clustering) are set out below:

Acute Inpatient (Acute IP)



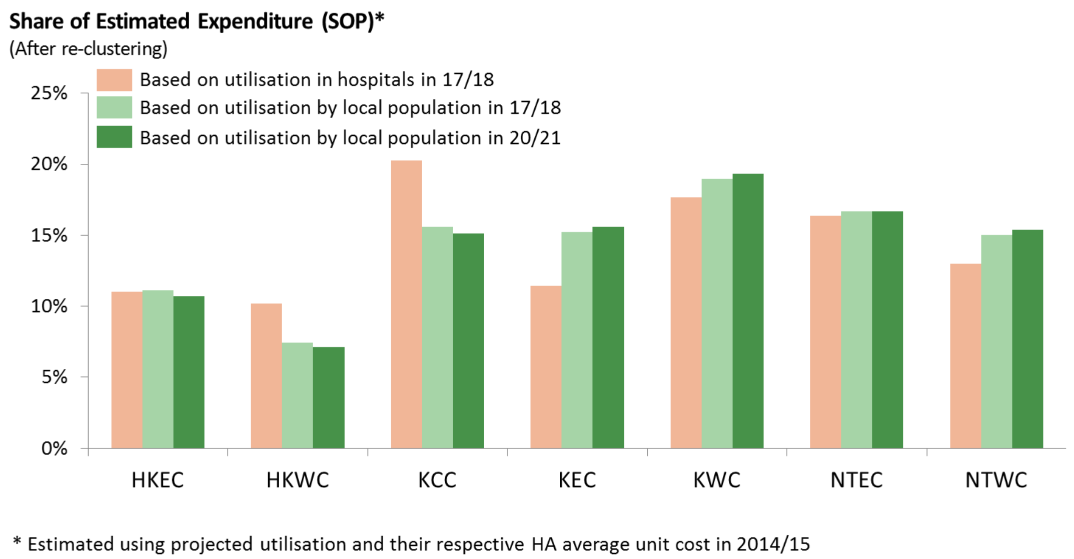
Annex D: Figure 1 – Hospital-based vs. TPU-based model for Acute IP

Non-acute Inpatient (Non-acute IP)



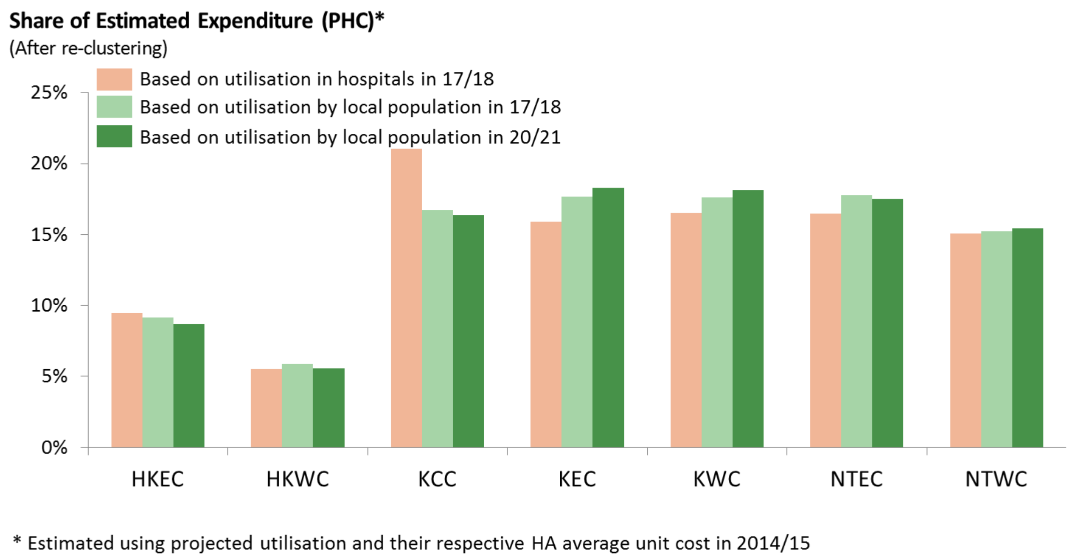
Annex D: Figure 2 – Hospital-based vs. TPU-based model for Non-acute IP

Specialist Outpatient (SOP)



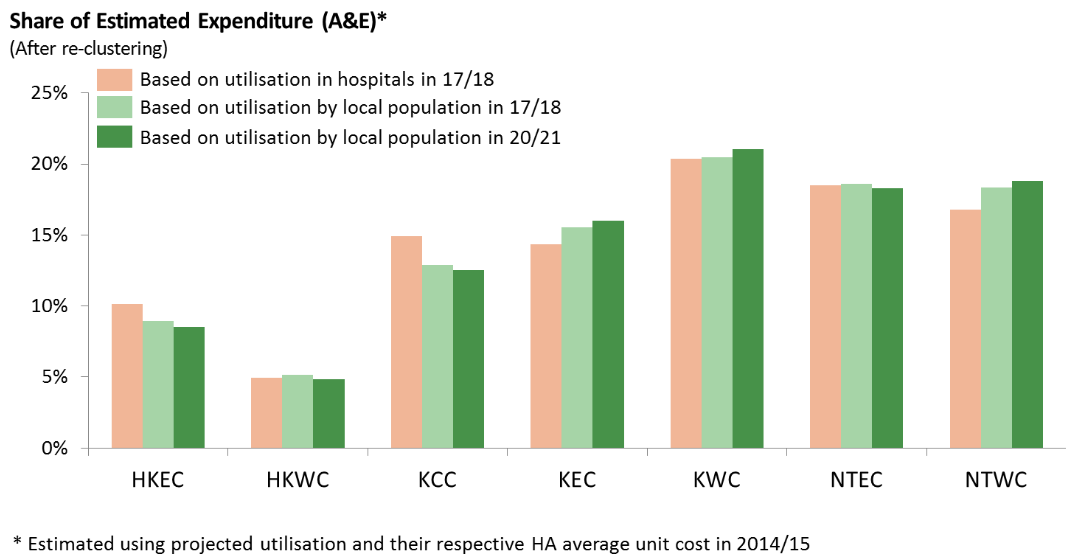
Annex D: Figure 3 – Hospital-based vs. TPU-based model for SOP

Primary Care (PHC)



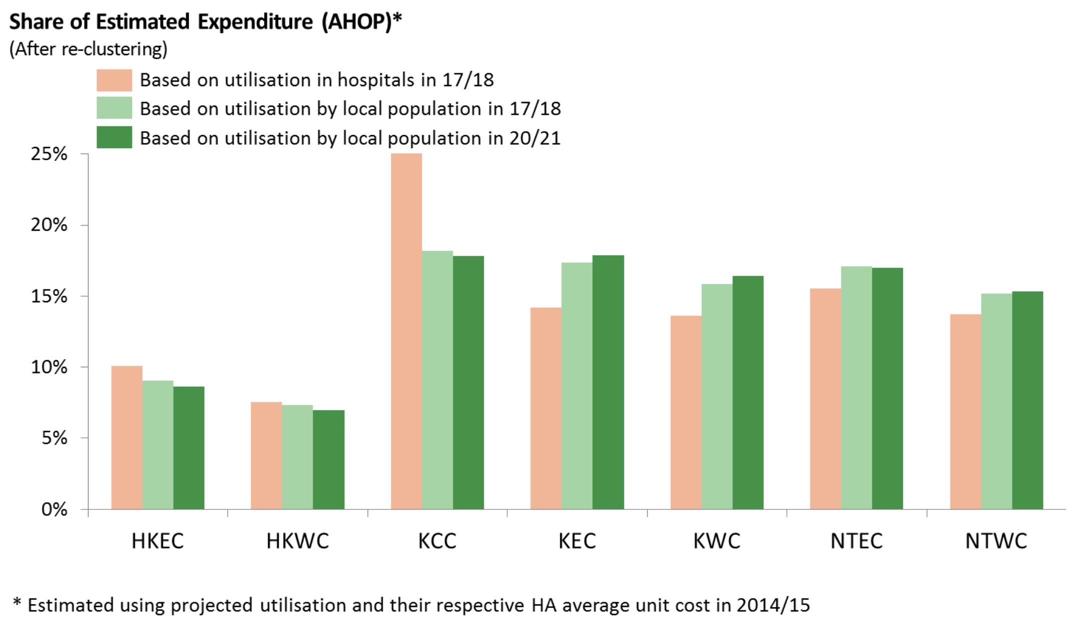
Annex D: Figure 4 – Hospital-based vs. TPU-based model for PHC

Accident and Emergency (A&E)



Annex D: Figure 5 – Hospital-based vs. TPU-based model for A&E

Allied Health Outpatient (AHOP)



Annex D: Figure 6 – Hospital-based vs. TPU-based model for AHOP

Annex E: Projects under 10-year Hospital Development Plan

The Government has earmarked $200 Billion for the implementation of the following projects:

Proposed Projects	
1	Community Health Centre (CHC) at ex-Mong Kok Market site
2	Extension of Operating Theatre Block of Tuen Mun Hospital
3	New Acute Hospital (NAH) at Kai Tak Development (Phase 1)
4	NAH at Kai Tak Development Area (Phase 2)
5	Redevelopment of Kwai Chung Hospital (Phase 1)
6	Redevelopment of Kwai Chung Hospital (Phases 2 & 3)
7	Expansion of Haven of Hope Hospital
8	Redevelopment of Queen Mary Hospital (Phase 1) - main works
9	Redevelopment of Our Lady of Maryknoll Hospital
10	Redevelopment of Kwong Wah Hospital - main works
11	CHC in Shek Kip Mei
12	Expansion of United Christian Hospital - main works (superstructure and remaining works)
13	Development of a CHC in North District
14	Redevelopment of Prince of Wales Hospital (Phase 2) (stage 1)
15	Hospital Authority Supporting Services Centre at Tin Shui Wai
16	Expansion of North District Hospital
17	Expansion of Lai King Building in Princess Margaret Hospital
18	Redevelopment of Grantham Hospital, phase 1

Source: An Update on Public Hospital Developments, Legislative Council Panel on Health Services (LC Paper NO. CB(2)652/15-16(04)

Annex E: Table 1 – Projects under 10-year hospital development plan

List of Abbreviations

A&E	Accident and Emergency
ACSC	Ambulatory Care Sensitive Conditions
Acute IP	Acute Inpatient
AHOP	Allied Health Outpatient
AOM	Administrative and Operational Meeting
ASH	Ambulatory Sensitive Hospitalisation
ASOI	Alternative Source of Income
BDO	Bed Days Occupied
C&SD	Census and Statistics Department
CBV	Capital Block Vote
CHC	Community Health Centre
CHP	Centre of Health Protection
CMS	Centres For Medicare & Medicaid Services
COC	Coordinating Committees
CS	Corporate Service
CSSA	Comprehensive Social Security Assistance
CUHK	The Chinese University of Hong Kong
DCCA	District Council Constituency Area
DCG	Diagnostic Cost Groups
DDU	Developmental Disabilities Unit
DH	Department of Health
DRG	Diagnosis Related Group

DS	Designated Service
EC	Executive Committee
EP	Eligible Persons
FC	Finance Committee
FHB	Food and Health Bureau
FM	Family Medicine
FTE	Full-Time Equivalent
GLM	Generalised Linear Model
GLMM	Generalised Linear Mixed Effect Model
GOPC	General Outpatient Clinic
HA	Hospital Authority
HCC	Hierarchical Condition Categories
HKEC	Hong Kong East Cluster
HKWC	Hong Kong West Cluster
HO	Head Office
HR	Human Resource
HSS	Highly Specialised Services
IRA	Internal Resource Allocation
IRAMD SC	Internal Resource Allocation Model Development Steering Committee
IRAMD WG	Internal Resource Allocation Model Development Working Group
IT	Information Technology
ITBV	Information Technology Block Vote
KCC	Kowloon Central Cluster

KEC	Kowloon East Cluster
KWC	Kowloon West Cluster
KWH	Kwong Wah Hospital
LBW	Low Birth Weight
M&HD	Medical and Health Department
MAPE	Mean Absolute Percentage Error
MPG	Medical Policy Group
MSDC	Medical Services Development Committee
NAH	New Acute Hospital
NGO	Non-Governmental Organisation
NLTH	North Lantau Hospital Intranet
Non-acute IP	Non-acute Inpatient
NTEC	New Territories East Cluster
NTWC	New Territories West Cluster
OC	Other Charges
OLM	Our Lady of Maryknoll Hospital
OT	Operation Theatre
PET	Positron Emission Tomography
PHC	Primary Care
PPMI	Privately Purchased Medical Items
PPP	Public-Private Partnership
PWH	Prince of Wales Hospital
PYNEH	Pamela Youde Nethersole Eastern Hospital

QEH	Queen Elizabeth Hospital
RAC	Regional Advisory Committees
RAE	Resource Allocation Exercise
RCHE	Residential Care Homes for the Elderly
S&P	Strategy & Planning
SBPC	Service and Budget Planning Committee
SFI	Self-financed Items
SHS	Special Honorarium Scheme
SMR	Standardised Mortality Ratio
SOP	Specialist Outpatient
T&Q	Tertiary and Quaternary
T&R	Teaching and Research
THC	Committee on Teaching Hospitals
THS	Thematic Household Survey
TPU	Tertiary Planning Unit
TSWH	Tin Shui Wai Hospital
UCH	United Christian Hospital
VIF	Variance Inflation Factors
WHO	World Health Organisation

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