A Tale of Two Asias: Air Pollution and Its Management in Asia

A Comparative Case Study Analysis

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Abstract

Asia, in its prioritisation on economic development over the environment, has some of the most polluted countries in the world. At the same time, there are other Asian countries, particularly Japan, that have made the effort to address the effects of economic development on the environment. The aim of this research study was to conduct a comparative case study analysis of the phenomenon of air pollution in Asia by analysing the air quality data of 24 different countries across three different years, as measured by the Air Quality Index (AQI). These Asian countries were divided into good air quality and poor air quality countries to capture the extent of the disparity of their experience of air pollution. A two-way ANOVA without replication was used to analyse the data to compare the main effects of AQI between the two categories of countries (good and bad air quality). Finally, there was no interactive effect between air quality and the year. The potential reasons were discussed in detail for the level average AQI of these countries throughout the 3 years. These findings gave us clear statistics of the Air Quality in the different regions of the continent. A qualitative analysis of how a sampling of Asian countries had been addressing three specific areas of air pollution—power generation, waste management, and public transport—offers insights as to the underlying discrepancies between the AQI of the good and poor air quality countries. The measures implemented by good air quality countries can provide insights as to how poor air quality Asian countries could be improving their management of these areas.

Keywords

Asia, air pollution, AQI(Air Quality Index)

Introduction

In a world that is driven by the pursuit of economic development, countries have persisted in using resources that pollute the environment, such as fossil fuels (Farrow et al., 2020, p. 1). Despite the fact that the new power plants using renewable sources like wind and solar are able to generate electricity at cheaper or similar costs as compared to fossil fuels (including coal and oil), fossil fuels continue to be the most used source for generating power due to the lobbying of oil and gas companies pushing for the use of outdated technologies (International Renewable Agency, 2018).

The consequence is that we are continuing to experience worsening air pollution all over the world. The use of fossil fuels releases pollutants described below:

- **Nitrogen oxides (NOx) and sulphur dioxide**: Caused by the burning of fossil fuels, these gases create particulate matter (discussed below) and smog to produce cardiovascular and respiratory diseases.
- **Ozone:** Ground-level ozone formed by the reaction of NOx with chemicals affects lung functioning, thus leading to conditions like asthma.
- **Particulate matter/ particles**: These are extremely small particles and liquid droplets in the atmosphere, which come from a combination of different chemicals (Aidan et al., 2020, p. 2).

The costs of air pollution are very high, in terms of both economic and human costs. Air pollution from fossil fuels amounts to around US$8 billion on a daily basis, i.e., 3.3% of the global GDP (Farrow, et al., 2020, p. 6). About 7.7 million people go to the emergency room every year due to their exposure to generated fine particulate matter (PM2.5) (which causes lung disease and asthma) and ozone (emitted by the burning of fossil fuels). About 1.8 billion sick leaves alone are due to PM2.5. Premature deaths worldwide equal about 4.5 million (Farrow et al., 2020, p. 1).

Air pollution's characteristics, due to the types of pollutants, sources of pollution, and environmental conditions, differ from region to region and country to country. The impact of air pollution also needs to factor in population, lifestyles, and geographical location. For example, a computer modelling study evaluating various sources of PM2.5 and ozone pollution — industry; land traffic; residential and commercial energy; biomass burning; power generation; agriculture; and natural. It found that 30% of the population was at risk of premature deaths in 2010 due to air pollution from residential and commercial energy sources — the primary causes of deaths from air pollution — in India and mainland

China (Lelieveld, J, 2015). In particular, power generation and land traffic were responsible for 14% and 5%, respectively, of premature deaths by air pollution. More specifically, the countries with the highest level of premature deaths caused by land traffic emissions were the US, Germany, Turkey, Russia and Japan, while power generation was the primary cause of premature mortality in Russia, Turkey, mainland China, and Japan (Lelieveld, J, 2015). Clearly, air pollution is a serious problem that afflicts countries all over the world. In this research study, the focus will be placed on Asia.

Description of the Research Study

The research aim was to conduct a comparative case study analysis of the phenomenon of air pollution in Asia through a mixed-method approach. Under the quantitative approach, the air quality data of 24 Asian countries, as measured by the Air Quality Index (AQI) from three different years, were compared. These countries were divided into two categories—good air quality versus poor air quality—in order to capture the extent of the disparity between the two categories of the countries in their experience of air pollution. Furthermore, the endeavours of the countries in tackling air pollution, particularly in three specific areas—power generation, waste management, and public transport—were also addressed.

As defined by Yin (2009), a case study analysis concerns a real-life investigation into a phenomenon within a specific context in order to identify underlying factors and patterns that have contributed to the situation. Therefore, it is highly appropriate for this research study that involved an in-depth evaluation of the phenomenon of air pollution in the real-life contexts of several Asian countries. With case studies, data could be gathered from a diversity of sources and analysed in multiple ways.

In this case, Quantitative data regarding air pollution (AQI) of 24 Asian countries across the years of 2018, 2019, and 2020, were gathered by IQ Air's (2021) “World's Most Polluted Countries in 2020 (PM2.5). IQ Air operates the largest real-time air quality platform in the world. It is an air quality technology company that engages global citizens, organisations and governments in the real-time Air Quality Index(AQI).

AQI is an easy to understand scale which clearly represents the health risk posed by ambient air pollution. It ranges from about 0 to 500 where high index values indicate a higher level of pollution which means a higher potential for unfavourable health conditions. WHO says that 0-50 AQI is good and 51-100 is moderate.

Data were analysed using Two-Factor ANOVA without Replication to compare the effects of AQI between the two good and bad air quality countries.

- 1a. **Null Hypothesis**: There is no difference between the mean AQI of good and bad air quality countries.
  1b. **Alternative Hypothesis**: There is a difference between the mean AQI of good and bad air quality countries.

- 2a. **Null Hypothesis**: There are no differences in the mean AQI across the three years.
  2b. **Alternative Hypothesis**: There are differences between the mean AQI across the three years.

- 3a. **Null Hypothesis**: There is no interactive effect between the air quality status of the countries and the year.
  3b. **Alternative Hypothesis**: There is an interactive effect between the air quality status of the countries and the year factor.

Furthermore, the data for the individual states during the three separate years were depicted in a bar graph. The visual depiction was used to generate even more detailed insights into the general and particular trends of Air Quality over the last 3 years. To explore the underlying factors that could account for the discrepancy between these two categories of country, quantitative data were gathered for mini case study analyses of a sampling of countries from these two categories with a focus on how they have been addressing the key areas of air pollution: power generation, waste management, and public transport.

Results and Discussions

In this section, the results of the analysis of the differences between the average air quality of Asian countries, categorised under "good air quality" and "poor air quality", across 2018, 2019, and 2020, will be presented and discussed in further detail (see Table 1).

Table 1

Raw Data of Countries with Good and Poor Air Quality (Cut-off Point Set at 29 $\mu g/m^3$)

Air Quality Category	**2020 Average**	**2019 Average**	**2018 Average**
Good Air Quality			
Vietnam	28.00	34.10	32.90
Iran	27.20	24.30	25.00
Sri Lanka	22.40	25.20	32.00
Kazakhstan	21.90	23.60	29.80
Thailand	21.40	24.30	26.40
Cambodia	21.10	21.10	20.10
Turkey	18.70	20.60	21.90
Cyprus	15.80	19.70	17.60
Taiwan	15.00	17.20	18.50
Philippines	12.80	17.60	14.60
Singapore	11.80	19.00	14.80
Japan	9.80	11.40	12.00

Poor Air Quality			
Bangladesh	77.10	83.30	97.10
Pakistan	59.00	65.80	74.30
India	51.90	58.10	72.50
Mongolia	46.60	62.00	58.50
Afghanistan	46.50	58.80	61.80
Indonesia	40.70	51.70	42.00
Bahrain	39.70	46.80	59.80
Nepal	39.20	44.50	54.10
China	34.70	39.10	41.20
Kuwait	34.00	38.30	56.00
Uzbekistan	29.90	41.20	34.30
United Arab Emirates	29.20	38.90	49.90

A Two-Way ANOVA with Replication was run to compare the differences between the countries with good air quality and countries with poor air quality to determine their statistical significance. Based on Table 2 (See Appendix), the main effect of air quality by country (good air quality country versus poor air quality country) yielded an *F* ratio of 131.02 (higher than *F* critical value of 3.86), p <.01. This indicates that the differences in the mean air quality index between countries with good air quality and countries with poor air quality (M =18.83 µg/m^3, *SD*=5.87 µg/m^3 vs. M =44.04 µg/m^3, *SD*=13.66 µg/m^3 in 2020; M=21.51 µg/m3 , *SD*=5.55 µg/m^3 vs. M= 52.38 µg/m^3, *SD* = 13.74 µg/m^3 in 2019; and M=22.13 µg/m^3, *SD*=7.07 µg/m^3 vs. M=58.46 µg/m^3 , *SD* = 17.07 µg/m^3 in 2018) of 25.21 µg/m^3, 30.87 µg/m^3, and 36.33 µg/m^3 are statistically significant, respectively. The mean disparity in countries with good air quality was more than double than that of countries with poor air quality.

As for the main effect of years, it is statistically significant with an *F* ratio of 3.69, p = 0.03. This statistical result is unsurprising, given the substantial discrepancy of the mean ratings across the three years between the countries with good air quality (M = 20.82 µg/m^3, *SD* = 18.49 µg/m^3) and the countries with poor air quality (M = 51. µg/m^3, *SD* = 44.47 µg/m^3). The discrepancy was 30.81 µg/m^3.

Finally, there was no interaction effect: the *F* ratio yielded was 1.42 (less than *F* critical value of 3.86), p =.25 This essentially means that the effect of the air quality factor was not related to the year factor.

Furthermore, a bar graph was generated to offer a visualisation of the extent of the differences between the two sets of countries and also between the individual countries and throughout the years.

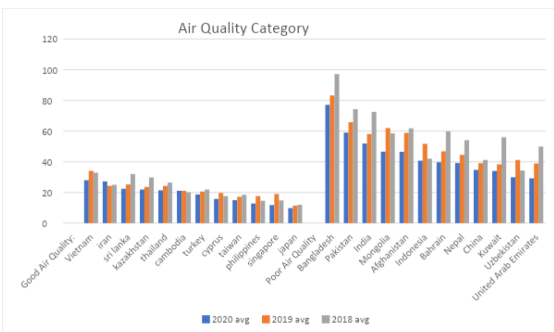

Figure 1 *Bar Graph of the Air Quality of Select Countries in Asia — 2018, 2019, 2020*

In general, all the countries improved over the three years, with the reduction in the air quality index. Nonetheless, it is also important to point out that the lockdown caused by COVID-19 in 2020 and the subsequent lockdowns and cessation of economic activity in different parts of the world, during the different times of the year, certainly contribute to the improvement in air quality (Gardiner, B., 2020). Even countries that increased in the air quality index in 2019, such as Cyprus, Singapore, Philippines, Vietnam, Cambodia, Mongolia, Indonesia and Uzbekistan had a reduction in value in 2020.

Looking more specifically at the two categories of countries with poor and good air quality, we can see those countries in the poor-quality category, such as Bangladesh, India, Pakistan, UAE, Kuwait, and Bahrain, showed drastic improvements between 2018 and 2020. The temporary decrease in air quality could be due to the nationwide lockdown imposed on these countries due to the COVID-19 pandemic(Gardiner, B., 2020). Conversely, the countries with good air quality were Singapore, the Philippines, Japan and Thailand. At the same time, it is important to point out that China, an East Asian country, as well as Indonesia, a Southeast Asian country, are in the poor air quality category. Countries that have a lower AQI have taken various measures to reduce their air pollution. Furthermore, they have not pursued economic development at the expense of the environment, as in the case of China, which had been pursuing economic development intensely in recent decades (Jiang et al.,2020).

Exploration of Challenges of Air Pollution Management and Solutions

The following discussion is about the endeavours of different countries in dealing with air pollution. These countries focused on different and more eco-friendly sources of power generation, different ways to manage waste and better public transport. The development in these three areas led to a major improvement in the environment especially when it came to reducing air pollution and lowering the AQI. The discussion was also useful in identifying solutions for addressing the air pollution problems.

Power Generation

One of the leading contributors in renewable energy and pollution-beating technology in the G7 group is Japan. One such example can be found in Kitakyushu. The impetus for the national government and the municipal government to adopt such technologies stemmed from the severe water pollution problem that had resulted from their reliance on the Imperial (Yawata) Steel in pursuit of economic growth (Allen, 2019). However, it had resulted in the contamination of the local bay by chemicals and other materials like plastics. The problem became so severe over time that the locals called it 'the sea of death' (Allen, 2019).

However, Kitakyushu's adoption of hydrogen power led to its biggest breakthrough in tackling its pollution problem. After partnering with the Research Association of Hydrogen Supply & Utilization Technology, the local government transformed the city into 'Hydrogen Town'. On January 15, 2011, test operations for Kitakyushu Hydrogen Town Project was started by the Research Association of Hydrogen Supply/Utilization Technology (HySuT) — an organisation of 13 companies working in collaboration with Fukuoka Prefecture and the city of Kitakyushu, under the support of the Ministry of Economy, Trade and Industry (METI) (*World's First Community Level Hydrogen Town,* 2011). Its aim was to create a hydrogen energy-based society in the future by powering neighbouring housing complexes, single-family homes, commercial complexes and public facilities through the use of hydrogen fuel cells with hydrogen generated as a by-product from steel plants in the area.

The effort paid off, the Kitakyushu Hydrogen Town Project became the first community-level exhibit in the world that operated using hydrogen fuel cells with hydrogen provided through pipelines (*World's First Community level Hydrogen Town Project Starts in Kitakyushu,* 2011). To ensure the stability, security and safety of the electric supply, with a suitable charging system in terms of the commercialisation of hydrogen supply via pipelines, the project also invested tremendous effort in evaluating odour-mixing and deodorising technologies and the cost of hydrogen gas through measurement and the functioning of hydrogen fuel cells(*World's First Community level Hydrogen Town Project Starts in Kitakyushu,* 2011).

Today, Kitakyushu 'Hydrogen Town' supplies hydrogen to residential and industrial areas, delivering power directly through fuel cells (*World's First Community level Hydrogen Town Project Starts in Kitakyushu,* 2011). Furthermore, Kitakyushu has become a leading city in renewable energies. The city, working with the private sector, through its investments in renewable technologies, has greatly reduced the emissions of soot and other harmful substances. Furthermore, wind farms can be seen all over the land and even offshore, thereby allowing the city to take full advantage of its heavy winds around the coast (Allen, 2019).

The good news is that Kitakyushu is just one of several counties in Japan, which is seeking to deliver pollution-battling technology. For example, in Ukishima, an 11-hectare plant contains 37,926 solar panels that are taking advantage of the sunlight, as it is in a location that is far away from any skyscraper (Allen, 2019). Similarly, the city of Kawasaki city is working with Tepco, a private company, to run a solar plant on Ogishima, a man-made island (Allen, 2019). The plants, combined, generate 20,000 kilowatts of energy for Tokyo, thus playing a major role in the cleaning up of Tokyo's air pollution by reducing the consumption of fossil fuels (Allen, 2019).

Waste Management

How countries manage their wastes has had a major impact on air pollution. Apart from incineration, recycling, particularly plastic waste, has been important for reducing greenhouse gas emissions.

Within the context of Asia, the differences between how the countries manage wastes stretch across a wide spectrum. The distinct approaches in waste management can be clearly seen at different points in the waste stream. On the one hand, the developed countries in Asia are inclined to use advanced technologies like incineration with energy recovery based on waste-to-energy technology and recyclable materials are recycled in a systematic manner. For instance, Japan, South Korea, and Singapore use tech-oriented methods for waste collection and transport (Hong et al., 2018). These methods include motorised vehicles and compactor and transfer stations. The city of Kawasaki has even transformed an industrial landfill near Tokyo's Haneda Airport by building the largest solar power plant on top of it, thus modifying the area and turning recycling waste into a business (Hong et al., 2018).

On the other hand, developing countries in Asia, like India, Pakistan, Bangladesh, and Cambodia tend to rely on the use of direct landfill, which is commonly associated with open, and sometimes, illegal, dumping and burning (Hong et al., 2018, p. 40). As incineration is a cheaper and easier way of disposing of waste and refuse, it is widely practised in most of Asia and the Pacific, especially in areas where there is limited access to waste management technologies. Rudimentary landfill sites are also a common place where incineration is practised. While countries such as the Philippines have enacted laws against waste burning that comes with the imposition of huge fines (Hong et al., 2018) the awareness and enforcement of these illegal activities remain limited or altogether lacking.

Vietnam is yet another country that is experiencing air pollution due to its incineration of plastic waste, as a common method used by Vietnamese cities and communities to discard plastic waste. Currently, there are only about 50 solid waste incinerators operating in Vietnam at a time, which do not fully cater to the needs of the communities (Nguyen Vu., N, 2019). The capacity of most of these incinerators' is small due to the scarcity of budget and energy (Nguyen Vu., N, 2019). Essentially, Vietnam's economic underdevelopment prevents it from being able to develop and operate modern and large-scale incinerators that would consume far too many resources than the municipal governments could afford (Nguyen Vu., N, 2019). Therefore, developing landfill sites and incinerators in Vietnam is not a long-term or sustainable solution to solve the issues related to plastic waste management. However, the collection of recyclables is largely informal and is achieved through community-based approaches like waste banks that are highly unreliable.

Vietnam is considered very under-developed in recycling plastic waste when compared to other countries in Asia. This can be seen by the example of Ho Chi Minh City. Despite having recycling facilities, nearly 19.2% of the 250,000 tonnes of low-quality plastic generated every year, i.e., 48,000 tonnes, are buried in landfills (Nguyen Vu., N, 2019, p. 4). The remaining 200,000 tonnes of plastic are either disposed of directly in the environment or recycled (Nguyen Vu., N, 2019, p. 4).

To promote a solution to the problem of plastic waste by recycling, the Prime Minister of Vietnam had approved the Solid Waste Investment Program for the 2011-2020 period. Seventy per cent of total solid waste in rural areas were expected to be collected and treated to ensure environmental hygiene, with 60% recycled for reuse, while 85% of the total volume of urban solid waste was to be collected and treated, with 60% recycled for reuse as of 2015 (Nguyen Vu., N, 2019, p. 5). The figures for the waste treatment for the rural and urban areas were supposed to grow to 90% and 85%, respectively (Nguyen Vu., N, 2019, p. 5).

While this is the right direction for solving the plastic pollution problem, the implementation of the policy in many aspects has not been synchronous and indeed inadequate. Based on the research done by the Department of Natural Resources and the Environment in 2018, Ho Chi Minh City has around 1000 plastic and waste recycling facilities in operation (Nguyen Vu., N, 2019, p. 4). However, almost all of them are equipped with old and obsolete technology for recycling waste. The operations of these facilities cause serious environmental pollution: about 94% of the city recycling facilities are not equipped with a proper wastewater treatment system and 84% do not have emission treatment systems (Nguyen Vu., N, 2019, p. 4). Hence, the facilities in Ho Chi Minh City's facilities do very little to aid the issue regarding plastic waste management and end up adding more to air pollution by their own industrial operation. It certainly doesn't help that the sorting of waste being extremely slow at the source, recycling of plastic waste is also under-developed when compared to other Asian countries (Nguyen Vu., N, 2019, p. 4). All the waste is mixed and is collected by the local or city trucks(Nguyen Vu., N, 2019, p. 4)

A big barrier to implementation has been the general psychology of the public, who continue to litter indiscriminately and choose not to engage in separating or classification of waste in households or small businesses (Nguyen Vu., N, 2019, p. 5). If the consumption of recycled products can be promoted, new recycling facilities can recover their investment fund and make a profit to promote new technologies in recycling (Nguyen Vu., N, 2019, p. 5)

Improved public transport

Well-developed public transport systems in the Asia and Pacific have led to the decrease in demand for personal transport. One such example of how a city was able to lower carbon dioxide emissions, among other benefits, by replacing the widespread use of personal transport with a public transport system is the city of Toyama.

As with many growing cities, the transformation in the demographics and the urban demographics in Toyama led to an over-reliance on personal vehicles and the concomitant deterioration in the quality of the public transport system (TDLC, 2021). A consolidated approach was then adopted for urban and transport planning, with the city collaborating actively with the private sector to build a Light Rail Transit (LRT) system in the most efficient manner to bring the residents back from the suburbs (TDLC, 2021).

The effectiveness of the public-private partnership was attested by the fact that the LRT project was completed in just three years, compared to the typical LRT project in Japan that typically takes 6–9 years (TDLC, 2021). Apart from the efficiencies in the administrative, legal, and financing procedures, the use of pre-existing assets and timely delivery led to economic efficiency. One of the main existing assets was the old rails that were reused to build tracks at a lower cost. This decision reduced the initial investment by nearly 75% compared to if the tracks were built from scratch (TDLC, 2021).

A key formula underlying the success of this project is the close collaboration between the government and the private sector. The city has adopted a scheme whereby the government is responsible for the tracks and vehicles, while a private company oversees its functioning (TDLC, 2021). In performing its role, the city of Toyama harnessed the operational expertise of the private sectors by creating Toyama Light Rail Company Ltd. — a public-private entity founded on the collaboration of local companies and the city of Toyama, with 50% of the ¥500 million capital provided by the local companies (TDLC, 2021). This alliance was only possible because of relationships built over time between the city of Toyama and private sectors and the city’s treatment of the companies as equal partners. This approach led to a coordinated attitude towards contributing to the public cause.

Conclusion

The aim of this research was to conduct a comparative case study analysis of the phenomenon of air pollution in Asia by analysing the air quality data of 24 different countries across three different years, as measured by the Air Quality Index (AQI). The hypothesis regarding the mean AQI of good and bad air quality countries yielded an F ratio of 131.02, $p < .01$. As for the main effect of years, it is statistically significant with an F ratio of 3.69, $p = 0.03$. Therefore, the null hypotheses about the difference between the mean AQI of good and bad air quality countries and the differences of the mean AQI across the years can be rejected. However, there is no interaction effect between the AQI and the year; therefore, this null hypothesis is not rejected.

The cut-off point was set at 29 $\mu g/m^3$ for the two categories of countries (good and bad air quality). The main differences between these countries were the public-private partnerships and relations, the attitude of the general public towards the environment and most importantly whether they were pursuing economic development at the cost of increasing pollution (Jiang et al., 2020).

Furthermore, this research study also captured the broader picture of the differences between the air quality of the countries in Asia by focusing on how a sampling of good and poor air quality countries have been generating power, providing public transport, and managing wastes.

- **Generating power:** In Japan, the national government and the municipal government had to adopt a technology due to the severe pollution especially in Japan's water bodies. This technology was the Kitakyushu Hydrogen Town Project where power was generated through Hydrogen. It aimed to create a hydrogen energy-based society. Today it delivers power directly through fuel cells and, the city working with private sectors, by its investments in renewable technologies has greatly reduced the emission of harmful substances (Allen, 2019).
- **Managing wastes:** Cities in developed countries use advanced technologies like incineration with energy recovery based on waste-to-energy technology and recyclable materials are recycled in a systematic manner. Whereas developing countries rely on the use of direct landfills, which is commonly associated with open, and sometimes, illegal, dumping and burning (Hong et al., 2018, p. 40).
- **Providing public transport:** Well developed transport system leads to a decrease in demand for personal transport which eventually leads to lower Carbon Dioxide emissions. In

the case of Toyama, the LRT project was completed in 3 years rather than the usual 6-9 years because of the public-private partnership. This drastically reduced the project cost and led to a coordinated attitude towards contributing to the public cause(TDLC, 2021).

If the governments of countries can work actively with the private sector in developing measures to tackle the management of the key sources of air pollution, as we have seen in Japan, it would be possible for us to reduce air pollution significantly across Asia.

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Appendix

Table 2

Two-Way ANOVA with Replication – Mean Air Quality of Countries with Good and Poor Air Quality

SUMMARY	2020 Average	2019 Average	2018 Average	Total
Good Air Quality				
Count	12	12	12	36
Sum	225.9	258.1	265.6	749.6
Average	18.8250000	21.5083333	22.13333333	20.82222222
Variance	34.4784091	30.7917424	49.96606061	38.33549206
SD	5.87183183	5.54903076	7.068667527	18.48953013
Poor Air Quality				
Count	12	12	12	36
Sum	528.5	628.5	701.5	1858.5
Average	44.0416667	52.3750000	58.45833333	51.6250000
Variance	186.615379	188.874773	291.3553788	245.4990714
SD	13.6607239	13.7431719	17.06913527	44.47303107
Total				
Count	24	24	24	
Sum	754.4	886.6	967.1	
Average	31.4333333	36.9416667	40.29583333	

Variance	271.622319	353.601667	507.4595471	

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	17078.6001	1	17078.60014	131.0241568	2.522E-17	3.98626948
Columns	961.088611	2	480.5443056	3.686655342	0.03035233	3.13591793
Interaction	370.221944	2	185.1109722	1.420140342	0.2489677	3.13591793
Within	8602.89917	66	130.3469571			
Total	27012.8099	71				