

VR Sports Location Selector

MATH3836: DATA MINING

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1 INTRODUCTION

Sports is a popular topic in recent years. The Chief Executive's 2023 Policy Address mentions that Hong Kong athletes have accomplished significant results in many major and international sports competitions recently, such as winning 53 medals in Asian Games in Hangzhou; thus, the Government will promote sports development constantly in Hong Kong, including supporting sports talents, maintaining Hong Kong position as a center for major international sports events, and developing sports as an industry, and promoting sports in the community (The Hong Kong Special Administrative Region of the People's Republic of China, 2023).

Since the Hong Kong government keeps promoting sports, we see business opportunities for sports-related products/services. However, being a sporting goods retailer is too normal and hard in Hong Kong because Decathlon has already become the largest sporting goods retailer in Hong Kong selling cheap but comprehensive sporting goods. Therefore, we are going to be virtual reality (VR) sport provider. We provide VR sporting goods in physical stores and establish VR sport centers.

In this project, we develop an innovative data mining tool on which to base our start-up business. To base our business, we have four fundamental questions, including

- who the users of our product are
- whether our goal is realistic
- what makes our product unique
- what impact our product may have on society

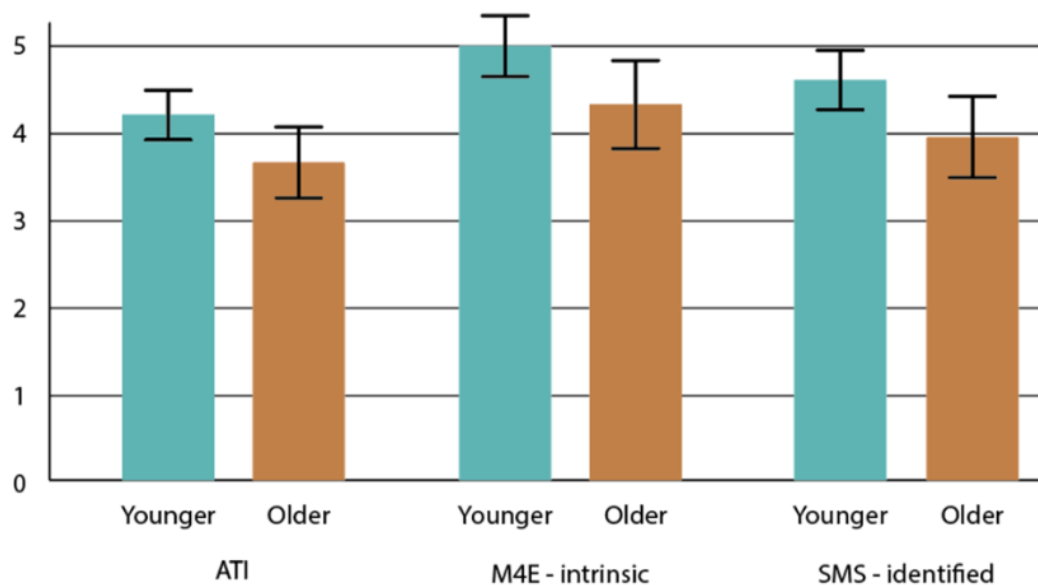
Our goal in this project is understanding targeted customers and find suitable locations for both VR sporting goods physical store and VR sport centre. First, we determined targeted users age by a research on VR, as well as we knew targeted users' wants and needs by Territory-wide Physical Fitness Survey for the Community 2023. Second, to make our goal be realistic, we used PCA to select location for VR sporting goods store by understanding Hong Kong age pattern among various areas, as well as K-mean clustering to select location for VR sports centre by comparing to existing sports facilities. Third, to examine what makes our product unique, we discussed our services and compared to other VR product providers and VR gaming centers. Fourth, we had to determine our product's impact on society. According to Kim and Ko (2019), the key aspect is the flow experience. Virtual Reality Spectatorship (VRS) engages the viewer in having an immense experience, leading to a higher flow level. This effect is caused by the level of interactivity. VR can deliver a richer sensory experience and greater mobility of viewing perspective, giving the sensation of "being there." This can enhance viewers' overall experience by creating a highly engaging and satisfying experience.

2 TARGETED CUSTOMERS

2.1 AGE

A research about “effects of user factors on user experience in virtual reality: age, gender, and VR experience as influencing factors for VR exergames” with 30 younger age participants aged 18 to 40 and 33 older age participants who are aged from 40 to 70 indicates younger age participants have higher Affinity for technology interaction, intrinsic motivation for exercise, and identified sports motivation scale than older age participants (Kojic et al., 2023).

Fig. 1. Mean value for ATI, A4R - Intrinsic, and SMS - Identified by age group



The above table shows the mean values of **affinity for technology (ATI)**, **intrinsic motivation for sports (M4E—*intrinsic*)**, and **identified motivation for sports (SMS—*identified*)** of all participants split by age group.

- **Affinity for technology interaction (ATI)** describes an individual’s response to or against engagement with technology. Younger participants reported statistically significantly higher ATI ($M = 4.20$, $SE = 0.14$) compared to older participants ($M = 3.65$, $SE = 0.19$).
- **The Motivation for Exercise (M4E)** was mainly designed to determine whether the participants are extrinsically or intrinsically motivated to exercise. *Intrinsic motivation* is defined as doing an activity because of its inherent satisfaction and enjoyment rather than for external reasons or rewards. Younger participants reported significantly higher intrinsic regulations when measured in motivation for exercise ($M = 5.00$, $SE = 0.18$) than the intrinsic regulation of older participants ($M = 4.35$, $SE = 0.24$).
- **A sports motivation scale (SMS)** has been included in the study as it was developed to measure an athlete’s motivation toward sports participation. Identified regulation is a form of extrinsic motivation where the individual has identified with the personal value and importance of the behaviour and has thus accepted it as their own. Younger participants also have a significantly higher value for the identified regulation sport motivation scale ($M = 4.63$, $SE = 0.18$) than older participants ($M = 3.98$, $SE = 0.21$).

To sum up, younger individuals are more willing to accept new technology such as VR. Also, the satisfaction and enjoyment brought by sports are more motivating to younger than older individuals. Furthermore, for individuals who exercise, a higher proportion of younger individuals are motivated by their values and the importance of sport relative to older individuals. Although the younger age participants in the above research are aged 18 to 40, we want to expand to more potential customers (i.e., those aged 7 to 59). We believe younger individuals will accept VR sports and be attracted by the gaming theme in VR sports, as well as older individuals will accept VR sports if we promote more extrinsic motivation for VR sports to them, such as health improvement. Therefore, we targeted children aged 7-11, adolescents aged 12-16, young adults aged 17-39, and middle-aged adults aged 40-59 as our customers.

2.2 WANTS AND NEEDS

Territory-wide Physical Fitness Survey for the Community 2023 indicates the favourite physical activities among different age ranges. The followings table shows the top three physical activities.

| Children: Favourite physical activities | | | |
|---|----------|------------|---------|
| Age | 1st | 2nd | 3rd |
| 7-11 | Swimming | Ball games | Cycling |

| Adolescents: Favourite physical activities | | | |
|--|------------|----------|-------------------------|
| Age | 1st | 2nd | 3rd |
| 12-16 | Ball games | Swimming | Skating/ Roller skating |

| Adults: Favourite physical activities | | | |
|---------------------------------------|-----------|---------------------|-----------------------|
| Age | 1st | 2nd | 3rd |
| 17-19 | Ball game | Running/ Jogging | Fitness/ Bodybuilding |
| 20-39 | Walking | Running/ Jogging | Fitness/ Bodybuilding |
| 40-59 | Walking | Hiking | Running/ Jogging |
| 60-69 | Walking | Hiking | Yogo/ Stretching |
| 70-79 | Walking | Tai Chi/ Badu Anjin | Yogo/ Stretching |

Within the age range of targeted customers (i.e., 7-59), ball games, fitness, running, walking, swimming, cycling, and skating are their favourite physical activities. VR sports can simulate real sports by providing immersive experiences that replicate the movements, strategies, and physical exertion associated with traditional sports, such as ball games, fitness, racing, and skiing. The following are VR sports games that have already been developed.

Fig. 2. Example of VR ball game: FITXR



Fig. 3. Example of VR fitness: FITXR



In addition, Territory-wide Physical Fitness Survey for the Community (2023) indicates that barriers for engaging physical activities for different age ranges. The followings are the top three barriers of them.

| Children: Barriers for engaging physical activities | | | |
|---|-------------|--------------------|------------|
| Age | 1st | 2nd | 3rd |
| 7-11 | Bad weather | Busy with homework | Feel tired |

| Adolescents: Barriers for engaging physical activities | | | |
|--|-----------------|--------------|-------------|
| Age | 1st | 2nd | 3rd |
| 12-16 | Muscle soreness | Lack of time | Bad weather |

| Adults: Barriers for engaging physical activities | | | |
|---|--------------|--------------|--------------|
| Age | 1st | 2nd | 3rd |
| 17-19 | Lack of time | Tired | Lazy |
| 20-39 | Tired | Lack of time | lazy |
| 40-59 | Tired | Lack of time | Lazy |
| 60-69 | Bad weather | Tired | Lack of time |
| 70-79 | Bad weather | Tired | Lack of time |

Within the age range of targeted customers (i.e., age 7-59), bad weather, lack of time, and tiredness are why they refrain from engaging in physical activities. VR sports can solve this problem. VR sports allow us to do exercise at home. We do not need to worry about the weather in the indoor area. Also, doing exercise VR sports at home reduces the time to travel to sports facilities, such as public sports centres and private gyms. We can do it anytime without worrying about the sports facilities' closing hours. Moreover, VR sports promote sports as games, and we can get excited by playing VR sports games. We will feel more exhausted in VR sports than in actual exercise.

As a result, VR sports can satisfy our targeted customers' wants and needs by offering plenty of sports choices and removing their barriers to doing traditional physical activities.

3 VR SPORTING GOODS STORE LOCATION SELECTION

3.1 UNDERSTANDING AGE PATTERN BY PRINCIPAL COMPONENT ANALYSIS (PCA)

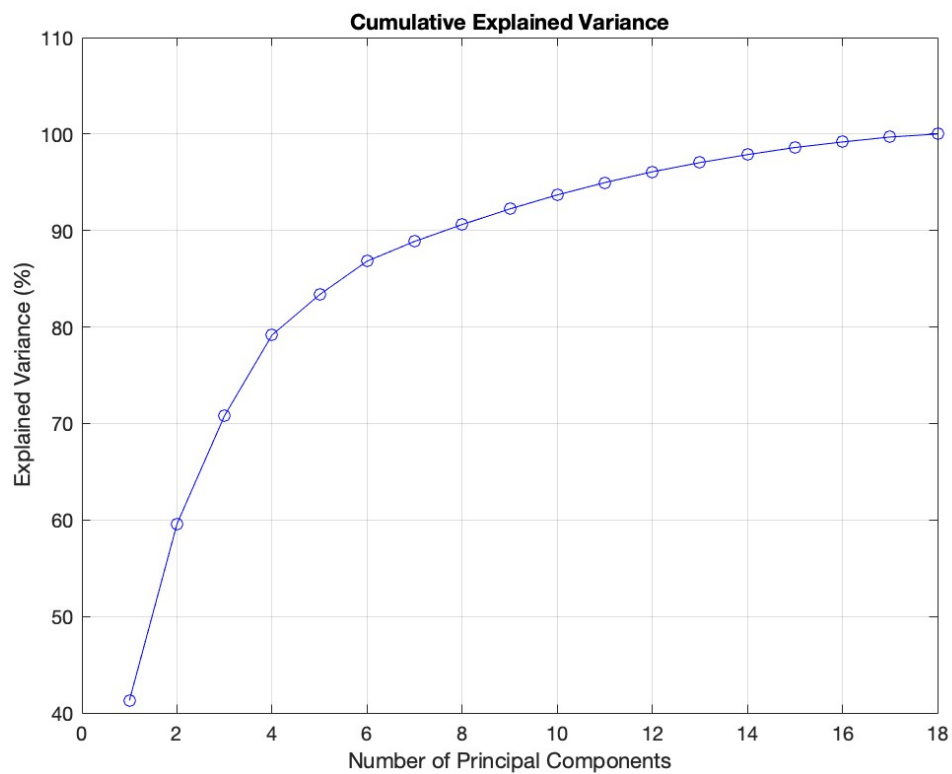
According to Population Census (2021), Table A303ae indicates the numbers of people by 452 district councils/ constituency areas and 18 age groups (i.e., from 0 to 85+). We want to know more about the relationship between constituency areas and age groups. However, the table is too large, making it hard to understand its underlying patterns. Hence, we used PCA for dimension reduction and focused on the principal components that cumulatively explained a variance of over 85%.

PCA is a method to find the projection direction so that the lower dimensions data has maximum variance. Mathematically, the eigenvector corresponds to the largest eigenvalue of the sample covariance matrix. In this project, we insert a table of numbers of people by 452 constituency areas and 18 age groups where constituency areas are observations and age groups are variables. The PCA calculation is done using MATLAB programming. Different constituency areas have different sizes, which leads to quite different numbers of people. However, we do not standardize the data to address the issue of scale differences because we do not want to know merely the age proportion in each area. We want to know the actual number of customers in the area so that we can calculate and eventually rank the score collected. Thus, we perform the PCA function in MATLAB by calculating the covariance matrix that captures the strength and direction of the linear relationship between age groups within each constituency area and the eigenvector that corresponds to the largest eigenvalue of the sample covariance matrix (i.e., loadings). The eigenvalues represent the variance explained by each principal component. Then, we multiply each normalized eigenvalue by 100 to obtain the percentage of variance explained by each principal component. We select principal components that make a cumulative percentage of variance explained over 85%. After examining the absolute loadings in each meaningful principal component, we will know what age pattern they are referring to. Then, we calculate the scores by multiplying the original variables by the loadings, and we arrange the score to know the performance of each area by its age pattern.

3.1.1 Selected Principal Components' Explained Variance

| Principal Components | Explained Variance (%) | Cumulative Explained Variance (%) |
|----------------------|------------------------|-----------------------------------|
| PC1 | 41.3018657 | 41.3018657 |
| PC2 | 18.281512 | 59.5833777 |
| PC3 | 11.2165611 | 70.7999388 |
| PC4 | 8.36679356 | 79.1667323 |
| PC5 | 4.18234776 | 83.3490801 |
| PC6 | 3.47638851 | 86.8254686 |

Fig. 4. Cumulative Explained Variance



By examining each principal component's explained variance, cumulative explained variance from PC1 to PC6 is over 85% explained variance among 18 principal components. Thus, we examined loadings from PC1 to PC6 by checking which contains the highest absolute loadings to find the age pattern among these six principal components.

3.1.2 Interpretation of Principal Component

| Age | PC1 absolute loading | PC2 absolute loading | PC3 absolute loading | PC4 absolute loading | PC5 absolute loading | PC6 absolute loading |
|---------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| 0 - 4 | 0.2295242 | 0.12421459 | 0.16807792 | 0.04470329 | 0.07915367 | 0.09722313 |
| 5 - 9 | 0.25527732 | 0.13778996 | 0.04477954 | 0.02881074 | 0.09528024 | 0.10757128 |
| 10 - 14 | 0.22675632 | 0.10921801 | 0.20114924 | 0.00197356 | 0.20404017 | 0.32599028 |
| 15 - 19 | 0.16636923 | 0.04319183 | 0.27572055 | 0.07906094 | 0.07691916 | 0.27246972 |
| 20 - 24 | 0.17977228 | 0.22592448 | 0.24065311 | 0.3024066 | 0.17469715 | 0.33927577 |
| 25 - 29 | 0.20474099 | 0.35068915 | 0.00497421 | 0.3898854 | 0.38394345 | 0.14864411 |
| 30 - 34 | 0.31670502 | 0.10996233 | 0.43276239 | 0.19716211 | 0.36229758 | 0.1344768 |
| 35 - 39 | 0.39818012 | 0.17763432 | 0.44434432 | 0.13445995 | 0.00506878 | 0.02830663 |
| 40 - 44 | 0.40014898 | 0.25530134 | 0.05872067 | 0.25221848 | 0.10451403 | 0.1041037 |
| 45 - 49 | 0.36643395 | 0.17958833 | 0.32218617 | 0.17307106 | 0.02798628 | 0.00524268 |
| 50 - 54 | 0.30168235 | 0.03933786 | 0.40714513 | 0.01599266 | 0.07943932 | 0.26336278 |
| 55 - 59 | 0.26022299 | 0.34148805 | 0.19142908 | 0.0507036 | 0.29119094 | 0.52763672 |
| 60 - 64 | 0.11590387 | 0.54293312 | 0.19463043 | 0.09320307 | 0.47507411 | 0.03799085 |
| 65 - 69 | 0.04560284 | 0.389836 | 0.17868731 | 0.34117094 | 0.08071671 | 0.33243992 |
| 70 - 74 | 0.01330611 | 0.19419931 | 0.02108829 | 0.43151662 | 0.19564315 | 0.27407874 |
| 75 - 79 | 0.0143931 | 0.10975992 | 0.07657371 | 0.2640925 | 0.21294035 | 0.03882589 |
| 80 - 84 | 0.0199602 | 0.08490909 | 0.09523299 | 0.24736125 | 0.21443115 | 0.07381308 |
| 85+ | 0.02348024 | 0.12169304 | 0.12548274 | 0.38972613 | 0.40406707 | 0.29952992 |

*red filling means the highest absolute loading.

The absolute loading values provide information about the strength and direction of the relationship between the original variable (age groups) and the corresponding principal component. Variables with higher absolute loading values in particular principle component contribute more to that. For instance, age 0-4, age 5-9, age 40-44, and age 45-49 have the highest absolute loading values in PC1, it suggests a strong relationship between these variables and PC1. This indicates that these age groups are the most influential in determining the variance captured by PC1.

However, it is also important to know the sign of the loadings since it provides insights into the underlying patterns in the data. Thus, we take the age groups of the highest absolute loading in each principle component as representative. For example, we learn PC1 by examining the sign of , age 0-4, age 5-9, age 40-44, and age 45-49 only.

| Age | PC1 loading | PC2 loading | PC3 loading | PC4 loading | PC5 loading | PC6 loading |
|---------|-------------|-------------|-------------|-------------|-------------|-------------|
| 0 - 4 | 0.2295242 | -0.1242146 | 0.16807792 | -0.0447033 | -0.0791537 | 0.09722313 |
| 5 - 9 | 0.25527732 | -0.13779 | 0.04477954 | 0.02881074 | 0.09528024 | -0.1075713 |
| 10 - 14 | 0.22675632 | -0.109218 | -0.2011492 | 0.00197356 | 0.20404017 | -0.3259903 |
| 15 - 19 | 0.16636923 | 0.04319183 | -0.2757206 | -0.0790609 | 0.07691916 | -0.2724697 |
| 20 - 24 | 0.17977228 | 0.22592448 | -0.2406531 | -0.3024066 | -0.1746971 | -0.3392758 |
| 25 - 29 | 0.20474099 | 0.35068915 | 0.00497421 | -0.3898854 | -0.3839434 | -0.1486441 |
| 30 - 34 | 0.31670502 | 0.10996233 | 0.43276239 | -0.1971621 | -0.3622976 | 0.1344768 |
| 35 - 39 | 0.39818012 | -0.1776343 | 0.44434432 | 0.13445995 | -0.0050688 | 0.02830663 |
| 40 - 44 | 0.40014898 | -0.2553013 | 0.05872067 | 0.25221848 | 0.10451403 | -0.1041037 |
| 45 - 49 | 0.36643395 | -0.1795883 | -0.3221862 | 0.17307106 | -0.0279863 | 0.00524268 |
| 50 - 54 | 0.30168235 | 0.03933786 | -0.4071451 | 0.01599266 | -0.0794393 | 0.26336278 |
| 55 - 59 | 0.26022299 | 0.34148805 | -0.1914291 | -0.0507036 | 0.29119094 | 0.52763672 |
| 60 - 64 | 0.11590387 | 0.54293312 | 0.19463043 | 0.09320307 | 0.47507411 | 0.03799085 |
| 65 - 69 | 0.04560284 | 0.389836 | 0.17868731 | 0.34117094 | 0.08071671 | -0.3324399 |
| 70 - 74 | -0.0133061 | 0.19419931 | -0.0210883 | 0.43151662 | -0.1956431 | -0.2740787 |
| 75 - 79 | -0.0143931 | 0.10975992 | -0.0765737 | 0.2640925 | -0.2129404 | -0.0388259 |
| 80 - 84 | -0.0199602 | 0.08490909 | -0.095233 | 0.24736125 | -0.2144311 | 0.07381308 |
| 85+ | -0.0234802 | 0.12169304 | -0.1254827 | 0.38972613 | -0.4040671 | 0.29952992 |

*yellow filling means the highest absolute loading while it is positive

*orange filling means the highest absolute loading while it is negative

PC1:

The positive loadings in age 0-4, 5-9, 40-44, and 45-49 suggest that areas with higher scores on PC1 tend to have more people in these age groups. This age pattern suggests that these areas may have **a higher concentration of babies, primary students, individuals in their child-rearing years, and individuals approaching middle age**. It could indicate areas with many **younger families** (i.e., families with parents aged 40-49 and children aged 0-9).

PC2:

The positive loadings in age 60-64 and 65-69 suggest that areas with higher scores on PC2 tend to have more people in these age groups. This age pattern suggests that these areas may have **a higher concentration of individuals transitioning into retirement or experiencing the early stages of older adulthood**. It could indicate areas with a higher retirement population or regions with amenities and services catering to the needs of older adults. However, **individuals aged 60-69 are not our target customers**. So, the areas with mostly age 60-69 is not our favourite location to set up physical store.

PC3:

The negative loadings in age 15-19 and 50-54, and the positive loadings in age 30-34 and 35-39, suggest that areas with higher scores on PC3 tend to have fewer people in the 15-19 and 50-54 age groups, but more people in the 30-34 and 35-39 age groups. This age pattern suggests that these areas may have **a higher concentration of working-age individuals, but lower concentration of secondary students and individuals in their late middle age.** It could indicate areas with **less older family (i.e., families with parents aged 50-54 and children aged 15-19).**

PC4:

The negative loading in age 25-29 and the positive loadings in age 70-74, 75-79, and 80-84 suggest that areas with higher scores on PC4 tend to have fewer people in the 25-29 age group, but more people in the 70-74, 75-79, and 80-84 age groups. This age pattern suggests that these areas may have **a higher concentration of individuals in their advanced older age and lower concentration of individuals in their early working years.** It could indicate areas with **relatively old community.** However, **individuals aged 70-84 are not our target customers.** So, the areas with mostly age 70-84 is not our favourite location to set up physical store.

PC5:

The negative loading in age 85+ suggests that areas with higher scores on PC5 tend to have fewer people in the 85+ age group. This age pattern suggests that these areas may have **a lower concentration of individuals in the oldest age group.** It could indicate areas with **diverse age groups with fewer individuals aged 85+.**

PC6:

The negative loadings in age 10-14 and 20-24, and the positive loading in age 55-59, suggest that areas with higher scores on PC6 tend to have fewer people in the 10-14 and 20-24 age groups, but more people in the 55-59 age group. This age pattern suggests that these areas may have **a higher concentration of individuals in their late middle age who are approaching retirement, but lower concentration of primary students and younger adults pursuing higher education.**

After interpretation what age pattern the principal components refer to, we arranged PC scores in descending order to see which constituency area is most related to the age pattern.

3.1.3 Top 5 Constituency Areas of PC1, PC3, PC5, & PC6 and Suggestions

PC1: Many younger families

| Area | District | Constituency Area | PC1 score |
|-----------------|----------|-------------------|------------|
| New Territories | Sai Kung | Wan Po South | 5000.70347 |
| New Territories | Sai Kung | Hoi Chun | 2968.74567 |
| New Territories | Tuen Mun | Tuen Mun Rural | 2885.1014 |
| New Territories | Tai Po | Wang Fuk | 2742.34947 |
| New Territories | Sha Tin | Wu Kai Sha | 2666.02842 |

These areas are more family-oriented, so we suggest having some pop-up stores for promotion. In the pop-up store, we sell limited family packages of VR sporting goods, such as a package of 2 sets of VR headsets and VR controllers. The family can enjoy family time with VR sports games at a lower cost than buying them separately. We also provide trials for both parents and children to try. Since children do not have the income or affordability as adults, VR sporting goods are mainly bought by their parents. Pop-up stores with trial and cheaper prices can motivate parents to buy. In addition, we understand individuals aged 40-49 may have low acceptance of new technology. The trial can offer them a point of view on new technology. Therefore, the first round of pop-up stores will operate in Malls in Tai Po and Sha Tin.

PC3: High acceptance, adaptability, and affordability individuals

| Area | District | Constituency Area | PC3 score |
|------------------|--------------|----------------------------|------------|
| Hong Kong Island | Southern | Wah Fu South | 1585.27661 |
| Hong Kong Island | Southern | Lei Tung I | 1356.39752 |
| Kowloon | Sham Shui Po | Lung Ping & Sheung Pak Tin | 1335.94611 |
| Hong Kong Island | Wan Chai | Tai Hang | 1283.69394 |
| Kowloon | Kwun Tong | Yau Tong East | 1268.48785 |

Median age of first child bearing is 32.7 in Hong Kong in 2022. PC3 does not have high concentration of baby or kids. We assume many individuals with aged 30-39 do not have child, and hence they have more leisure time to play VR sport. Also, individuals aged 30-39 have high acceptance and adaptability to VR. They also have high affordability when it comes to buying more professional VR sports gear, such as full-body trackers. Except from age 30-39, individuals aged in 25-29 and 40-44 also have positive loading which means areas above also contains many individuals aged in 25-29 and 40-44. Individuals aged in 25-29 have relatively low affordability as they just start to work. Individuals aged in 40-44 may have concerns about new technology. Age in 25-44 are our major targeted customer because they are more likely to accept and purchase VR products. To balance their needs and income level, we suggest having the largest physical store with testing area, beginning area, and professional area in Sham Shui Po Lung Ping. Sham Shui Po is popular for selling electronic/technology products. It can also attract people who are going to buy technology products but do not live in Sham Shui Po.

PC5: diverse age groups

| Area | District | Constituency Area | PC5 score |
|-----------------|--------------|---------------------|------------|
| New Territories | Tuen Mun | Yan Tin | 749.850277 |
| Kowloon | Kwun Tong | Kwun Tong On Tai | 701.674966 |
| New Territories | Yuen Long | Shap Pat Heung West | 692.068501 |
| Kowloon | Wong Tai Sin | Lung Sing | 657.693268 |
| New Territories | North | Queen's Hill | 656.04347 |

These areas have diverse age groups with less individuals aged 85+ which means these areas do involve many targeted customers with different ages, income level, and needs. However, the age pattern is wide. We did further analysis based on the sign of loadings. Only ages 5-19, 40-44, and 55-69 have positive loadings here. For the targeted customer, we only have individuals aged 7-19 and 40-44 which is inadequate demand for our products. As a result, we suggest to have small stores to balance the rent and the actual number of customers to ensure profitability. The stores will offer basic VR products, such as a headset, controller, game console, and tracking system installed on the headset. In addition, the small physical stores will be located in Tuen Mun Yan Tin and Kwun Tong On Tai in the first stage.

PC6: Individuals in their late middle age

| Area | District | Constituency Area | PC6 score |
|------------------|-------------------|-------------------|------------|
| Hong Kong Island | Central & Western | Centre Street | 738.95093 |
| New Territories | Tai Po | Lam Tsuen Valley | 635.873463 |
| New Territories | Kwai Tsing | Kwai Luen | 570.139816 |
| Kowloon | Wong Tai Sin | Choi Wan West | 558.264302 |
| New Territories | Kwai Tsing | Lai Wah | 539.660879 |

For individuals aged in 55-59, if they have child, they may give birth at around 30 years old which is 25-29 years ago. Their children should be aged in 25-29 which are probably living their own. They are hard to be attracted to VR sport by their children because they are not living together. Therefore, we need to provide more extrinsic motivation for individuals aged in 55-59, like health improvement. We suggest to have pop-up stores with areas testing their physical level, and hence professional staff can offer them some suggestion that how to use VR sport improve health. Also, the pop-up store can provide trials for them to experience VR first. We suggest to locate the pop-up store in Central & Western and Wong Tai Sin which are in Hong Kong Island and Kowloon while New Territories has pop-up store in Tai Po and Shatin as suggestion of PC1.

4 VR SPORTS CENTRE LOCATION SELECTION

4.1 POPULATION STANDARDS

According to Hong Kong Planning Standards and Guidelines, numerous sports facilities standards related to population are included. We picked a public sports centre as a reference for selecting a location for VR sports centres. Sports centres offer various sports types that are similar to what we want to include in the VR sports centre.

| Built Facility | Provision Standard | Site Area [#] | Remarks |
|----------------|---------------------|-----------------------------|--|
| Sports Centre | 1 per 50 000-65 000 | 0.6 ha (i.e. 100m x 60m) | With*: 8 x badminton, or 2 x basketball, or 2 x volleyball 2 x tennis plus 3 x Squash Courts 1 x Activity/Dance 1 x Fitness Training |

Based on the Population Census (2021), the total Population in 2021 is 7411945. Thus, we need at least 114 sports centres (i.e., $7411945/65000 = 114.029923$). We only have 104 sports centres now. This reveals that Hong Kong has inadequate sports centres. At the same time, the Territory-wide Physical Fitness Survey for the Community 2023 indicates that 86.1% of adult participants used public sports facilities. Among these 86.1% of participants, 56.1% of them require more than 15 minutes to travel to the sports facilities. We assume people will be less motivated to go to the sports centre far from where they live. Thus, we want to open VR sports centres somewhere close to where people live but far away from existing public sports centres. VR sports centres can be an alternative for people who want to exercise.

4.2 K-MEANS CLUSTERING

Population census (2021) provides data on the number of people living in 452 district council constituency areas. We added 452 points of constituency areas by its polling station coordinates with numbers of people as weighting (i.e., the weightings are added by duplicating the points by times the number of people in that area where a total number of points equals the total population in Hong Kong in 2021).

We selected a number of clusters (i.e., the number of centroids) by dividing the population standards by the total population in Hong Kong in 2021, which is 114. However, when performing the K-means clustering, the map function initially did not identify and differentiate the harbor and land regions. As a result, we found that some centroids were located on the Victoria Harbour. Therefore, we divided constituency areas according to their respective islands: Hong Kong, Kowloon, and New Territories.

| | Total Numbers of People (1) | Numbers of centroids by dividing population standard |
|------------------|-----------------------------|--|
| | | Sports Centre (1)/65000 |
| Hong Kong Island | 1 195 529 | 18 |
| Kowloon | 2 232 339 | 34 |
| New Territories | 3 798 795 | 58 |
| Other Island | 185 282 | 3 |
| Total | 7 411 945 | 114 |

Due to the insignificant number of centroids required and available data points, we excluded the other islands from our analysis. Thus, the total number of centroids we found is 111 (i.e., $18+34+58=111$). By removing Tung Chung Man Tung Road Sports Centre, Mui Wo Sports Centre, Praya Street Sports Centre, Cheung Chau Sports Centre, and Peng Chau Sports Centre, the number of existing sports centres decreased to 99 (i.e., $104-5=99$).

Fig. 5. Centroid locations for major Hong Kong Islands

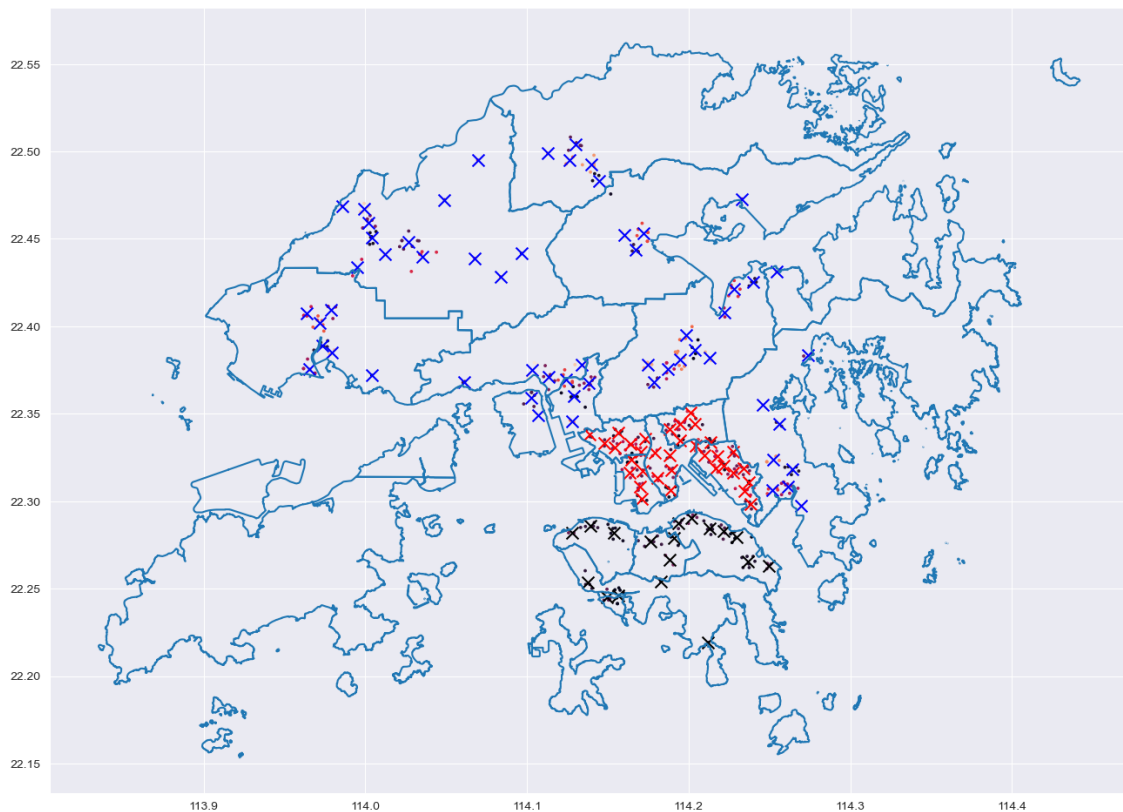


Fig. 6. Centroid locations on Hong Kong Island

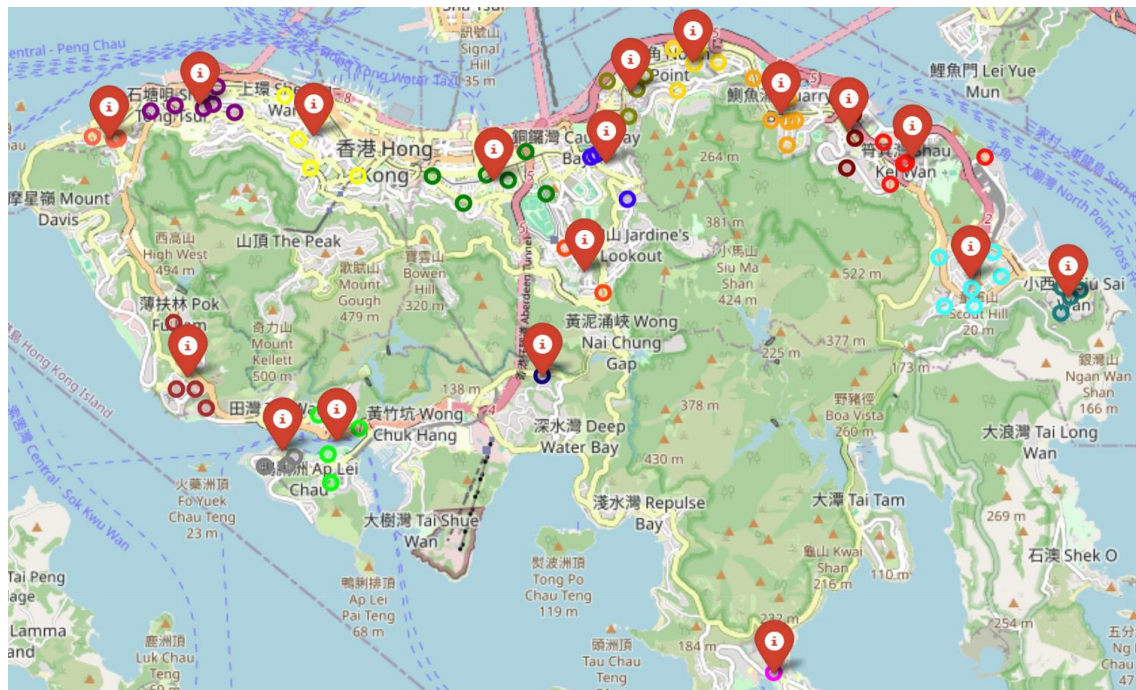


Fig. 7 Centroid locations on Kowloon Area

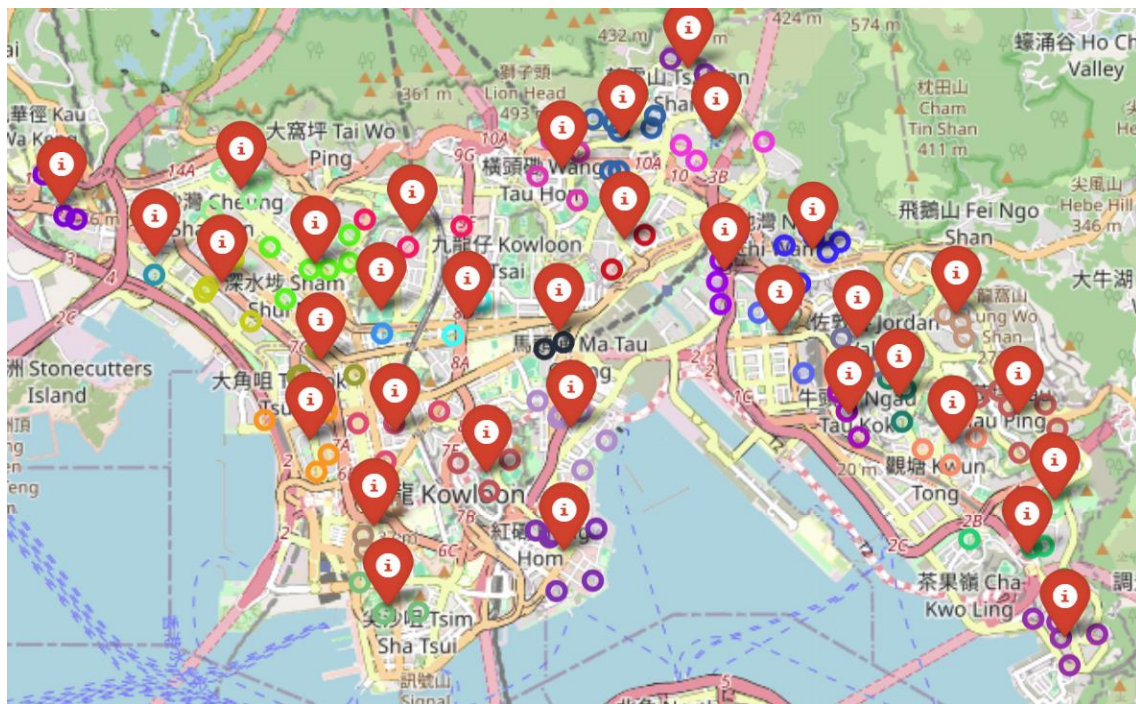
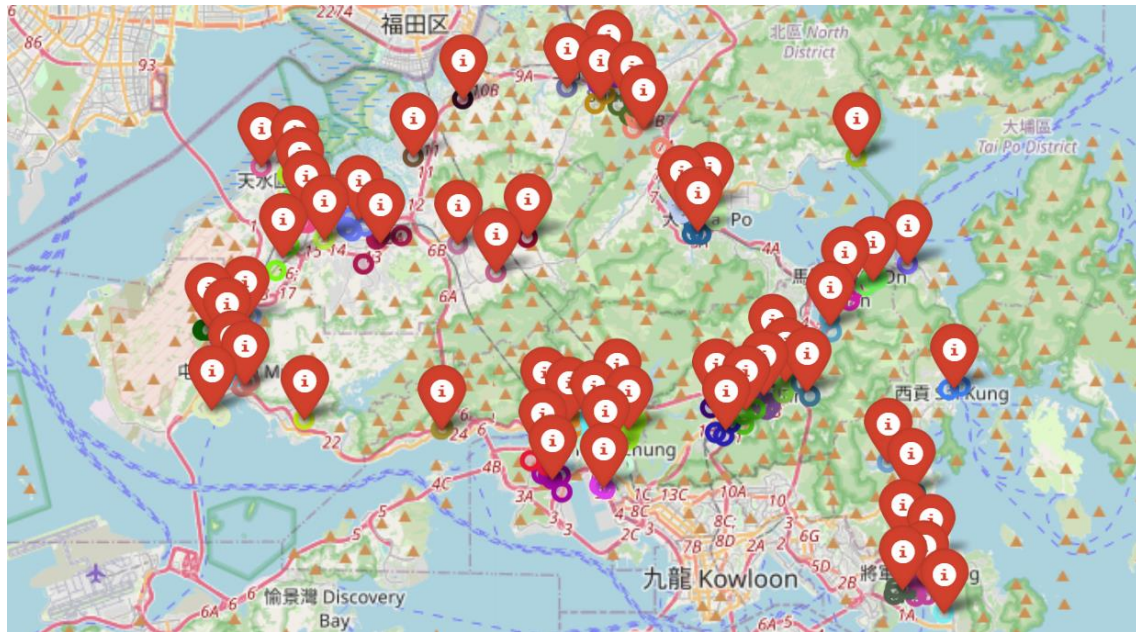


Fig. 8 Centroid locations on New Territories Area



4.3 COMPARISON

We used a one-hot encoding structure for the location of sports facilities. Due to limited time constraints for data cleaning and processing, we also limited the scope of our analysis to four different types of sports facilities: Badminton Courts, Basketball Courts, Volleyball Courts, and Table Tennis Tables. Some recreational centres offer multiple types of sports facilities at the same location. Therefore, performing the analysis for each type of facility separately could offer additional insights. The table below shows the head of the dataset.

| Name | District | Latitude | Longitude | Badminton Courts | Basketball Courts | Volleyball Courts | Swimming Pools | Table Tennis Tables |
|---------------------------------|--------------|-------------|-------------|------------------|-------------------|-------------------|----------------|---------------------|
| Tai Tau Leng Sitting-out Area | NORTH | 22.50028734 | 114.1232912 | 1 | 0 | 0 | 0 | 0 |
| Choi Hung Road Badminton Centre | WONG TAI SIN | 22.33753226 | 114.1969974 | 1 | 0 | 0 | 0 | 0 |
| Bowen Road Temporary Playground | WAN CHAI | 22.27141317 | 114.1748416 | 1 | 0 | 0 | 0 | 0 |
| Tung Fong Children's Playground | NORTH | 22.508607 | 114.1007659 | 1 | 0 | 0 | 0 | 0 |
| Pak Fuk Children's Playground | NORTH | 22.49462208 | 114.1336743 | 1 | 0 | 0 | 0 | 0 |

After plotting a scatter plot of the centroids and locations of selected sports facilities (badminton courts, basketball courts, and table tennis tables), we could visualize where new sports facilities could be located. The locations needing further attention could be ranked based on the distance between the centroids and the nearest selected sports facilities.

Fig. 9. Centroids and Selected Sports Facilities

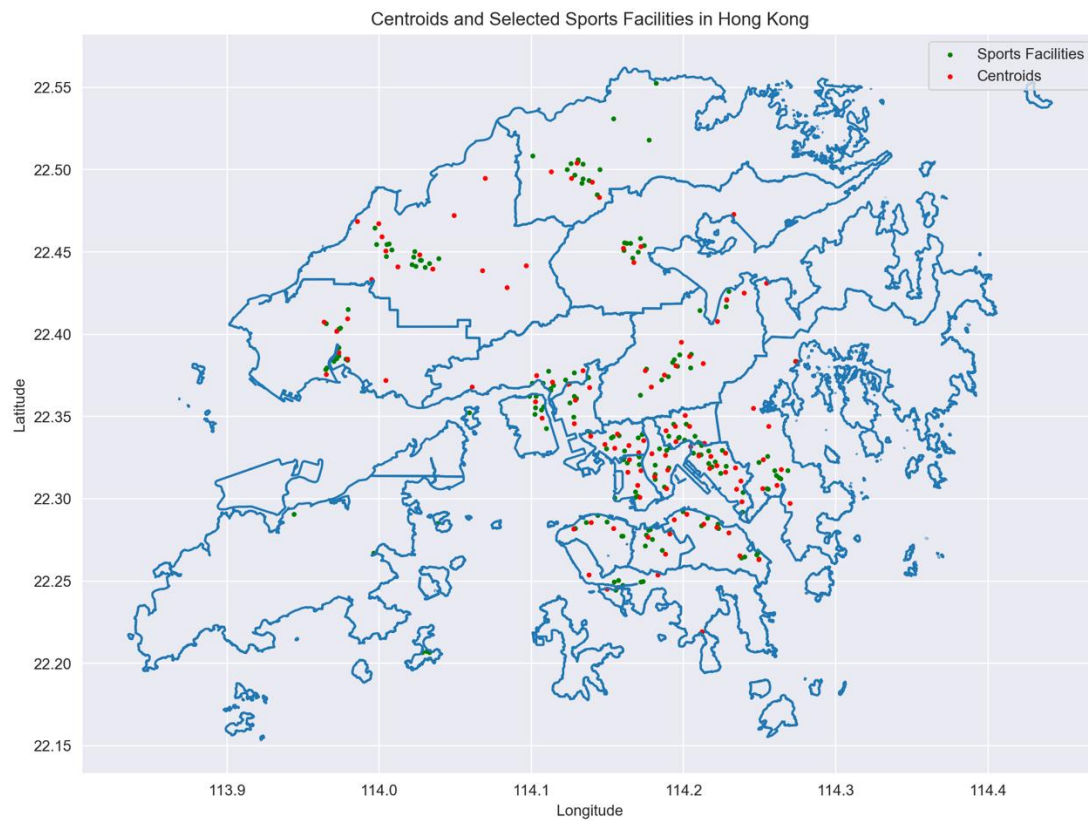
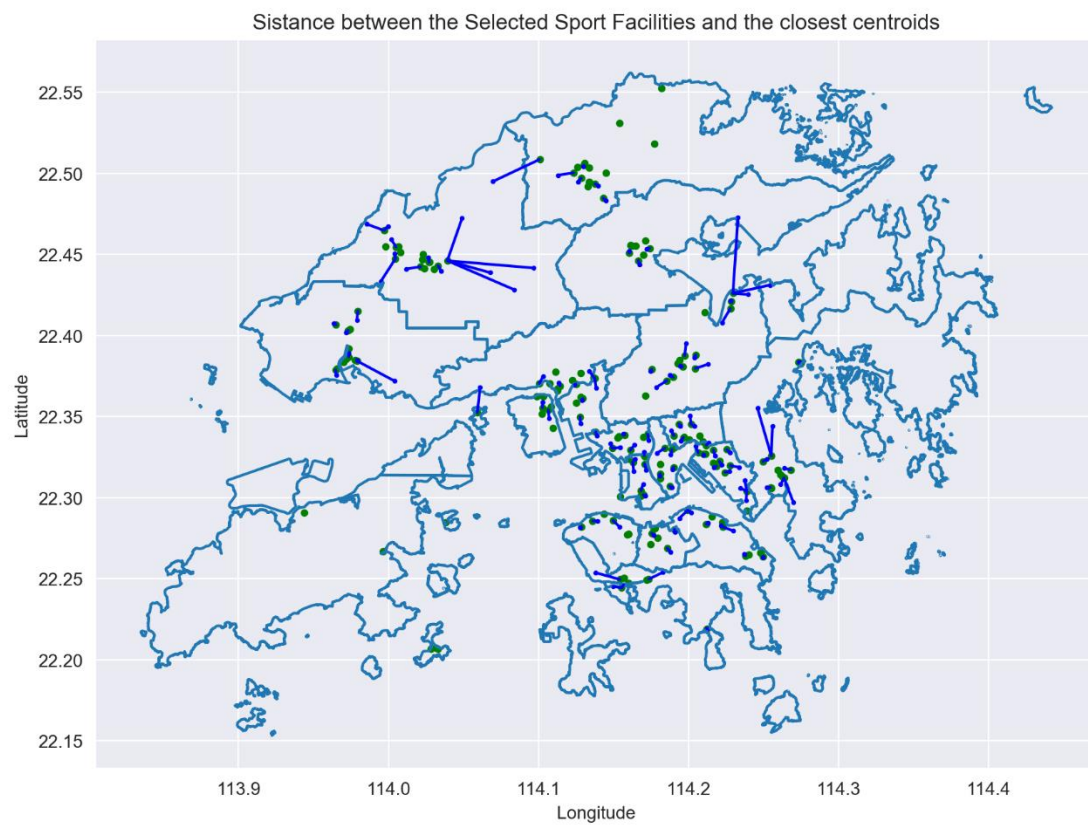


Fig. 10. Distance between the Selected Sports Facilities and the Closest Centroids



4.3.1 Hong Kong Island

On Hong Kong Island, the mean distance between the 18 centroids to the nearest selected sports facilities was 517 meters, the standard deviation was 523 meters, and the third quartile was 632 meters. Therefore, to make our analysis more concrete, we focused on distances exceeding 750 meters. The centroids at Pok Fu Lam and Kellet Bay were found to be most distant from Aberdeen Sports Centre, 2223 meters.

Fig. 11. Distance between the Selected Sports Facilities and the Closest Centroids on Hong Kong Island

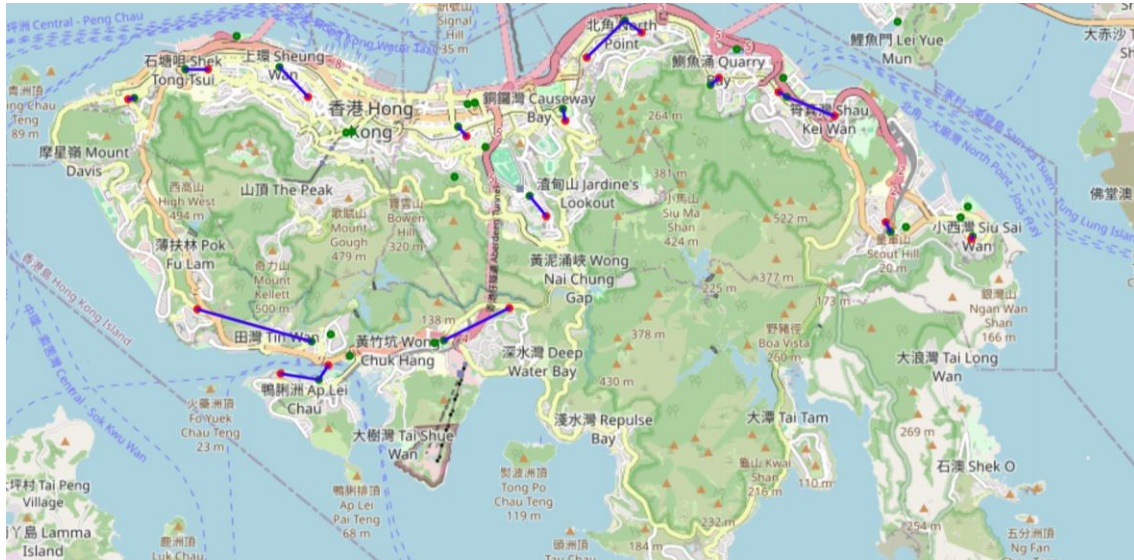
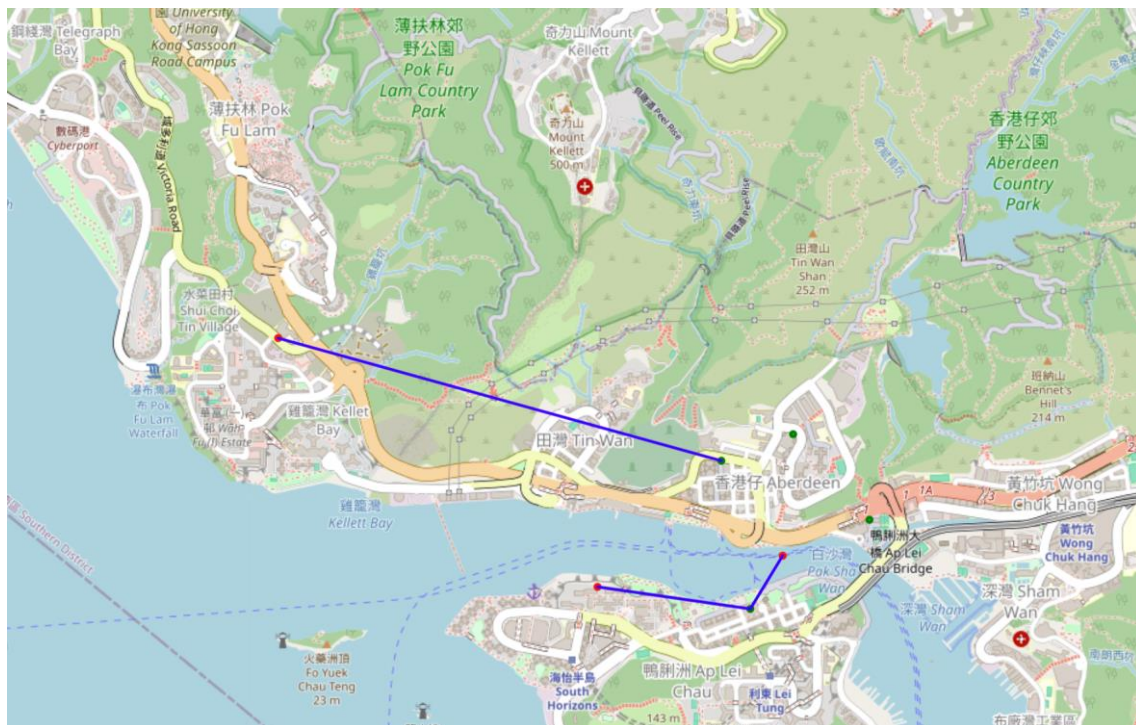


Fig. 12. Distance between Aberdeen Sport Centre and Centroids at Pok Fu Lam & Kellet Bay



Pok Fu Lam:

Setting up a VR sports centre in Pok Fu Lam is good because Hong Kong University is close to Pok Fu Lam and Kellet Bay. A minibus takes around 20 minutes to travel from Hong Kong University to our VR sports centre. The VR sports centre allows HKU students to do group activities, such as VR football.

However, Pok Fu Lam has no commercial or industrial buildings available. We switched to setting up a VR sports centre at point that the second long distance between Centroid and the existing sports centre, South Island School. There are two options for commercial or industrial buildings, and they are both next to Wong Chuk Hang MTR station. The convenience of transportation can attract people who live outside of the constituency area to come. Also, people who live in Pok Fu Lam can go there easily. They have buses on routes 70, 72, and 78, and it takes around 20 minutes to get there. Obviously, the VR sports centre in Wong Chuk Hang takes a bit longer to get to than the Aberdeen Sports Centre for Pok Fu Lam people. We believe the novelty and enjoyment of VR Sports that traditional sports cannot bring them can motivate them to come.

Fig.13. Wong Chuk Hang Building

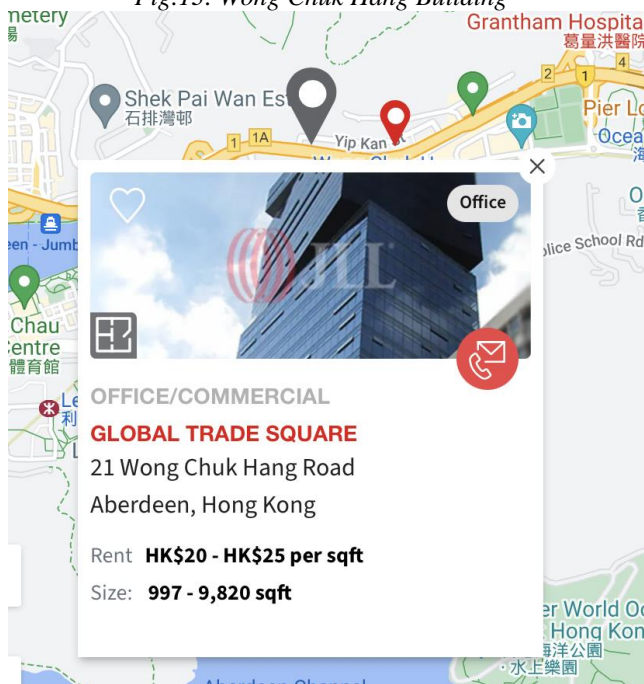


Fig. 14 Wong Chuk Hang Building



4.3.2 Kowloon

As the most densely populated area, the Kowloon area had relatively abundant sports facilities, and it may not be a priority to develop any new ones. The mean distance is 291 meters with a standard deviation of 230 meters and a third quartile of 531 meters.

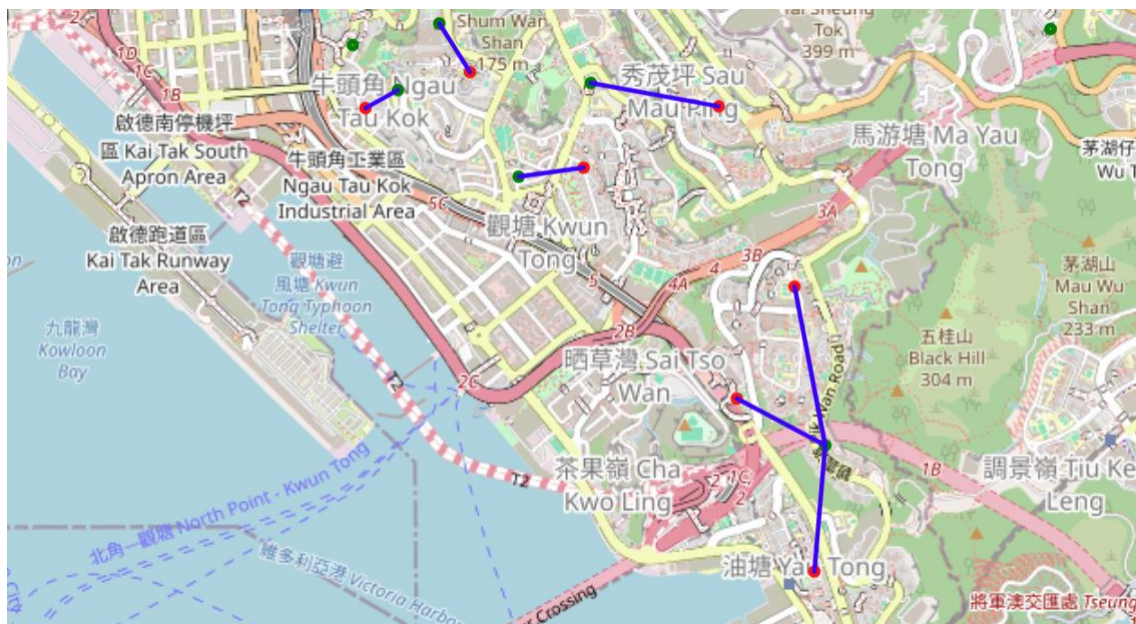
Fig. 15. Distance between the Selected Sports Facilities and the Closest Centroids on Kowloon



Kwun Tong

Yet, among the top five centroids with the highest distance, three were located in Kwun Tong, with distances of 1052 meters, 901 meters, and 785 meters.

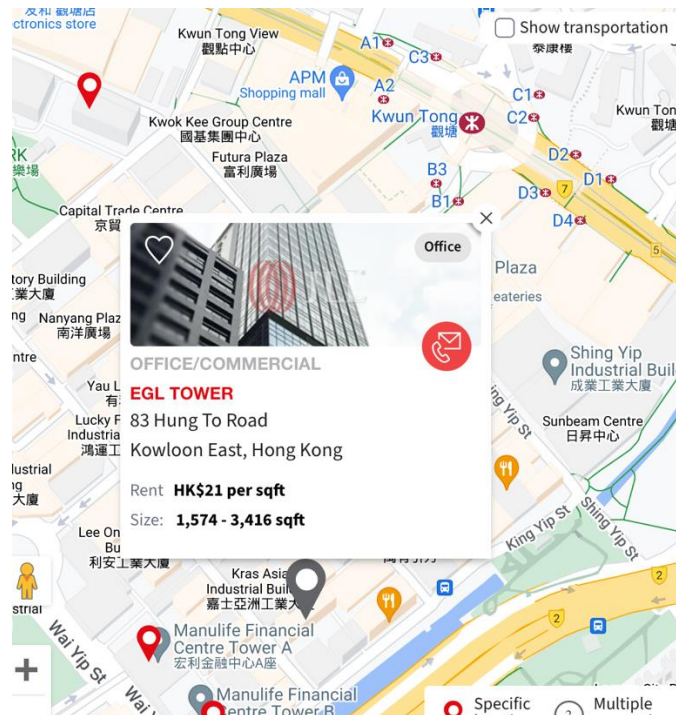
Fig. 16. Distance between Sport Facilities and Centroids in Kwun Tong



The above centroids that far away from existed sport facilities are near to Ping Tin, Yau Lai, and On Tat in Kwun Tong district. Population census (2021) indicates Kwun Tong is the second high population district in Hong Kong. We believe Kwun Tong district also has many young individuals who are interested in VR sport. Also, Kwun Tong is popular of its renovate and multifunctional commercial and industrial buildings. Thus, it is suitable to set up VR sport centre in Kwun Tong. We

picked EGL Tower as our VR sport centre location. People from Ping Tin, Yau Lai, and On Tat can go there by bus or MTR with around 20 minutes. In addition, commercial and industrial buildings near EGL Tower are popular among young individuals nowadays. There are many cultural and creative markets, shops, restaurants in those building. They can drive more young customers and revenue to our VR sports centre.

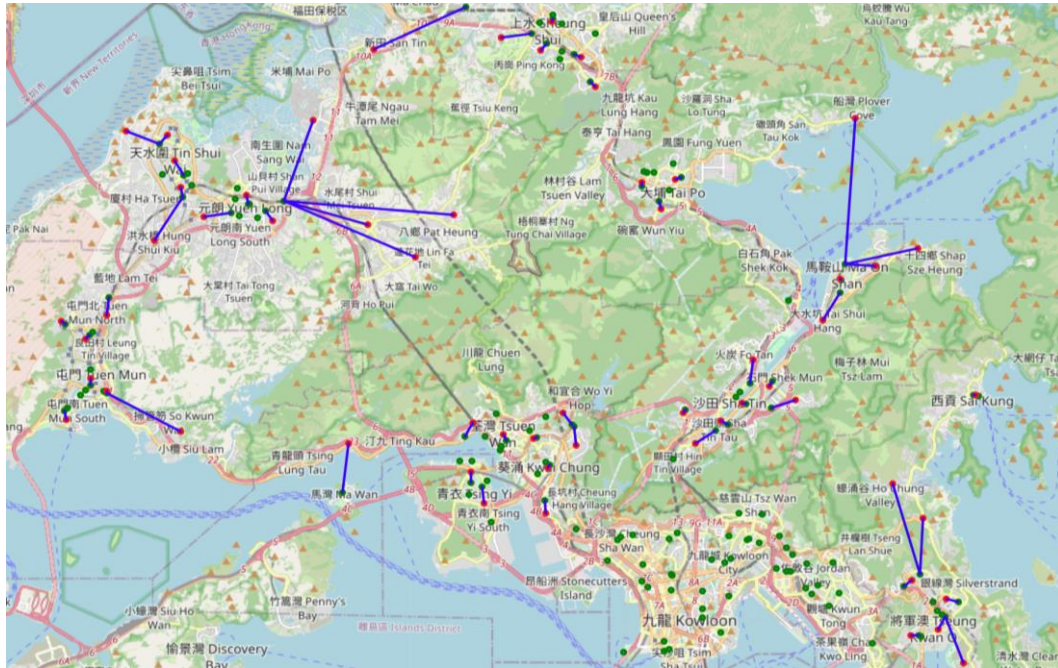
Fig. 17. Kwun Tong Building



4.3.3 New Territories

Considering that New Territories is mostly a rural area with the least population density, we focused on the centroids, which were over 3000 meters away from the nearest sports facility. The highest mean distance (858 meters) and standard deviation (1151 meters), while the third quartile is 968 meters.

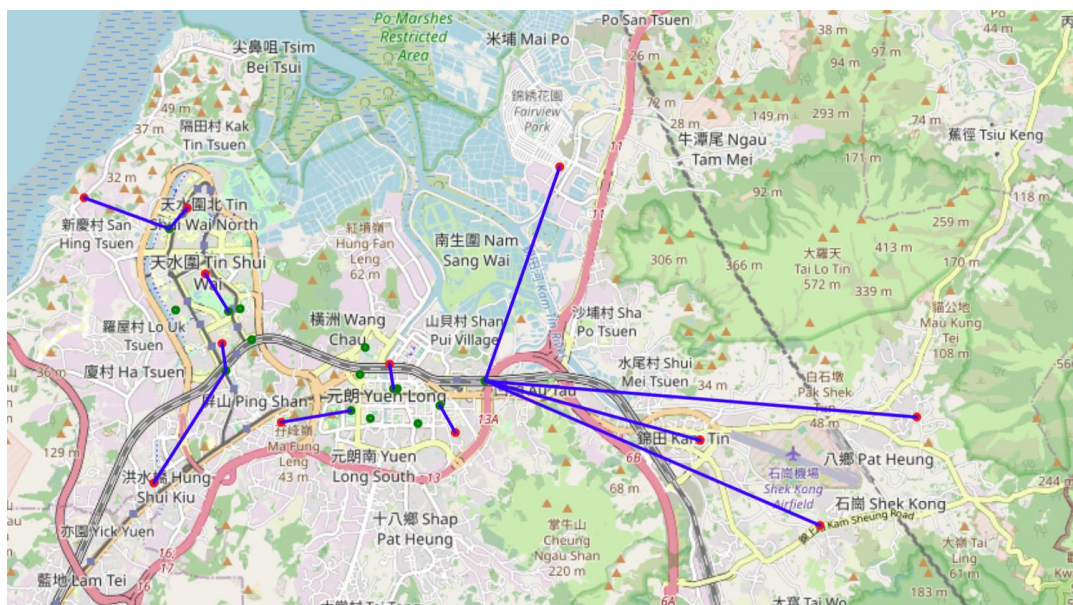
Fig. 18. Distance between the Selected Sports Facilities and the Closest Centroids on New Territories



Yuen Long

Kam Tin, Shek Kong, Pat Heung, and Ngau Tam Mei were all areas that had the nearest sports facility at Yuen Long Town Cycling in common, which for some was 5000 meters away.

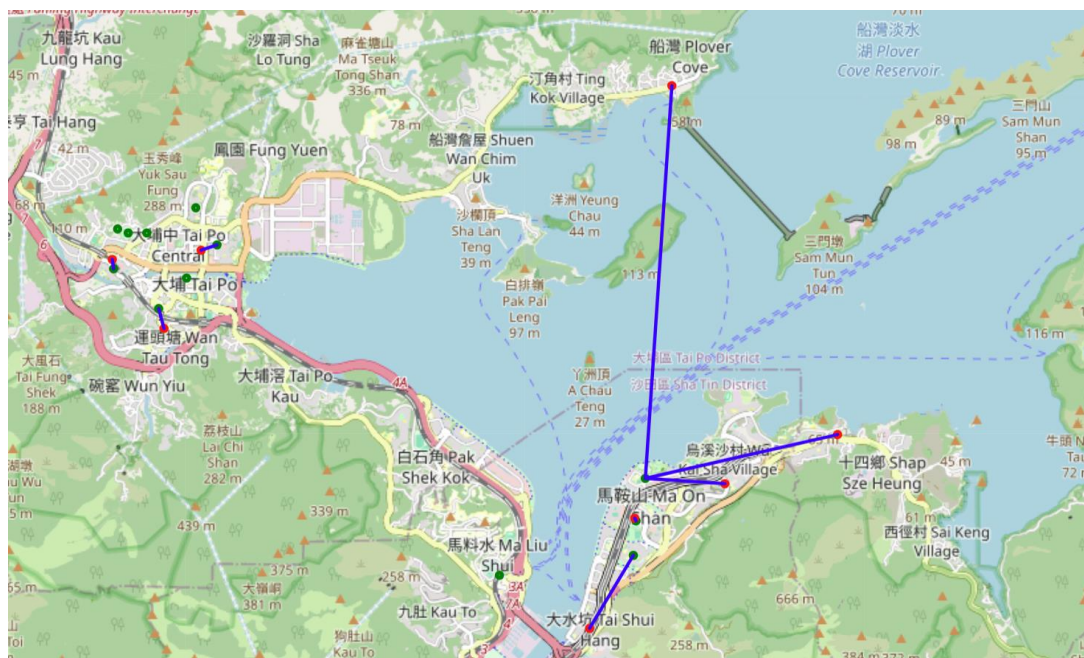
Fig. 19. Distance between Selected Sport Facilities and Centroids in Yuen Long



Tai Po

Several village areas in the Tai Po district, such as Plover Cove, had none of the selected sports facilities in 5000 meters of range.

Fig.20. Distance between Ma On Shan Sports Centre and Centroids in Tai Po



The centroids in Yuen Long and Tai po far away from existed sports facilities is mostly in the rural area while sport centre usually is built in urban area. Refer to Population census (2021), total population in Yuen Long is 668 080 while total population in Tai po is 316 470. Due to income concern, we decide to build VR sport centre in urban area in Yuen Long first instead of Tai Po. Although there has already had many public sport facilities, we believe VR sport centre can be an alternative in doing exercise by providing excitement that traditional sport cannot provide, such as game theme. The VR sport centre will set in Yuen Long One North which is 12 minutes travel time from either Long Ping station or Yuen Long Station. Thus, people live inside or outside of Yuen Long can go there easily.

Fig.21. One North outward

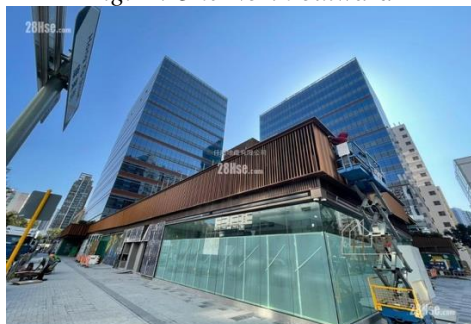
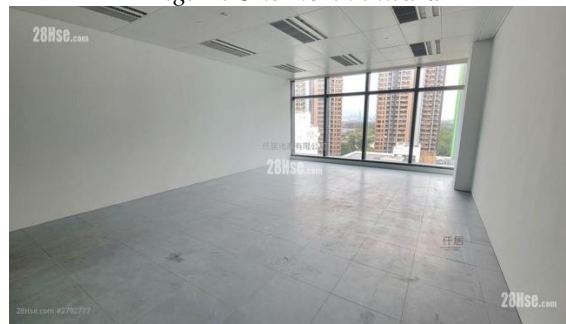


Fig.22. One North inward

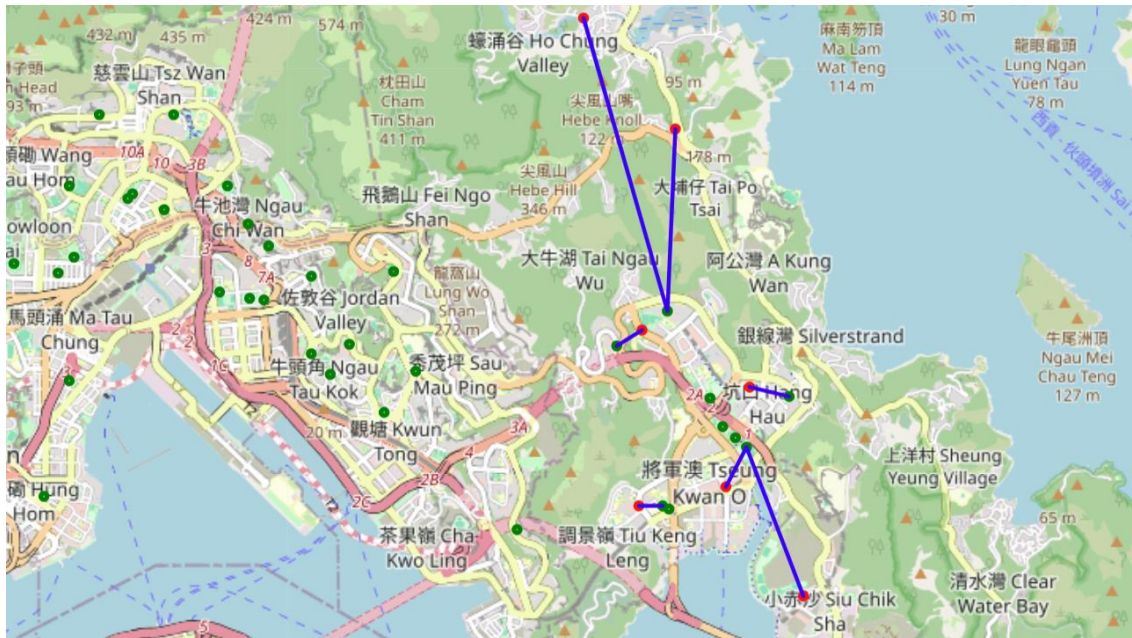


| | |
|----------------|--|
| Monthly Rental | Lease HKD\$29,014 |
| Gross Area | 1,630 ft ² Unit Price: @17.8 |
| Estate | One North New Territories Yuen Long |

Sai Kung

In Sai Kung District, Po Lam Sports Centre was the nearest to Ho Chung Valley and Ta Ku Ling centroids, despite being 3052 meters away.

Fig.23. Distance between Selected Sport Facilities and Centroids in Sai Kung



Tai Po Tsai is the area of The Hong Kong University of Science and Technology. We believe there has already had sufficient sport facilities provided by the university to students. In addition, there are no sport facilities next to them because there are rural area, such as Ho Chung Valley.

Ho Chung Valley only has 16828 people live in there. Due to income concern, we do not suggest to have VR sport centre in Sai Kung at the first stage. If they are interested, they can go to Kwun Tong VR sport centre. The transportation from Sai Kung to Kwun Tong is convenient and less than one hour.

5 RESULTS

5.1 VR SPORTING GOODS STORE

Due to cost concerns, we would have an online store to reduce the cost of opening many physical stores. However, we understand customers' physical store needs, such as sales or return and testing. Therefore, we pick a few areas to open physical stores and pop-up stores by understanding the age patterns of different areas.

- **The largest physical store** near Sham Shui Po Lung Ping and Sheung Pak Tin with testing area, beginner area, and professional area
- **Small Physical store** near Tuen Mun Yan Tin and Kwun Tong On Tai with basic VR sporting goods (i.e., headset, controller, game console, and tracking system installed on the headset)
- **Pop-up store** in Malls in Central & Western, Tai Po, Sha Tin and Wong Tai Sin with testing area, family package, and limited discount

5.2 VR SPORTS CENTRE

We hope to find some new locations closer to high-population areas, which can lower the time spent traveling to sports facilities. Hence, people can save time for transportation or get less tired from heavy transit. According to our analysis, we can determine the location of the new facilities based on the distance between the centroids and the sports facilities. Longer distances indicate a higher cost of traveling time. Considering popularity, densely populated areas with greater distances from sports facilities are the perfect locations to open VR sports centre. By placing VR sports facilities in such areas, we not only tap into a ready audience but also fill in the gaps in the current sports facilities by targeting locations further away from them. The followings locations of VR sports centre are based on the distance comparison, population, and cost and income concern.

- **Hong Kong Island: GENESIS**
 - Address: 33-35 Wong Chuk Hang Road, Aberdeen, Hong Kong
 - Rent: $\$17.5 * 2000\text{sqft} = \35000 per month
- **Kowloon: EGL TOWER**
 - Address: 83 Hung To Road, Kowloon East, Hong Kong
 - Rent: $\$21 * 2000\text{sqft} = \42000 per month
- **New Territories: One North**
 - Address: 8 Hong Yip Street, Yuen Long, Hong Kong
 - Rent $\$17.8 * 1630\text{sqft} = \29014 per month

6 CONCLUSION

6.1 UNIQUENESS

We want our business to be people-oriented. Currently, many VR products are sold in large electronic stores. Those stores do not specifically segment the VR products into beginner level or professional level, as well as do not provide a testing area. We understand customers may have many concerns about new technology and the price. We hope to allow them to figure out the benefits of VR by themselves. Thus, we set up physical stores and pop-up stores. For customers who want to try VR sports for a longer time before they purchase, they can go to our VR sports centre.

In the VR sports centre. We can organize a workshop for people who want to try VR sports. The VR sports centre has options from the beginner package to the professional package (i.e., the beginner package is just a headset and controller; the professional package also includes a VR simulator, Omni Treadmill, etc.). People can come to the sports centre and try it first. If they are interested, they could order from the sports centre immediately. Except for the VR sports centre's long-term experience function, it is also an entertainment place for people to enjoy gaming and sports. We are welcome to groups and families.

Nowadays, AME stadium is the only one in Hong Kong that combines sports and esports, while VR Arena is the first one in Hong Kong to have an Omni Treadmill, which is designed to provide a multidirectional running experience. As far as we know, Hong Kong does not have a VR sports centre that entirely does sports with VR tools as VR Arena does. We will combine sports with game themes. Complete VR tools can provide a profound experience for customers to enjoy the excitement. At the same time, customers exercise to enhance their physical level.

In addition, to keep our VR sports centre unique and new, we will have VR sports games with different and updated game themes. For example, for October, the month of Halloween, we will have a zombie theme. People will play badminton, basketball, etc., with zombies. We will set up a recommendation system to promote new VR sports games and adjust the difficulty of the VR sports game by analysing what kind of sports customers usually play, what game themes they like, and how is the performance.

6.2 FUTURE WORK

6.2.1 Enhancing our analysis

Currently, our data analysis only considers four types of sports facilities: basketball, badminton, table tennis, and volleyball. However, we aim to expand our data in the future for other facilities to enhance our analysis of other sports facilities in Hong Kong, such as private fitness rooms and tennis courts. In this way, we can have a better understanding of the density and distribution of sport facilities in different constituency areas.

6.2.2 Analysis in other sectors

Our analysis can also be applied to other fields, such as the food industry, to find locations of restaurants or the real estate industry to find suitable locations for setting-up property agencies. This can lead to the better development of the city by equally creating different sports facilities in the 452 constituency areas, thereby improving the quality of life of people living in all areas.

6.2.3 For improving time efficiency

Our location tool can be used with apps like Google Maps to find the location of a place closest to customers. This can save them time as they can find the shortest distance to reach their destination.

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8 APPENDIX

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Figure 1. Population Density by Hong Kong District

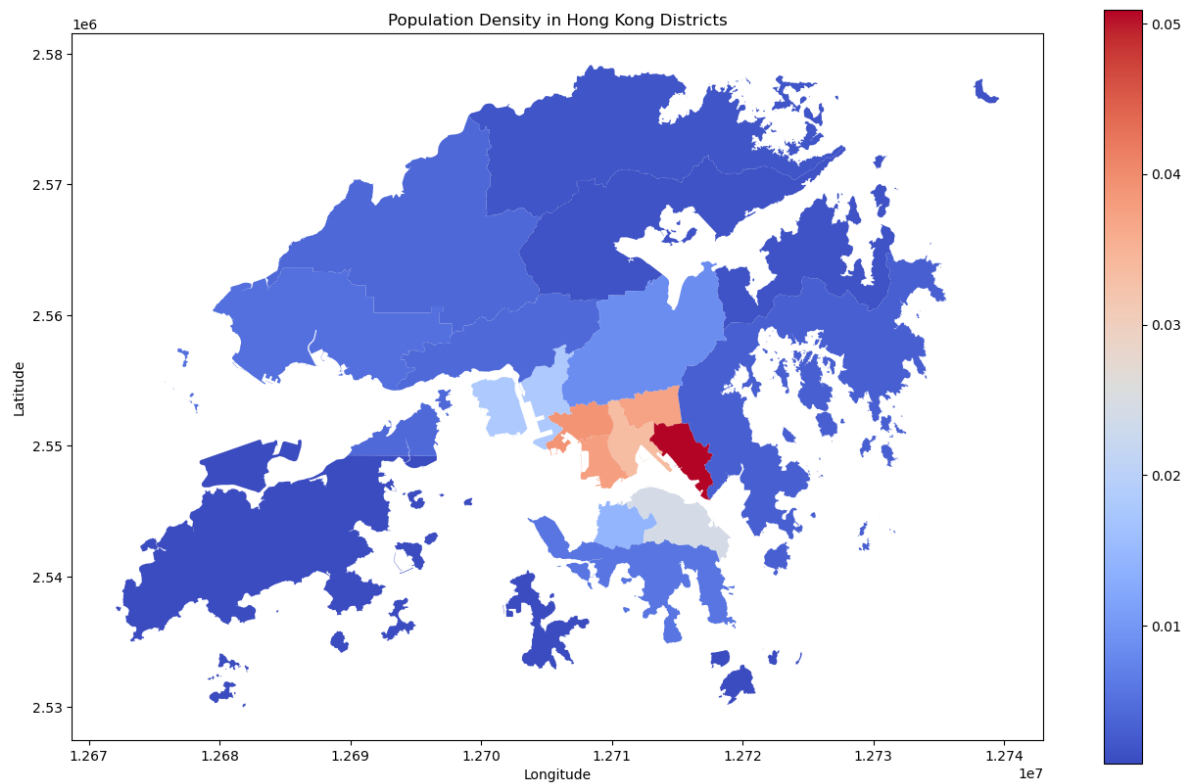


Figure 2. Population Proportion by Hong Kong Districts

