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Front Pages

Athens Journal of Sciences

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Gregory T. Papanikos, President, ATINER.

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18-21 July 2022, Athens, Greece

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- Abstract Submission: **6 June 2022**
- Acceptance of Abstract: 4 Weeks after Submission
- Submission of Paper: **20 June 2022**

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- Athens Sightseeing: Old and New-An Educational Urban Walk
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Academic Member Responsible for the Conference

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- **Dr. Bala Maheswaran**, Head, Electrical Engineering Unit, ATINER & Professor, Northeastern University, USA.

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Sentiment Analysis of International Relations with Artificial Intelligence

By Dadhichi Shukla[*] and Stephan Unger[±]

Geopolitical strategy is characterized by a dynamic and complex structure of entity relationships, geo-spatial data and human decisions. We employ machine and deep learning techniques to retrieve the sentiment between countries through scraping and analyzing news articles. The change in the sentiment score between countries allows to analyze historic developments of international relations as well as to evaluate the primary and secondary network effects of potential events and policy decisions on the global relationship structure. We find that the key for the most accurate real mapping of the sentiment score between countries is the maximization of the quantity of news while simultaneous minimization of the noise added by the news. Moreover, we show the potential of Artificial Intelligence (AI) to improve and forecast international relations.

Keywords: *Natural language processing, international relations, sentiment analysis, geo-political forecasting.*

Introduction

Strategic decision making depends on a variety of aspects. These aspects are very often a diffuse formation and inter-dependencies of historic formations, relations, internal political structures, economic situations, and strategic goals. These factors are most often given like an externality to the decision making process. On top of that comes the individual characteristic of the decision maker, which depends on preferences, experience and personal goals. These factors might very often be in conflict with the existing externalities. But not only individuals can be in conflict with the external structure, also whole political or economic bodies such as of governmental groups or institutions are getting regularly in conflict with either given structures, or forces which are counteracting their goals. This makes the decision making process sometimes to a random process and thus, outcomes hard to predict.

First, it is important to clarify who the decision maker is. Very often, a country or the country's leaders are seen to be as the decision makers on a geo-political level. But the subject is far deeper reaching as one might think in the first moment. Since all geo-political structures are built up like a hierarchical pyramid, the key influencing factors are very often and very likely to find below the top level, e.g., in forms of advisors, institutions, think tanks, foundations, influential corporations, or other entities.

In order to better understand which influence the underlying structures will

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have on the leader's final decision, it is often very useful to be able to model the goals and preferences of each of these entities separately, as well as the structure of their relationship to each other, including their significance and relevance in the decision making process.

The problem is that with the increasing granularity of the sub-structure, the signals become more and more uncertain, or disturbed, meaning that institutional choices or preferences for certain decisions will vary increasingly the more individual factors are considered. On top of that comes that at a certain point it not only gets too complex to model the individual inter-relationships but also too diffuse and the marginal utility of the gained insights decrease.

Therefore, it makes sense to follow a certain high-level approach for modeling purposes. Nevertheless, underlying factors should be comprised and available to the system according to their relevance and significance to the overall decision making process.

An important point to stress is the factor that in a globalized world, political structures face a layover of independent structures, which can be seen as external, or hybrid structures, such as international organizations such as the United Nations, Warsaw Treaty Organization, North Atlantic Treaty Organization (NATO), etc. This means that the analysis of the individual actors, e.g., countries, must be conducted under the light of the interweaving of international Non-Governmental Organizations (NGOs) with national entities.

In this paper we apply Natural Language Processing (NLP), entity classification, and sentiment analysis to major geo-political news headlines involving countries to map geo-political relationships between countries. We then construct and feed a network structure with the extracted sentiment values and conduct several tests for reliability and robustness. Our key hypothesis is that the sentiment of news articles is a valid measure of the relationship between two countries. Furthermore, the sentiment analysis between two countries allows to deduct a network sentiment structure in such a way that it reflects reality. This in turn allows to conduct predictions about future relationship developments between countries.

In the literature, research on NLP and text mining is being conducted on several levels, from conceptual/theoretical modeling to technical optimization. One common denominator amongst most recent literature is its reference to artificial intelligence and machine learning. Fehlmann and Kranich (2019) analyze how AI systems can be tested, depending on the system's goals and objectives. Razek (2021) investigates the theoretical interdependence between the two evaluation notions of operational observation and mathematical modeling, two concepts which are crucial in the fundamental conception of an NLP machine learning framework. He finds that mathematical modeling needs operational observation simply to be credible and that the second needs the first for deeper research.

Other, more technology-applied approaches extend regular NLP frameworks and incorporate new database structures which allow faster accessing and processing of generated data, i.e., Burdack et al. (2018) introduce a specialized, lightweight in-memory database management system which perfectly fits to the characteristics of time series sensor data. They show that time series sensor data

can be stored efficiently using a new table structure. Their storage logic leads to an efficient data access of the compressed in-memory data structure, thus, every reporting or analysis task accesses the data efficiently and fast.

Regarding the theoretical analysis of International Relations there exist several approaches to geo-political decision making analysis and prediction. A key-fundamental analysis of the different approaches is presented by Allison Graham (1971), who distinguishes three different types of models, which are used by most analysts to explain and predict the behavior of national governments: 1. The Classical model (the rational actor model), 2. The Organizational Process model, and 3. The governmental (bureaucratic politics model).

All these types of theoretical models can nowadays be learned and trained in AI models using NLP and text mining techniques, paired with game theoretical models. Traditionally, learning has been studied either in the unsupervised paradigm (e.g., clustering, outlier detection) where all the data are unlabeled, or in the supervised paradigm (e.g., classification, regression) where all the data are labeled (Zhu and Goldberg 2009). Named entity classification problems have been studied by various researchers and is an ever increasing topic. Collins and Singer (1999) show that the use of unlabeled data can reduce the requirements to train a classifier for unlabeled data by making use of the leverage of natural redundancy in data. Yogatama et al. (2015) use embedding methods for fine grained entity type classifications and show that these outperform state-of-the-art methods on benchmark entity classification data sets. Niu et al. (2003) apply a bootstrapping approach to named entity classification and show that this method approaches supervised name entity performance. Cimiano and Voelker (2005) address the unsupervised classification of named entities with regard to large sets of classes which are specified by a given ontology.

We use the FLAIR NLP framework, provided by Akbik et al. (2019), to facilitate training and distribution of state-of-the-art sequence labeling, text classification and language models, which provides an interface for conceptually very different types of word and document embeddings.

For context-dependency we use Bidirectional Encoder Representations from Transformers, or short-called: BERT (Alammar 2019), which is an open-source neural network-based technique for natural language processing pre-training. It is a major force behind Google Search.

The contribution of this paper to the existing literature is the application of NLP and sentiment analysis to geo-political news in order to evaluate and predict geo-political sentiment. We are the first to our knowledge who apply NLP and sentiment analysis to country classifications.

In the next section we give an overview about our system architecture and explain the data and methodology we use. Then we present the results obtained from our sentiment analysis. Following, we discuss the limitations of geo-political sentiment analysis and afterwards we provide an outlook about future developments. Finally, we conclude in the Conclusions section.

The Architecture

NLP Framework

Sentiment analysis of a news event among countries involves two steps: (1) filter country pairs, (2) analyze the sentiment of the news event. To perform text analysis we adapt FLAIR, state-of-the-art NLP framework. The flair framework provides access to numerous machine learning techniques, specifically deep learning models, for text analysis of news headlines, speech, and embeddings. Embeddings are important since they characterize the context in which a word should be understood. Standard methods produce different embeddings for the same word depending on its contextual usage. The string "Washington" for instance would be embedded differently depending on whether the context indicates this string to be a last name or a location. While shown to be highly powerful, especially in combination with classic word embeddings, such methods require an architecture in which the output states of a trained language model (LM) are concatenated with the output of the embedding layer, thus adding architectural complexity.

Classic approaches combine classic word embeddings with character-level features trained on task data (Ma and Hovy 2016, Lample et al. 2016). To accomplish this, they use a hierarchical learning architecture in which the output states of a character-level convolutional neural network (CNN) or recurrent neural network (RNN) are concatenated with the output of the embedding layer.

A deep learning model Peters et al. (2018) is used for named entity recognition (NER), which can identify person, location, and organization from a piece of text. A semantic similarity search is performed to identify affiliation of the recognized entities with their respective countries. Finally, a sentiment analysis deep learning model is used to estimate the sentiment of the news, and categorize it as positive or negative. The results of the two steps are integrated to learn about the relations among countries.

Data and Methodology

We take daily global news by utilizing newsapi.org. Due to limitations in news access we are limited to 100 news inquires per day. For our purpose we are want to focus on the 20 most geo-politically active countries in recent times. Therefore, we create our own G20-list of countries, which includes: USA, Russia, China, UK, Ukraine, Germany, India, Iran, Israel, Turkey, North Korea, South Korea, Japan, Australia, Saudi Arabia, France, Italy, Greece, Pakistan, and Indonesia.

The time frame we analyze spans from March 24, 2021, to May 23, 2021. In total, we analyze more than 7,000 news articles directly addressing the country pairs. Moreover, we analyze not only the news headline, but also the news description. This provides a much more accurate sentiment score because more words can be analyzed. The sentiment score ranges from 0 to 1. For negative sentiments we multiply the sentiment score with -1. Since it lies in the nature of

political news articles that headlines and descriptions are very often similarly formulated, while BERT is trained on a variety of linguistics, the sentiment scores are very often very narrow to each other. To better distinguish the sentiment scores from each other, we perform a simple mapping using the 'tanh' function, which still returns values between 0 and 1, but stretches the values in such a way that they become more distinguishable while not changing their explanatory power.

It is important to note that the sentiment score we obtain does not reflect the severity or strength how good or bad a news is, but displays the probability that the particular news has a positive or negative sentiment. In that sense, we can derive the severity or strength of a certain news, assuming that severe events are mostly formulated in a very clear and strong way, while uncertain events or situations will most likely lead to very vague statements and news situations. Therefore we can interpret the obtained sentiment score not only as probability of its accuracy, but also as strength indicator for a positive or negative situation.

The methodology is chosen to follow a sequential process. The first step involves the filtering of news associated with a certain country pair, e.g., all news on a particular day between USA and Russia. Then this news is being scraped and analyzed by BERT to figure out the sentiment associated with this news. In case of multiple news on a day we take the average sentiment score. This value is then being mapped through the 'tanh' function. In order to generate a rolling time window we then take the average sentiment score over the past 30 days. We apply this methodology to all country pair combinations.

Results

Table 1. *Sentiment Scores for All Analyzed Country Pairs from 03/24/2021-05/23/2021*

		Positive			**Negative**			**Negative**
Country 1	Country 2	Sentiment	Country 1	Country 2	Sentiment	Country 1	Country 2	Sentiment
UK	USA	0.12	USA	Russia	-0.07	Israel	Turkey	-0.30
Germany	USA	0.40	USA	China	-0.18	Israel	North Korea	-0.76
India	USA	0.34	USA	Ukraine	-0.76	Israel	South Korea	-0.26
Israel	USA	0.42	USA	Iran	-0.22	Israel	Australia	0.00
Japan	USA	0.20	USA	Turkey	-0.76	Israel	Greece	-0.41
Australia	USA	0.73	USA	South Korea	-0.11	Israel	Pakistan	-0.58
France	USA	0.68	USA	Italy	-0.59	Israel	Indonesia	-0.63
Greece	USA	0.76	USA	Pakistan	-0.74	Turkey	Saudi Arabia	-0.58
Israel	Russia	0.06	USA	Indonesia	-0.76	Turkey	France	-0.27
South Korea	Russia	0.05	Russia	China	-0.30	Turkey	Greece	-0.30
Japan	Russia	0.12	Russia	UK	-0.19	Turkey	Indonesia	-0.11
France	Russia	0.09	Russia	Ukraine	-0.54	North Korea	South Korea	-0.39
Italy	Russia	0.30	Russia	Germany	-0.01	North Korea	Japan	-0.05
Greece	Russia	0.75	Russia	India	-0.20	North Korea	Australia	-0.76
Indonesia	Russia	0.72	Russia	Iran	-0.38	South Korea	Japan	-0.06
Italy	China	0.04	Russia	Turkey	-0.46	South Korea	Australia	-0.17
Greece	China	0.76	Russia	North Korea	-0.03	South Korea	Indonesia	-0.48
Germany	UK	0.10	Russia	Australia	-0.23	Japan	Australia	-0.25
Japan	UK	0.19	Russia	Saudi Arabia	-0.04	Japan	Pakistan	-0.71
Saudi Arabia	UK	0.31	Russia	Pakistan	-0.53	France	Italy	-0.08
France	UK	0.04	China	UK	-0.43	France	Greece	-0.06
Italy	UK	0.31	China	Ukraine	-0.17	France	Pakistan	-0.72
Australia	Ukraine	0.52	China	Germany	-0.12			
Italy	Ukraine	0.53	China	India	-0.15			

Greece	Ukraine	0.75	China	Iran	-0.07			
Indonesia	Ukraine	0.72	China	Israel	-0.01			
Iran	Germany	0.04	China	Turkey	-0.24			
Israel	Germany	0.11	China	North Korea	-0.36			
Turkey	Germany	0.35	China	South Korea	-0.02			
South Korea	Germany	0.73	China	Japan	-0.14			
Japan	Germany	0.48	China	Australia	-0.45			
Australia	Germany	0.42	China	Saudi Arabia	-0.19			
Saudi Arabia	Germany	0.75	China	France	-0.14			
Italy	Germany	0.11	China	Pakistan	-0.58			
Greece	Germany	0.04	China	Indonesia	-0.18			
Pakistan	Germany	0.75	UK	Ukraine	-0.24			
Turkey	India	0.13	UK	India	-0.22			
South Korea	India	0.17	UK	Iran	-0.63			
France	India	0.32	UK	Israel	-0.32			
Italy	Iran	0.75	UK	Turkey	-0.45			
Greece	Iran	0.75	UK	North Korea	-0.70			
Pakistan	Iran	0.19	UK	South Korea	-0.09			
Indonesia	Iran	0.67	UK	Australia	-0.07			
Japan	Israel	0.06	UK	Greece	-0.48			
Saudi Arabia	Israel	0.50	UK	Pakistan	-0.72			
France	Israel	0.05	UK	Indonesia	-0.70			
Italy	Israel	0.45	Ukraine	Germany	-0.48			
South Korea	Turkey	0.75	Ukraine	India	-0.71			
Japan	Turkey	0.75	Ukraine	Iran	-0.74			
Australia	Turkey	0.36	Ukraine	Israel	-0.69			
Italy	Turkey	0.33	Ukraine	Turkey	-0.55			
Pakistan	Turkey	0.58	Ukraine	France	-0.44			
France	North Korea	0.49	Germany	India	-0.05			
Pakistan	North Korea	0.17	Germany	France	-0.16			
Saudi Arabia	South Korea	0.75	India	Iran	-0.19			
France	South Korea	0.75	India	Israel	-0.04			
Italy	South Korea	0.75	India	North Korea	-0.48			
Saudi Arabia	Japan	0.06	India	Japan	-0.05			
France	Japan	0.44	India	Australia	-0.17			
Italy	Japan	0.70	India	Saudi Arabia	-0.19			
Indonesia	Japan	0.28	India	Italy	-0.14			
Saudi Arabia	Australia	0.75	India	Greece	-0.19			
France	Australia	0.31	India	Pakistan	-0.26			
Italy	Australia	0.75	India	Indonesia	-0.25			
Greece	Australia	0.76	Iran	Israel	-0.55			
Pakistan	Australia	0.74	Iran	Turkey	-0.70			
Indonesia	Australia	0.32	Iran	North Korea	-0.60			
France	Saudi Arabia	0.75	Iran	South Korea	-0.41			
Italy	Saudi Arabia	0.75	Iran	Japan	-0.60			
Greece	Saudi Arabia	0.19	Iran	Australia	-0.18			
Pakistan	Saudi Arabia	0.21	Iran	Saudi Arabia	-0.40			
Greece	Italy	0.18	Iran	France	-0.41			
Indonesia	Pakistan	0.72						

Figure 1. *30 Day Moving Average Sentiment Score between USA and Russia from 04/23/2021-05/23/2021*

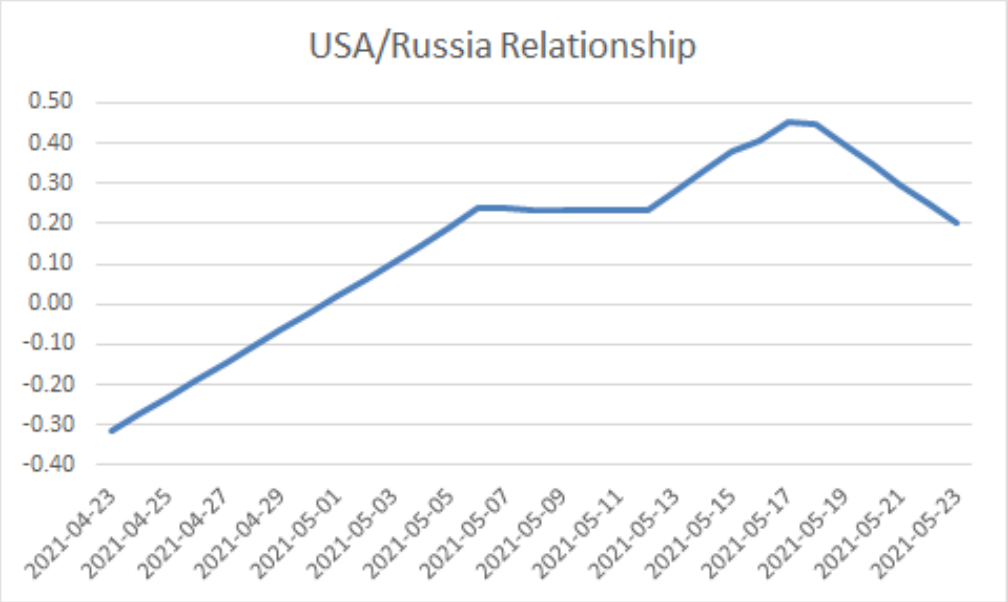


Figure 2. *30 Day Moving Average Sentiment Score between USA and China from 04/23/2021-05/23/2021*

Figure 3. *30 Day Moving Average of Sentiment Score between USA and Germany from 04/23/2021-05/23/2021*

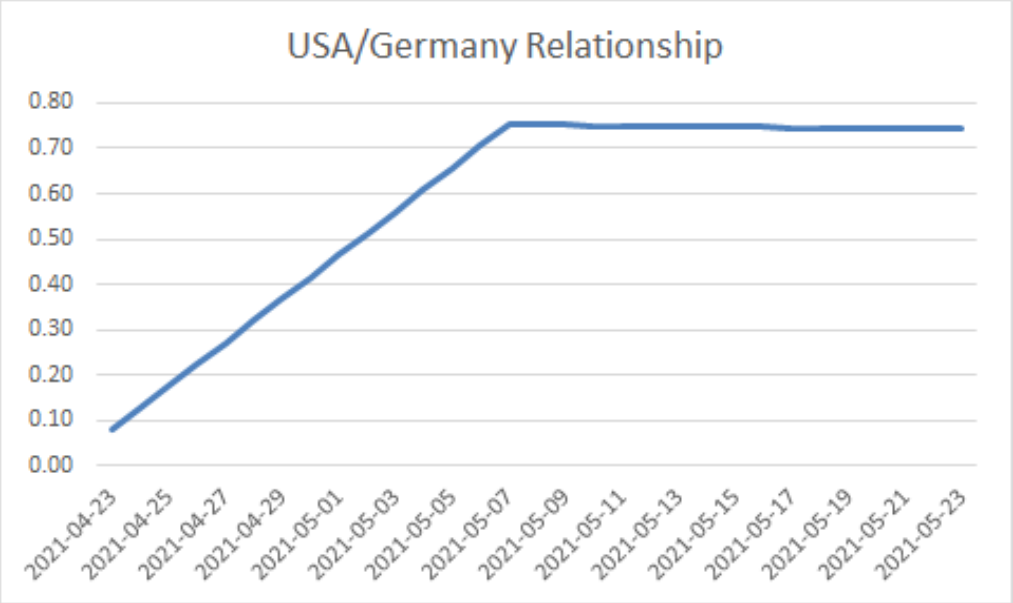


Figure 4. *30 Day Moving Average Sentiment Score between Turkey and Greece from 04/23/2021-05/23/2021*

Figure 5. *30 Day Moving Average Sentiment Score between Russia and Ukraine from 04/23/2021-05/23/2021*

Figure 6. *30 Day Moving Average Sentiment Score between Russia and Saudi Arabia from 04/23/2021-05/23/2021*

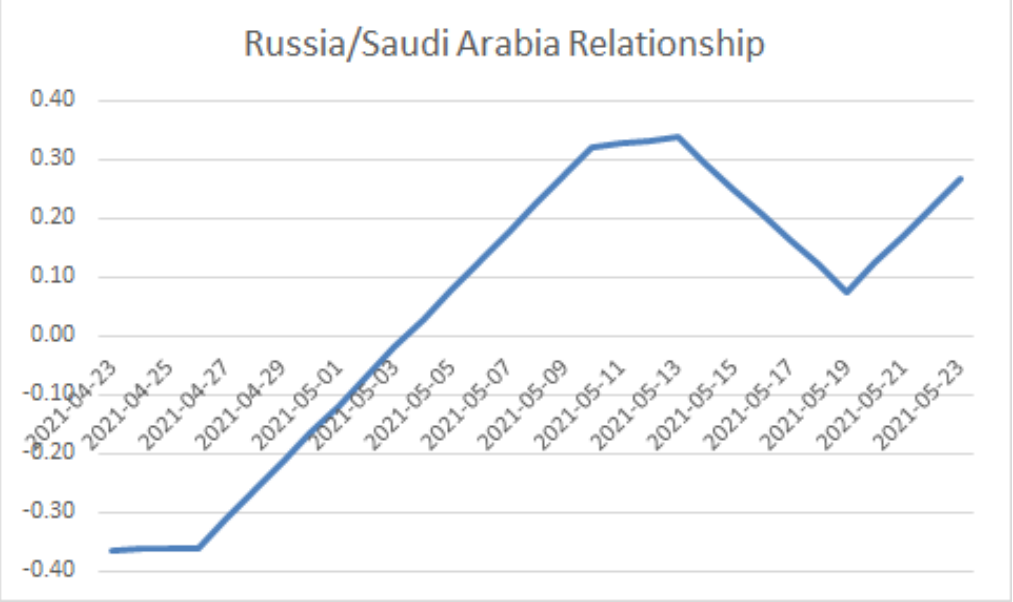


Figure 7. *30 Day Moving Average Sentiment Score between Iran and Israel from 04/23/2021-05/23/2021.*

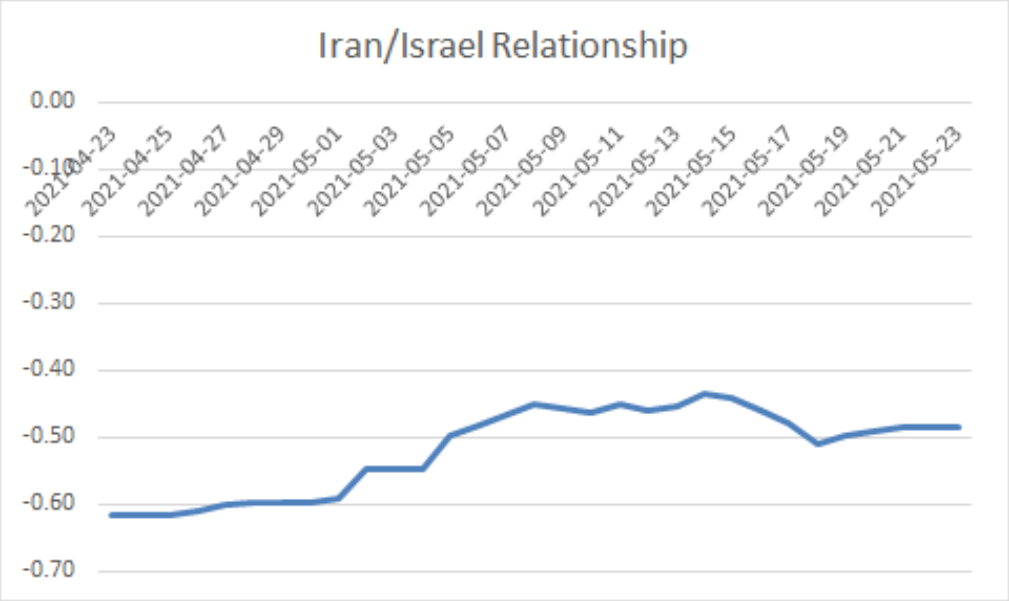


Figure 8. *30 Day Moving Average Sentiment Score between Iran and Saudi Arabia from 04/23/2021-05/23/2021*

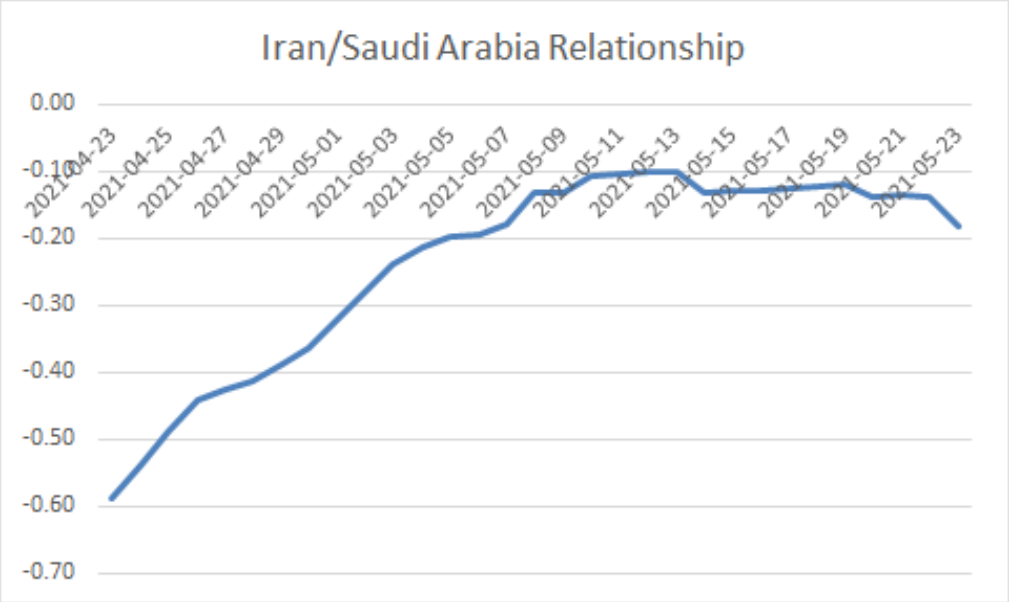
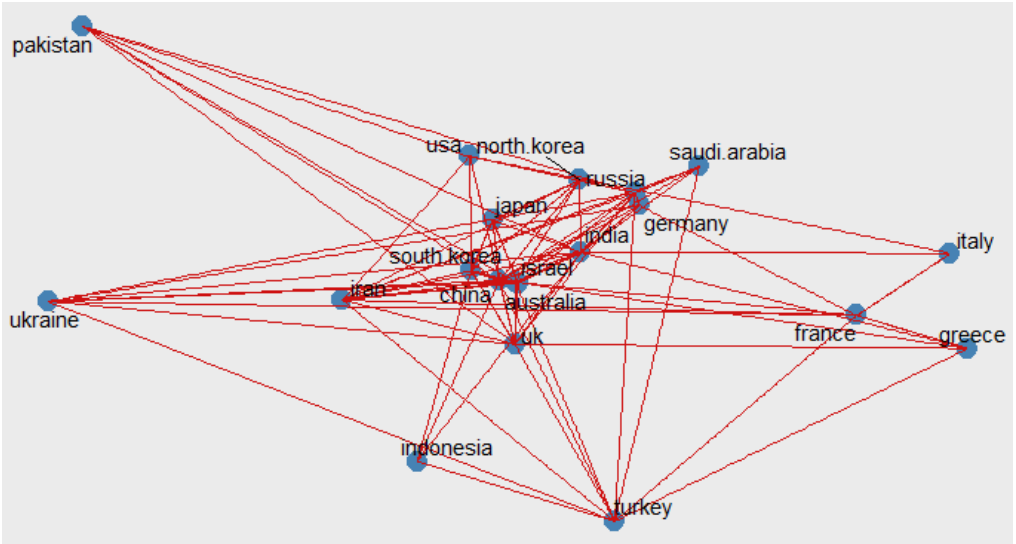


Table 1 reports the average sentiment scores for all 20 country combinations for the time period between 03/24/2021-05/23/2021. We can see that the overall sentiment across all news concerning the relationship between all country pairs was 59.32% more negative than positive. Some of the news were close to a value of 0, indicating a high uncertainty of being correctly interpreted. However, a closer analysis of the news being scraped and processed reveals the high complexity of entity recognition and correctly associating the sentiment score with the relevant

entities. The high uncertainty can be mainly attributed to the complexity of semantic of language.

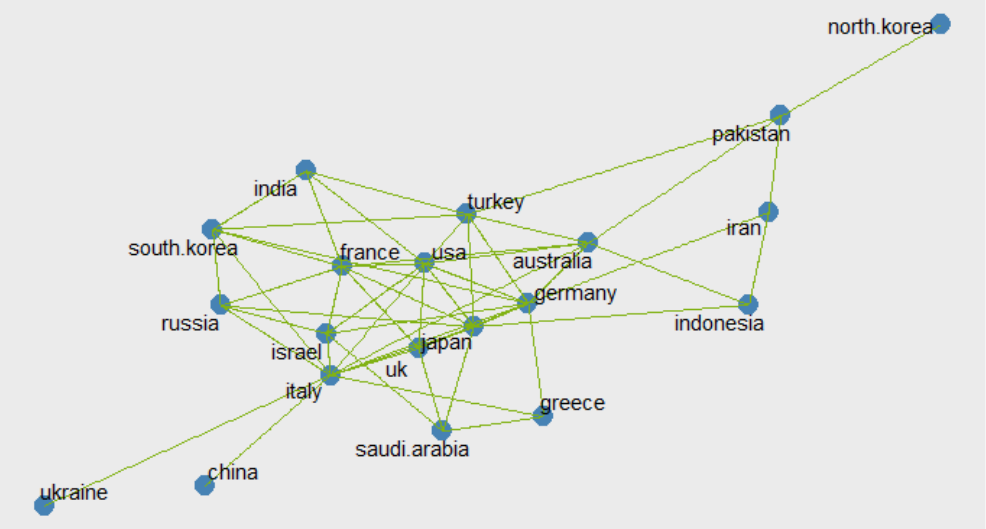
Figures 1-8 show the 30 day moving average development of the sentiment score between some randomly selected country pairs. We can see that for certain country pair combinations, such as Russia/Ukraine, Iran/Israel, and USA/China, the system seems to capture the correct sentiment and to reflect reality. For other country pair combinations, the sentiment is subject to a much higher uncertainty, meaning that the development of the sentiment between these country pair combinations can't be fully trusted, e.g., between USA/Germany and Russia/Saudi Arabia. One of the main reasons, which can be taken from the graphs, is the mostly linear development of the sentiment scores, which indicates that not much news was being analyzed, making the prevailing sentiment score more vulnerable to wrongly interpreted news. Nevertheless, most developments seem to reflect reality in terms of catching the positive or negative sentiment. It is very important to note again that the values do not reflect the actual condition of the sentiment between two countries, but reflect the probability, or uncertainty, that the sentiment is either positive or negative.

Figure 9. *Network Diagram of Negative Sentiment Relationships from 04/23/2021 -05/23/2021*



Note: Countries close to each other have a lower magnitude of negative sentiment.

Figure 10. *Network Diagram of Positive Sentiment Relationships from 04/23/2021-05/23/2021*



Note: Countries close to each other have a higher magnitude of positive sentiment.

Figures 9 and 10 show the network diagram of all negative, respectively positive sentiments between countries for our testing period from 04/23/2021-05/23/2021. The countries with the closest distance to each other are of higher sentiment than the country pairs which are further apart. So, countries in close neighborhood are in better relationship to each other than countries with a greater distance. We can see that network diagrams are very useful to visualize the relative distance, and therefore the status of the international sentiment relation between countries. It is important to note that only country pairs which are directly connected with each other care subject of measurement. For our analyzed time period we find the relationships between e.g., Pakistan/Russia, Pakistan/USA, or Turkey/Greece to be worse than the relationships between e.g., USA/Russia, Japan/Russia, or China/USA. At the same time we can see that the relationships between e.g. France/USA, USA/Australia, or USA/Japan are better than between e.g., Ukraine/Italy, Japan/Indonesia, or Turkey/Pakistan.

Limitations

General limitations of this analysis are the constraint data sources and reduced ability of entity recognition, as well as linguistic barriers coming along with the interpretation of news headlines. Improvements of the quality of the results can definitely be achieved by inclusion of more news sources and APIs, as well as the integration of more countries. Moreover, by recognition of political players such as politicians and institutions, the information basis can also be extended. We also tried to include entity name recognition, but due to linguistic barriers, such as indirect speech, irony, special characters, multiple entities, etc., the sentiment score was rather getting more distorted than improved. One key element in improving

international sentiment relationship measurement is the quantity of analyzed news sources. Due to the high degree of noise in news headlines and complexity of language, the degree of imperfection in news interpretation is rather high. Therefore, a high number of news inputs will smooth out the random noise effect and provide rather accurate trends and relative sentiment differences, following the logic of the law of large numbers.

To provide an example: The relationship between USA and Russia was negatively determined with a sentiment score of -0.5621 on 04/03/2021 by the following news: "USA vs. Russia: Who would have won a Cold War naval conflict?", by Robert Farley on nationalinterest.org. We can see that this news was certainly not related to an active development, but rather reflected the prevailing negative sentiment be- tween the two countries. However, to determine the current sentiment, we would need more news. The problem is that by broadening the news basis dilutes the relevance of the posts, while a stricter filtering reduces the number of potentially analyzed articles, which will again have a negative effect on the accuracy of deter- mining the current sentiment score. Nevertheless, a more accurate filtering seems to dominate the need of increasing the quantity of news.

However, there are certainly single news headlines which are being analyzed correctly, e.g., on 05/02/2021, the system returned a negative sentiment score of -0.6884 between Russia and Ukraine by the following news: "How Russia tested power grid attacks in Ukraine", published by CBS news. The question in determining the accuracy of the current sentiment between two countries depends therefore very heavily on the ratio between correct, or relevant news to incorrect, or irrelevant news.

Future Developments

NLP is not a new concept for various kinds of applications. However, in the sphere of international relations, it hasn't been well established yet due to its technical limitations. Nevertheless, the technological development is progressing at an unprecedented level and can be expected to increase at an exponential rate. Recent developments allow insights in future developments, and thus, what role NLP will play in the future development of international relations itself.

Interestingly, Schrodt (1991) already mentioned in 1991 that the AI/ International Relations (IR) community is characterized by a healthy level of internal debate. He lays out some perspective on the concepts used in AI/IR. O'Connor et al. (2013) describe a new probabilistic model for extracting events between major political actors from news corpora. They recover expert-assigned event class valences, and detect real-world conflicts to evaluate the model's performance on political science benchmarks. Their research shows that the direction NLP might be heading towards will be an Intelligence Augmentation-related one. In contrast to Artificial Intelligence works to augment human intelligence and support it in their decision-making functions. This means that while NLP will become more and more powerful in its speed and capacities to capture the content and meaning of published news, statements, and political texts,

human experts will always need to be at the last stage to interpret and set the insights gained from NLP into policies or action. This is at the same time not only a sufficient but also a necessary condition due to security reasons as it might not be in humanity's interest if countries' defense systems react to a machine-read and interpreted news article without human supervision.

Another future development of NLP concerning International Relations is the sphere of pattern-based biomedical relation extraction systems. After the occurrence of a world-wide pandemic, the necessity of global communication and inter- action got in the focus of countries' governments and authorities. NLP will play a crucial role in developing faster response systems and promotion of international co- operation, not only in the bio-medical sphere, but also in the coordination of global policies. Peng et al. (2014) already provided a novel framework to facilitate the development of a pattern-based biomedical relation extraction system which aims to identify designated relations among biological entities reported in literature. Such kind of functionality will be brought up to a level such that it can be incorporated into direct policy coordination for inter-governmental responses.

Moreover, NLP has a huge potential to capture trends and deduct future impacts of social developments such as preferences, concerns, and latent wishes of society. Already nowadays, bots and other tools are able to communicate with humans and process their feedback and reactions. This data is then being used to optimize search profiles, detect and reveal social networks, and utilize it for commercial or national defense purposes. Wiedemann (2016) lays out potential text Mining applications for Qualitative Data Analysis in the Social Sciences. In International Relations, such detection of network profiles will be made possible by progressing NLP technology, using machine learning algorithms, smart technology and real time interactive surveillance and response protocols, such as enabled by 5G.

In general, future technological advances will enable governments and other political institutions to utilize NLP and text mining in such a way that the management of the political process will be optimized.

Conclusion

In this paper we present a deep learning neural network NLP approach for analyzing geo-political news and building a relational network structure to interpret and measure international relations. Our approach is to search for 20x20 country pair-related news through newsapi.org and then utilize BERT, the NLP engine used to optimize google search, to retrieve the sentiment between each country pair. We track each day's sentiment score for all country pair combinations and aggregate it for all country pairs over a 30-day rolling time window for 30 days.

We find that measuring international relations through NLP has a huge potential as already simple entity classifications and sentiment measurements seem to capture the real sentiment of international relations. The question is of course,

what the real sentiment is. There is no precise answer to this question, but observers of international relations have a sense if certain relationships are more positive or negative, and which development each relationship takes. Besides very useful information that can be extracted, such as the relation between positive to negative news world-wide, or country-pair specific, the certainty of the sentiment and the relative level of sentiment compared to other countries can also be revealed by construction of a network structure. The implications of such insights are very useful to any player in international or domestic politics, as certain trends can be made visible, and the impact of possible policy or event scenarios can be measured. Despite the impressive realistic mapping of international scenarios using a very limited news access, certain general limitations could be detected such as the trade-off between broadening the news basis and narrowing it down. Broadening the news basis allows the system to analyze more news. Due to the high error rate in measuring single news headlines, due to linguistic and semantic reasons, as well as the high complexity of detecting the relationship between multiple entities mentioned in one and the same news headline, a high rate of incoming news is necessary to capture the correct trend. Contrary, with increasing the inflow of scraped news headlines, the degree of noise increases proportionally, meaning that more irrelevant news is being processed, which can significantly skew the sentiment score.

Therefore, our key finding is that the driver of quality of international relationship sentiment forecasting is the relationship between quantity and quality of scraped news. While the increase of quantity of scraped news increases the probability for detecting the correct trend, it adds noise at the same time. This calls for an increase in quality of scraped news. But an increase in the quality of news automatically reduces the quantity of relevant news and makes therefore the sentiment score more vulnerable to changes in semantics. The most accurate real mapping of the sentiment score at a time t of international relations can thus be defined by

$$SC_t = max_Q\, min_N\, (Q_i, N_i), \quad (1)$$

where Q_i is the quantity of news being analyzed for country pair i, N_i is the noise generated by the news of country pair i, measured by its relevance.

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Territorial Infrastructure: Drafting of a Calculation Evaluation Method

By Elsa Negas[*] & Rui Seco[±]

This study proposes a method for calculating the level of urban infrastructure and basic urban services on a given territory. It aims to contribute to a more accurate knowledge of the territory and the city, through the creation of an assessment tool for the urban condition, with the goal of overcoming imprecision hindering urban planning and management. Urban infrastructure is here understood in a broad sense, integrating usual urban attributes —roads, pavements, electricity, water supply, sanitation, etc.—but also a set of urban services and equipment traditionally provided by city and urban environment—administration, representation, culture, health, education and security, among others—and also other conditions diagnosed as significant for the current evolutionary trend of extended urbanity, such as mobility—integrating roadways, public transport networks, soft mobility devices and infrastructures —and access to and integration in communication and information networks —voice and data communication, fix and mobile. The development of this calculation method takes into account different relative weights for this set of conditions in order to obtain a balanced assessment of the level of infrastructure. In the future, the next stage will consist of testing in the field in order to fine tune and validate its usability in different scenarios.

Keywords: *urban condition, territory, infrastructure, measuring systems, calculation*

Introduction

This study proposes a method for calculating the level of urban infrastructure and basic urban services, addressing the inaccuracy in this field by providing a new tool to measure and compare these assets on a given territory.

Authors like Nijhuis and Jauslin (2015) state that planning and design of cities and regions are important issues to address sustainability and face the "climate crisis puzzle"[1]. This is particularly significant facing the global urbanization processes of today's networked metropolis, where cities are shaped and interconnected by infrastructure through the territory, a process towards what

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[1]"Cities and regions are believed to be a significant part of the 'climate crisis puzzle' and their significant contribution needs to be assessed if we are to address the various environmental and social challenges to achieve sustainability and resilience on a large scale. For this to be materialized, though, design principles need to take part in the territorial transformation processes" (Nijhuis and Jauslin 2015).

François Ascher called "metapolis"[2]. These evolutions tend to replace the role of traditional cities, in the sense described by city historians like Lewis Mumford (Mumford 1938), changes that Françoise Choay - one of the major references in architecture theory in the 20th Century - called "the reign of the urban and the death of the city" (Choay 1999). In an effort to better understand and interpret these complex and intertwined transformations, recent theory is already referring to the present as an "infrastructure time" (Addie 2022)[3].

The calculation of the level of territorial infrastructure aims at contributing to a more accurate knowledge on the territory and the city, in order to overcome the inaccuracy and ambiguity that Bourdin (2010), among others, states that hinders planning, reasoning and regular urban management[4]. Angheloiu and Tennant (2020) emphasise that cities and regions "need to concentrate their focus on achieving the goals of global policy frameworks in response to the climate crisis while they focus on a response to zero-emissions, net zero routes and zero-waste solutions". Different fields of knowledge, from climatology to health or social responsibility, have already created indicators that measure complex situations, comprising multiple factors with variable relative weights[5].

Many features contribute today to the definition of the urban condition, which merges with social and economic dynamics. Recent swift evolutions in technologies and communications reorganized the production processes and services, having major impacts on the current transformations of the territory. This has affected traditional city cores which have lost their central importance and their role in economic and administrative functions has spread widely across entire regions, following new patterns of spatial organization and interconnection. Individual and public accessibility, road networks, information technologies and basic urban services—besides traditional urban infrastructures—are today key in defining urbanity, being difficult to quantify in an objective and precise basis. This study thus proposes the drafting of a tool for evaluating the features that are significant to establish an urban condition[6].

The objective is to create a pondered rating for the infrastructure level of a place, corresponding to a specific location. The classification can be made in any place in the world since the criteria considered are those commonly classified as urban infrastructure.

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[2]The *metapolization* described by Ascher (2001) is a continuous ongoing process with global impact that is reshaping the territory, in which connections through infrastructure, namely communications and technology, acquire major relevance (Ascher 2001).

[3]Addie (2022) has used the "infrastructure time" concept in order to analyze the production of infrastructure and to question several aspects of the production of urbanization and the urban condition (Addie 2022).

[4]Bourdin, in his highly influential text *L'Urbanisme d'Aprés Crise*, indicates the "triumph of vague concepts" and specifically in relation to the urbanism of the last decades, points out the "weakening of the scientific references and the multiplication of actors involved in decision and activity", aiming at a more accurate and reliable understanding of the urban environment (Bourdin 2010).

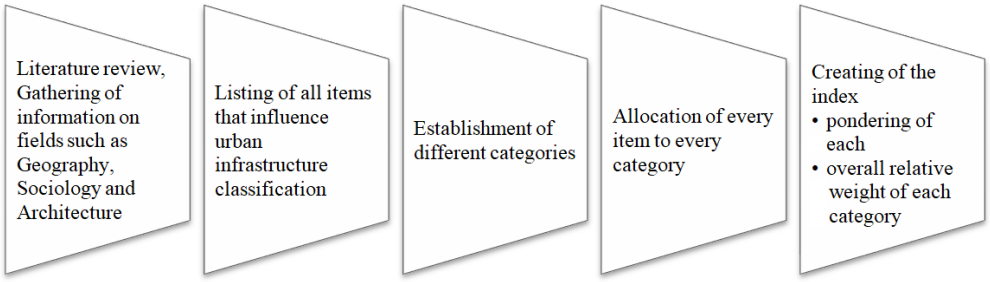
[5]Among multiple examples of this type of studies can be named Turker (2009) in the field of social responsibility, Greer and Watson (1987) in human health or Wofsy (2011) in climatology.

[6]Urban infrastructures open manifold political horizons, but realizing progressive infrastructure futures "require[s] a deep understanding of existing infrastructure institutional practices and how they are embedded in the preferences and aspirations of urban residents" (Simone and Pieterse 2017).

Methodology

With the purpose of creating a tool for the assessment of the infrastructure level, five stages have been outlined, conducting to the creation of a single calculation formula (Figure 1).

Figure 1. *Overview of the Process of Developing an Urban Condition Evaluation Tool*



Source: Elsa Negas & Rui Seco 2021.

The first step was a literature review on the urban condition and the most relevant infrastructure assets and basic urban services involved in its definition. This information supported the listing of a set of relevant items that make up the conditions and influence urban life, in a broad range that includes different sorts of services and facilities.

These outputs were then organized into specific different categories to make its processing operable and practical. The items were allocated to their categories, then the way to quantify their quality and availability was defined (in a specific-guided approach to every item), and their relative weights were pondered in the calculation of the categories. The overall relative weight of each category was also pondered, in order to balance its impact in the global formula.

This process is not yet finished or closed, as this balance is in the process of fine-tuning by experimenting its testing in the field, using the assessment formula in various conditions and different areas of the territory to make adjustments.

Implementation

For the purpose of creating an infrastructure evaluation method, urban infrastructure is considered in a broad sense, which integrates usual urban attributes —roads, pavements, electricity, water supply, sanitation, etc. —but also a set of urban services and equipment traditionally provided by the city and the urban environment —administration, representation, culture, health, education and security, among others —and also other conditions diagnosed by a bibliographic review as significant for the current evolutionary trend of extended urbanity, such as mobility —integrating roadways, public transport networks, and also soft mobility devices and infrastructures —and access to and integration in communication and information networks - voice and data communication, fix and mobile.

In the development of this method for the calculation of urban infrastructure and basic urban services are taken into account different weights of each of this set of conditions in order to obtain a balanced assessment. This balance will be fine-tuned through a process of testing in the field using the calculation in different conditions and areas of the territory. However, it must be noted that the relative weight of the distinct components of the formula should in the future be variable according to the purpose of its use, i.e., distinct variants of calculus may be produced in order to assess different aspects of the urban condition —to settle a business, the most important issues to evaluate are not the same of those to verify the urbanity of a residential neighborhood or the urban integration of a university campus.

On the other hand, the use of specific versions of this tool to systematically assess a given area of the territory will enable the opportunity to compare, identifying disparities and relative advantages, and to evaluate progress over time, creating new and reliable data that can be used to support urban management, decision-making processes and spatial planning.

This paper presents the design of the index, integrating all items identified as having influence in the infrastructure of the territory, grouped into categories with different relative weights. This composed index allows the calculation of the level of infrastructure and basic urban services in a spotted location[7].

Territorial Infrastructure Evaluation

The availability of infrastructure is not uniform throughout the territory. Yet, it is of the utmost significance at the present time, given our way of life increasingly based on technology, accessibility and communication. Both classical and technologically advanced infrastructures, as well as basic urban services, are indispensable for communities, inhabitants and their economic development.

The creation of a comprehensive calculation method for the level of infrastructures covers these factors, based on a field analysis to be performed for the assessment. This evaluation is based on the verification of the availability of a series of items of a specific location of the territory, both infrastructure and basic urban services related. For this geographic point is then calculated a global value of urban infrastructure, using an equation that takes into account the different relative weight of a set of parameters.

The repetition of this process of identification and calculus for several locations throughout a given area will display the variations that occur in that territory.

[7]Despite the limitations that an index may present, there are many advantages in synthesizing data, in terms of the simplicity when communicating information; the Portuguese Governmental Agency for the Environment recommends that indexes are designed to simplify data on complex phenomena in order to improve its reporting, gaining in intelligibility, clarity and usability of the collected information, while losing in detail and specificity (DGA-DSIA 2000). In this specific case, it has allowed the identification and classification of the items that influence infrastructure, as well as their quantification, facilitating its consulting, cross-referencing and use in future research.

To evaluate the degree of infrastructure five key infrastructure categories have been identified:

- transport systems (subway, train, bus, 'soft' mobility);
- basic urban services (administration, commerce, culture, health, education);
- 'traditional' urban infrastructures (streets, sidewalks, water supply and sanitation, energy/electricity, public lighting);
- automotive accessibility (roads, traffic, parking);
- telecommunications (voice and data networks, broadcasting).

These key infrastructure classes are given specific ponderings in the calculation, being themselves composed by several items. The weight of each specific category in the global calculation reflects its relative weight in the evaluation; this will eventually be adjusted to correspond to particular applications or requirements.

Drafting of the Calculation Method

For calculating the level of urban infrastructure, each class is assigned an elemental factor, integrating with different pondering the items that composes it on a scale of 1 to 5 (I_i,$i=1,2,...,5$). The Infrastructure Index (*Inf*) is then calculated on the basis of the indicators per category in a weighted manner, as shown in the formula:

$$\begin{cases} Inf = \sum_{i=1}^{5} f_i I_i \\ \sum_{i=1}^{5} f_i = 1 \end{cases}$$

Notice that the weighting of each category conveys the relative weight it has in the infrastructure assessment.

The following five sections of the text present the construction of the calculation method for each of the identified five key categories, integrating their respective components and relative weights.[8]

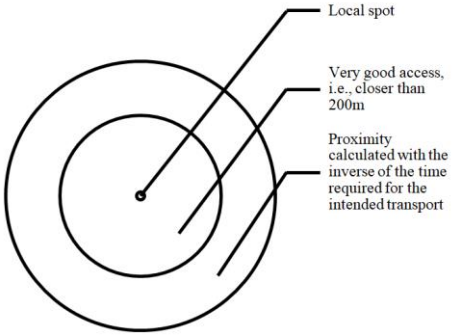
[8]The first two sections - transport systems and basic urban services - have been previously addressed by Negas and Seco (2020).

Transport Systems

For transport classification, the following factors are considered prevalent: proximity of access, frequency of passage and existence of a network of at least two distinct means of transport[9].

As the notion of proximity and accessibility is subjective, it was made uniform as follows: in the infrastructure index, the distance is calculated based on the duration of a walk, considering that 5km are travelled in one hour[10]. All accesses at a distance of 200m or less are considered to be very good, corresponding to a 2.4 minute walk[11] (Figure 2).

Figure 2. *Proximity to Transport*



Source: Elsa Negas & Rui Seco 2021.

The quantification of the frequency of each means of transport is based on a Likert scale with 7 levels[12], reflecting the time interval between consecutive public transports on working days in the 7h00-22h00 schedule:

7 - The time interval between consecutive journeys is a maximum of 3 minutes.
6 - A maximum of 10 minutes between consecutive carriage runs.
5 - The time interval between consecutive carriage runs is a maximum of 20 minutes.
4 - The time interval between consecutive carriage runs is a maximum of 30 minutes.
3 - The time interval between consecutive carriage runs is a maximum of 50 minutes.
2 - The time interval between consecutive journeys is a maximum of 2 hours.
1 - Otherwise.

This is intended to distinguish the frequency with which the location is served by public transport, either the nearest or the second alternative. To this classification is added the fact of whether or not night public transport exists (whatever the frequency).

[9]For information on mobility, public transport, and the quantification of its gaps, see Silva (2017) or Currie (2010), among others.
[10]Despite this subjectivity, the accessibility to transports and mobility are serious factors in establishing social exclusion, which needs to be addressed (Preston and Rajé 2007).
[11]On this matter, Carr et al. (2010), among others, have developed studies on walkability for pedestrians.
[12]The use in statistics of this type of scales has been further explored by Negas (2021).

Network transport indicates that the location under consideration is both a point of departure and point of arrival to a variety of other destinations and may have access to different locations. The branch transport designation means that the location has available a public transport which originates and terminates at a location where network transport then exists. The category 1 infrastructure index is calculated using the formula:

$$I_1 = \sum_{i=1}^{5}\left(p_i \times \frac{1}{t_i}\right) + p_6\left(0{,}5 \times \frac{n_i - 1}{6} + 0{,}5 \times \frac{n_i - 1}{6}\right) + p_7$$

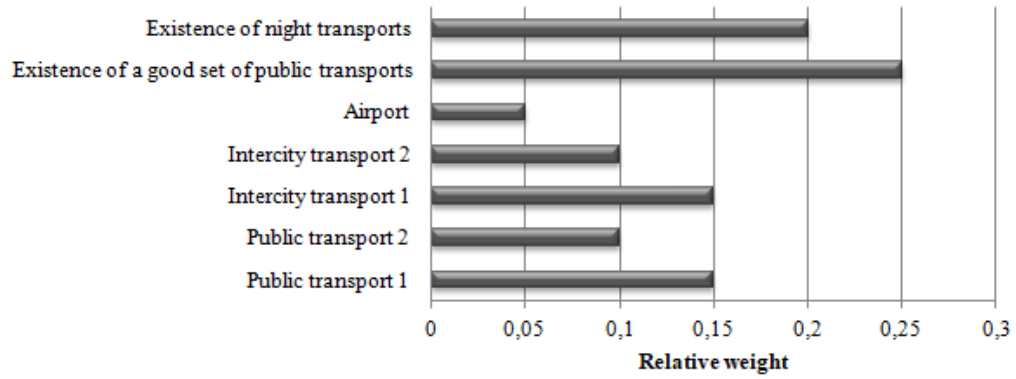
Subtitle:

I_1- value of the first index representing in the study the transport network, for the calculation of the infrastructure index (*Inf*)
p_i - relative weight attributed to factor i
t_i - travel time to factor i (accesses at a distance up to 200m are considered very good, valued as 1)

Items: i=1 nearest public transport; i=2 second nearest public transport alternative (for example bus and metro); i=3 nearest intercity transport; i=4 second nearest intercity transport alternative (it has to be different from the first one for example bus and train); i=5 airport; i=6 existence of a good set of public transports; i=7 existence of night transports.

After performing some simulations, the following weightings were established (Figure 3).

Figure 3. *Transport Systems Category Items Relative Weight*



Source: Elsa Negas & Rui Seco 2021.

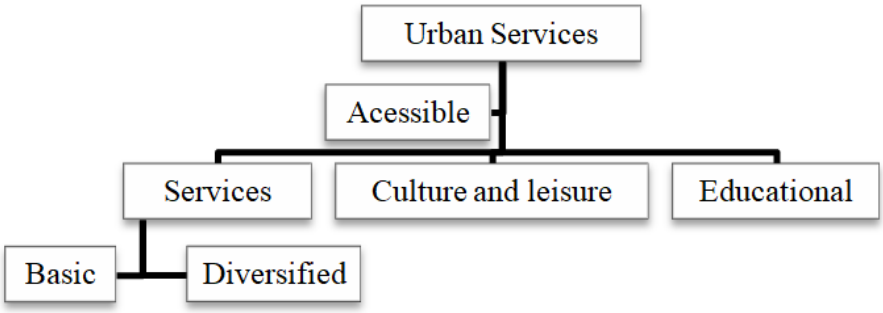
The sum of all weightings equals the unit:

$$\sum_{i=1}^{7} p_i = 1$$

Basic Urban Services

Infrastructure influences and is influenced by the existence of services, culture and leisure, as well as the existence of educational institutions (at different levels) and tertiary services (in this case different levels are also identified). In this criterion, the distance from where services are located is relevant and should be discriminatory. In this sense, all services that are more than two and a half kilometers away (corresponding to a 30 minute walk, as previously considered) should be classified as absent. Hence, proximity and accessibility are valorized in this criterion. The elements considered fundamental in urban services are presented in Figure 4.

Figure 4. *Different Urban Services*



Source: Elsa Negas & Rui Seco 2021.

In the second category, Basic Urban Services, the following items were considered of relevance:

- Tax Office.
- Post Office.
- Banking Services.
- Cinema.
- Theatre.
- Congress Center.
- Exhibition Centre.
- Tertiary sector levels I, II, III and IV.
- Schools levels I, II, III and IV.
- Higher Education.

Among these ten items, two are rated according to a 4 level Likert scale:

1 - Tertiary Sector:

Level I - coffee shop and grocery store.

Level II - ATM, pharmacy, clothing store, hairdresser.

Level III - diversified services, including insurance brokerage, telecom operators.

Level IV - verifies the previous level and accumulates large diversified commerce.

2 - Schools

Level I - elementary school.

Level II - elementary school (with either kindergarten and elementary school or elementary and II grade).

Level III – all schools up to highschool (at least one school of each level, from nursery).

Level IV - verifies the previous level and accumulates technical education.

The category 2 infrastructure index is calculated using the formula:

$$I_2 = \sum_{i=1}^{7}\left(p_i \times \frac{1}{t_i}\right) + \sum_{i=8}^{9}\left(p_i \times \frac{n_i - 1}{3}\right) + p_{10} \times \frac{1}{t_{10}}$$

Subtitle:

I_2 - value of the second index representing in the study urban services, for the calculation of the infrastructure index (*Inf*)

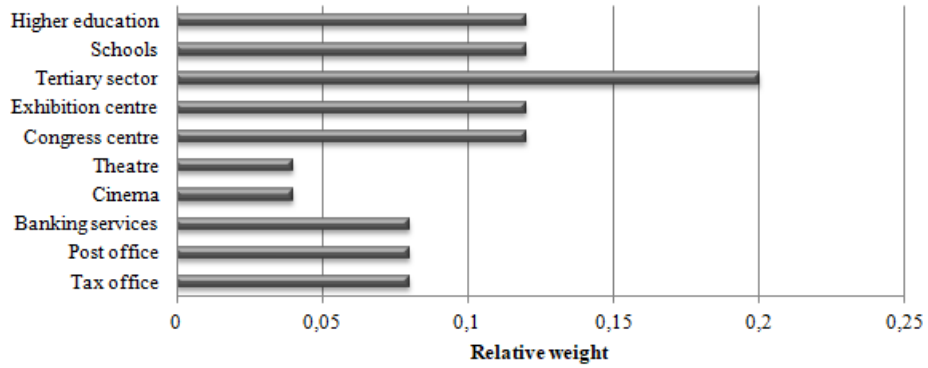
p_i - relative weight attributed to factor *i* if it exists within a radius of two and a half kilometers (corresponding to a 30 minute walk, as previously considered)

t_i - travel time to factor *i*

Items: i=1 tax office; i=2 post office; i=3 banking services; i=4 cinema; i=5 theatre; i=6 congress centre; i=7 exhibition centre; i=8 tertiary sector; i=9 schools; i=10 higher education.

After performing some simulations, the following weightings were established (Figure 5).

Figure 5. *Basic Urban Services Category Items Relative Weight*



Source: Estejo 2021.

The sum of all weightings equals the unit:

$$\sum_{i=1}^{10} p_i = 1$$

Urban Infrastructure

Regarding the category that classifies the existing urban infrastructure in a given location, the following analyses were considered:

- Existence or inexistence of infrastructure; if existent, its updating and modernity.
- Its quality, durability and suitability for the environment.

The following items were considered important:

Water supply;	Solid Waste Collection;	Sidewalks;
Sanitation;	Free collection of large	Handicap accessibility;
Street lighting;	waste items/ junk;	Soft mobility lanes;
Electricity;	Recycle bins;	Urban equipment (benches, etc.).

The measurement in this index should enhance:

- The existence of infrastructure.
- The quality of the infrastructure.
- Their design and usability.
- The suitability of the employed materials.
- The most ecological and environmentally friendly options.

Accessibility is still an important point, and in this criterion a radius has to be defined, indicating the distance at which the infrastructures are considered to exist or not. The same 200m radius was considered (as already applied); in the case of infrastructure inexistence the index value has to suffer a penalty[13].

How to rank quality? The 3 most convenient modes are identified in this case study (more efficient, more durable and with better environmental performance); 4 different gradations can be assumed; Q_i, $i= 1,2,3,4$:

1 - None of the identified modes is being applied.
2 - The third mode is being applied.
3 - The second mode is being applied.
4 - The best mode is being applied.

On the items plumbing, sewerage, street lighting and electricity the quality has to be assessed.

[13]In the case of recycling, the established maximum distance for considering eco-points existence is 400m.

In quantifying the infrastructure index, both the quality criterion [how collection is carried out and the frequency] and the separation of solid waste between differentiated or non-differentiated waste and recyclable or non-recyclable waste must be applied; this separation reveals population behaviour and accessibility, which in the case of recycling eco-points is considered to exist if the distance is less than or equal to 400m.

The item "free collection of large waste by public services" is a binary variable and assumes the value "1" when it exists and "0" otherwise.

The item sidewalks should classify their adequacy for circulation, mainly if they are elevated enough in relation to the road to avoid accidents and contact with gutters; the classification is made using a 4 level Likert scale:

1 - No sidewalks.
2 - There is a space for pedestrian circulation but at the same level as the road.
3 - There are elevated sidewalks, but do not permit handicap circulation.
4 - Everyone can circulate safely.

Handicap circulation requires wider sidewalks, access ramps and the non-existence of improperly parked cars; also in this item the classification will be carried out through a 4 level Likert scale:

1 - Does not apply.
2 - Applies with many limitations.
3 - Applies.
4 - All restrictions have been taken into account allowing good circulation for all.

The last item of the urban infrastructures category, soft mobility infrastructure, has undergone a strong implementation in various parts of Portugal, such as the entire district of Lisbon, with the implementation of proper tracks for the circulation of scooters and bicycles, and renting and sharing systems. These solutions are simultaneously more ecological, safer and allow people to move around in a way that is beneficial to the environment and health. Its classification will be carried out by a discrete quantitative variable with domain {1, ..., 4} corresponding to the following grading:

1. No access to dedicated lanes within a distance of 12 minutes (one kilometer).
2. With access to dedicated lanes within a distance between 6 minutes (half kilometer) and 12 minutes (one kilometer).
3. With access to dedicated lanes within a distance between 200 meters and half a kilometer (six minutes).
4. Dedicated lanes within a distance less than or equal to 200 meters.

As a result of strong innovations, both at the level of construction materials and their maintenance, the index for this criterion —urban infrastructure —should reflect and aggravate a penalization for the use of very polluting materials or of

those that require inefficient maintenance. Thus in this criterion, whenever a non-polluting solution exists it should be considered as the most efficient option.

The infrastructure index for category 3 is calculated using the formula:

$$I_3 = \sum_{i=1}^{6}\left(p_i \times \frac{Q_i - 1}{3}\right) + p_7 \times b_7 + \sum_{i=8}^{10}\left(p_i \times \frac{n_i - 1}{3}\right)$$

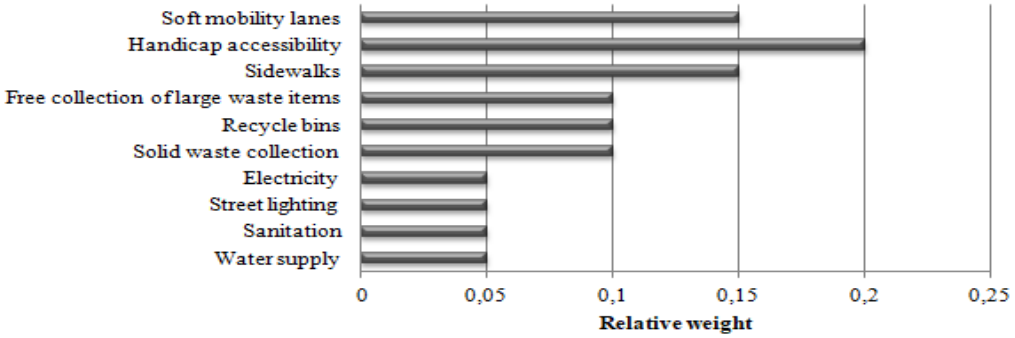
Subtitle:

I_3 - value of the third index representing in the study urban infrastructure, for the calculation of the infrastructure index (*Inf*)

Items: i=1 water supply; i=2 sanitation; i=3 street lighting; i=4 electricity; i=5 solid waste collection; i=6 recycle bins; i=7 free collection of large waste items; i=8 sidewalks; i=9 handicap accessibility; i=10 soft mobility lanes.

After performing some simulations, the following weightings were established (Figure 6).

Figure 6. *Urban Services Relative Weight*



Source: Elsa Negas & Rui Seco 2021.

The sum of all weightings equals the unit:

$$\sum_{i=1}^{10} p_i = 1$$

Automotive Accessibility

The level of infrastructure is also determined by the quality of the roads, the proximity to highways, i.e. ease of circulation, accessibility, parking and safety. Facility of circulation has to be rated taking into consideration the quality of road connections and safety. In this fourth category, Automotive Accessibility, the following items were considered significant:

- Quality of the roads.
- Proximity to motorways or expressways.
- Parking.

The index should value:

- Safety in the circulation both of cars and pedestrians.
- Ease of parking.

The item road quality is assessed on the ground without any distance being attributed. As in the previous case, the quality is classified on a 4 level Likert scale $Q_i, \mathrm{i} = 1, 2, 3, 4,$ which in this case combines the quality of the road surface with driving safety and the existence of a verge (or sidewalk) that minimizes the possibility of accidents:

1 - The track has no quality pavement or safety.
2 - The track has some quality in pavement and safety.
3 - The track has good quality but safety can be improved.
4 - The track and safety are of the desired quality.

The proximity to motorways or expressways allows easy access to other locations, which can be important in terms of employment or supply. This classification will be made on a Likert scale with 7 levels (1- very far and 7- very close), which must be analyzed on a case by case basis. Parking availability will be rated on a Likert scale where:

1 - Safe parking is not available.
2 - Parking is scarce or difficult to access.
3 - Parking is sparse but secure and easily accessible.
4 - Easy to park and safe.

The category 4 infrastructure index is calculated using the formula:

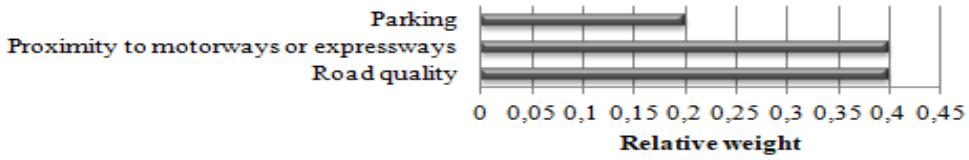
$$I_4 = p_1 \times \frac{Q_1 - 1}{3} + p_2 \times \frac{Q_2 - 1}{6} + p_3 \times \frac{n_3 - 1}{3}$$

Subtitle:

I_4 - value of the fourth index representing in the study road accessibility, for the calculation of the infrastructure index (*Inf*)

Items: i=1 road quality; i=2 proximity to motorways or expressways; i=3 parking (Figure 7).

Figure 7. *Automotive Accessibility Items Relative Weight*



Source: Elsa Negas & Rui Seco RS 2021.

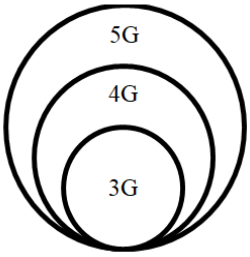
Telecommunications

In this category the following factors were valued:

- Type of internet connection.
- Availability of fix and mobile data connection.
- Number of available connection providers.

In the Portuguese situation, the availability of connection on a specific location can be consulted on-line[14]. It is a fact that some areas only have the possibility of ADSL communications, while others already have the possibility of fiber optics connection; the infrastructure index must highlight this difference in a reinforced way. In the scope of fiber optics, 5G already exists in parts of the country and the possibilities are shown in Figure 8.

Figure 8. *Fiber Optics Modalities*



Source: Estejo 2021.

In this telecom specification the following issues were considered important:

- Number of providers.
- ADSL/Fiber optic.
- Meagre internet access.

It should be noted that a binary variable has been created:

$$b_1 = \begin{cases} 1 \text{ if there is phone line on the location} \\ 0 \text{ if otherwise} \end{cases}$$

Thus the entire category takes on the value "zero" if there is no possibility of installing a landline telephone. In Portugal there are 4 internet operators. In the first item the number of providers with network in the case study location is directly introduced.

Subsequently and based on the capabilities of the networks, a scale is drawn up, which has a maximum of 7 levels and allows a correlation. The following

[14]The availability of internet and mobile connection in the Portuguese territory can be consulted on: https://pplware.sapo.pt/informacao/anacom-freguesias-internet/.

grades were used: ADSL (1); 3G (3); 4G (4); 5G (6) and fibre optic (7). The aim is to value the most up-to-date option which allows greater speed and reliability in the transmission and/or reception of data.

The network quality is also a factor under analysis; for this item a Likert scale with four levels was implemented. The category 5 infrastructure index is calculated using the formula:

$$I_5 = b_1\left(p_1 \times \frac{Q_1 - 1}{3} + p_2 \times \frac{Q_2 - 1}{6} + p_3 \times \frac{n_3 - 1}{3}\right)$$

Subtitle:

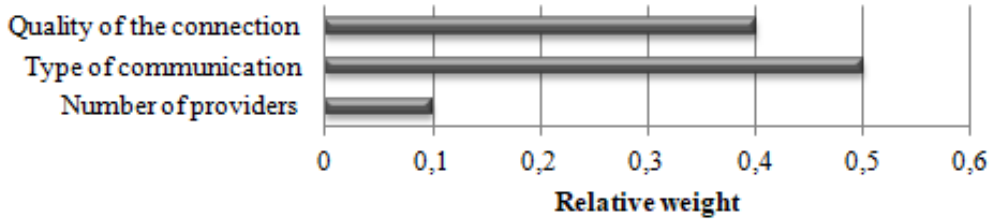
I_5 - value of the fifth index representing in the study telecommunications, for the calculation of the infrastructure index (*Inf*)

$$b_1 = \begin{cases} 1 & \text{landline phone available} \\ 0 & \text{otherwise} \end{cases}$$

Items: i=number of providers; i=2 type of communication; i=3 quality of the connection.

After performing some simulations, the following weightings were established (Figure 9).

Figure 9. *Telecommunications Items and Relative Weights*

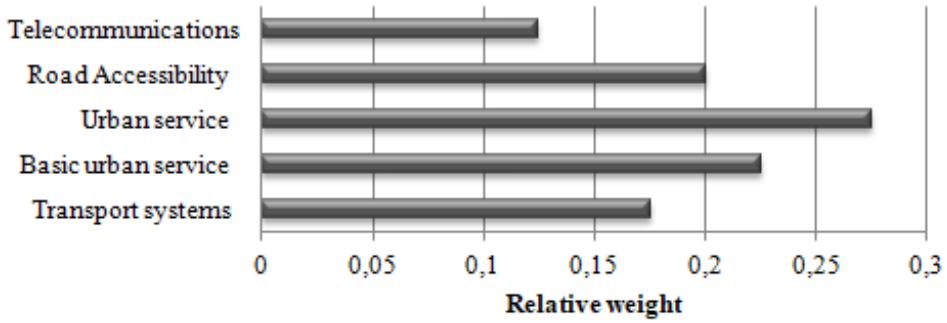


Source: Elsa Negas & Rui Seco RS 2021.

Infrastructure Index Calculation

Following the calculation of the index for each category, the overall infrastructure index is calculated, and it is necessary to assign the weighting to each category; in this case the following weightings were established (Figure 10).

Figure 10. *Infrastructure Categories and Relative Weights*



Source: Elsa Negas & Rui Seco 2021.

The infrastructure index is the outcome of the following calculation:

$$Inf = \sum_{i=1}^{5} f_i I_i = 0{,}175I_1 + 0{,}225I_2 + 0{,}275I_3 + 0{,}2I_4 + 0{,}125I_5$$

This comprehensive equation encompasses the weighting of the 5 key categories, in turn resulting from the weighted calculation of the sub-categories that compose them.

Findings

To test the workability of the infrastructure index, its use was experimentally simulated in five distinct locations in the city of Lisbon, with notably different characteristics regarding infrastructure and basic urban services: one in the old urban core, two in central areas with major urban activity and transports connections, and two others on mainly residential areas of the immediate outskirts.

From this first test analysis there were found some variances in results that enable the possibility to perceive between how the existent disparities are reflected in the index outputs.

It can be noticed that the 'Services and Telecommunications' categories are not discriminatory, since their existence and respective quality is homogeneous (consistently guaranteeing a 40% evaluation), but the remaining categories reveal some important differences:

- Intercity transports are not close to all locations, and night transports are not homogeneously available as well.
- The city center has 100% in the services index, but in some places accessibility has constraints, regarding aspects like sidewalk width (very narrow) and the ease and safety of parking.
- Moving away from the center the accessibilities have a 100% evaluation, but not all services are provided within the predefined distance.

The obtained results were:

$$0{,}71 \leq Inf \leq 0{,}93$$

It should be noted that these data refer to a set of points located within the urban area of a city (in this case Lisbon), and therefore reflect the presence of a considerable range of services and infrastructures.

Conclusions

The study of infrastructure commits to a future in which the collection, storage, processing and interpretation of information will be facilitated allowing us to advance our understanding of the urban condition and urban well-being, as pointed Bannister and O'Sullivan (2021) who assert beliefs in the contributions of Big Data[15].

The territorial infrastructure evaluation is intended to assess an area as small as feasible, as it is based on walking times that allow the classification of the access to services, schools and public transport, among others.

Aspects as distinct as mobility, access to transport, its diversity and periodicity, the quality of road connections, access to technology, sanitation, administration and public services, as well as culture and leisure, among many others, are contemplated, permitting to assess the present situation, as also to evaluate the potential for economic and social development.

The consideration of such a large number of items requires the quantifiable treatment of each of them and their total and relative weighting. It is important to recognize the balance between each item in the category to which it belongs and the weighting of the category in the global assessment.

The resultant formula can be applied to any area and with the same pondering factors can be in given cases performed statistical analyses, identification of asymmetries and comparisons between different locations with the same geographical (proximity to rivers, lakes, oceans or inland), demographic, social or employment characteristics[16].

This aggregate index will allow the assessment of the existent infrastructure, aiming at the interpretation of the territory and its potentialities. The aim is to calculate the infrastructure level in different places, allowing the identification and quantification of asymmetries.

The measurement is performed in percentages, allowing asymmetries to be highlighted.

From the experimental testing of its use to assess infrastructure in different locations in the city of Lisbon it was found that there are noticeable translations of the different conditions in the results obtained, both in the breakdown calculations of the different categories and in the final assessment values. The obtained overall

[15]"We reaffirm a belief that the Big Data contributions of greatest significance and lasting value will be those maintaining the clearest focus on using Big Data to advance our understanding of the urban condition and urban well-being" (Bannister and O'Sullivan 2021).

[16]Although the overview of the calculation for some categories and their items is described basing on the Portuguese context, its transposition to other realities is straightforward.

ratings, between 71% and 93%, revealed the differences from central areas with major urban activity to more peripheral and mono-function oriented zones.

These results also show a match to areas inside a consolidated urban area, reflecting the presence of a considerable range of services and infrastructures. The broadening of the tests to less urbanized districts could indicate its suitability for more contrasting situations.

It is important to note that each category can be evaluated individually, but the overall quantification of the 5 categories (including all items from every category and subcategory) in different locations of the same area (urban or rural) will enable the opportunity to promote the rectification of constraints, identifying investment priorities that can lead to a better infrastructure balance in the territory.

Future Developments

The performing of panel data analysis will enable the opportunity to calculate the infrastructure index for different locations over different time periods, which will make it possible (in the medium and long term) to verify trends of evolution and to calculate variations.

It will then enable the use of the calculation method as an evaluation system, to produce analytic data that can then be cross-referenced with other indicators, like the development level, education level, unemployment rate or birth rate.

Testing the implementation of the aggregate index in the field in different geographic realities of the territory will help to fine tune the balance and relative weighting of the categories and sub-items. This will constitute the next stage of the research.

As the study is part of a broader research dedicated to the estuary of the Tagus River and its territory, it will focus on the analysis of the heterogeneity of the estuarine environment, identifying and studying the differences in the levels of urbanization of this territory.

In the future, the goal will be to apply the index to different locations and periodically review the items and their quantification due to the technologies upgrading and the increasing significance of the implementation of eco-sustainable solutions.

The urban infrastructure level calculation method is intended to constitute an operative contribution to the analysis of the territory, considering however that, as André Corboz stated, other kinds of knowledge are also indispensable for its understanding, in addition to statistics and quantifications, enabling it as a semantized and *discursible subject*[17].

Acknowledgments

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[17]To Corboz (1983), the territory must be recognised for its own character, stemming from its culture and history.

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The Growth of Teacher's Mathematical Knowledge for Teaching as Participating in a Primary School Teacher's Professional Learning Community

By Ya-Lan Huang[*] & Erh-Tsung Chin[±]

Teacher's Professional Learning Community (PLC) should effectively operate through sharing teaching resources, professional dialogues, and collaboration to reduce pupil's learning achievement gaps and make teaching close to their learning experiences through providing learning scaffolding. This study adopts a qualitative research method to investigate the change of participants' Mathematics Knowledge for Teaching (MKT) of a primary school teacher PLC which has been running for three years. The three research subjects are experienced teachers and none of whom are mathematics or science majors. According to the framework of the MKT (Hill et al. 2008), the qualitative data which include PLC meeting videos, lesson observation sheets, interviews, and learning feedback are analyzed and triangulated by the researchers and other mathematics educators. The results show that PLC may help teachers improve their MKT. At the beginning of the PLC, the discourse was mainly related to the teacher's Knowledge of Special Content Knowledge (SCK) and Knowledge of Content and Teaching (KCT). It reveals that the participants ought to be energized in SCK and KCT, and the PLC activities should be specially arranged in these two aspects. After the continuous professional dialogue and teaching practices, the teacher's KCC, Knowledge of Content and Student (KCS), and Special Content Knowledge (SCK) are improved most significantly, which also promotes the student learning achievements.

Keywords: *mathematics teaching, teacher professional development, teacher professional learning community, mathematics knowledge for teaching*

Introduction

Teachers should strengthen the connection with their students' knowledge and skills to enhance their learning. Mathematics education of teachers' professional knowledge follows Shulman's seminal idea about pedagogical content knowledge (PCK) (Shulman 1986). Shulman introduced that pedagogical content knowledge inflects pupil's learning. PCK assumes teachers' ability to design effective instruction and skills to contribute to students' learning (Hill et al. 2008). Ball et al. (2008) have pioneered the consideration of Mathematical Knowledge for Teaching (MKT). MKT is an analytical tool to measure teachers' mathematical knowledge. Many researchers considered MKT to study mathematics teachers' knowledge in order to improve their teaching and promote students' effectiveness. Most of the

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primary teachers in Taiwan do not major in mathematics or science, but they all have to teach mathematics, even the teachers who possess weak abilities in mathematics teaching. Thus, they have to make plans to improve their own teaching of mathematics. A teacher professional learning community (PLC) should effectively operate through sharing teaching resources, professional dialogues, and collaboration to reduce pupils' learning achievement gaps and make teaching close to their learning experiences through providing suitable learning scaffolding. A powerful experience has happened in the classes that are utilizing and sharing teaching reflection which can help teachers to improve their teaching (Putnam and Borko 2000). Many Taiwan teachers lack sound mathematical understanding and skills. They need to have more support and resources for improving their teaching.

Recently, PLC has emerged as a support community to help teachers grow in their teaching practice. The partners have the same demands in PLC. When teachers have identified with PLC, they need to improve their curriculum, teaching and students' learning which is the correct teaching development (Stigler and Hiebert 1997). Teachers need to know how to promote their students to achieve, and identify what conditions are most likely to facilitate their mathematical learning. A teacher in PLC should effectively operate through sharing teaching resources to assess their teaching for understanding their students' ability for learning. According to the framework of the MKT (Hill et al. 2008), they would lead to a greater understanding of the constructs of mathematical knowledge for teaching. The study discussed teachers' knowledge using the MKT framework in the PLC. In the PLC, teachers prepare to preserve programs and share their teaching and resources to develop teachers' professional ability for achievement. In past studies, most of the qualitative data collection includes PLC meeting videos, lesson observation sheets, interviews, and learning feedback, which are analyzed and triangulated by the researchers and other mathematics educators. The research question is as follows: What kind of teachers' change in MKT do the members of a primary school teacher PLC have? We hope to get some suggestions for teachers regarding how to facilitate their teaching effectively in the PLC.

Literature Review

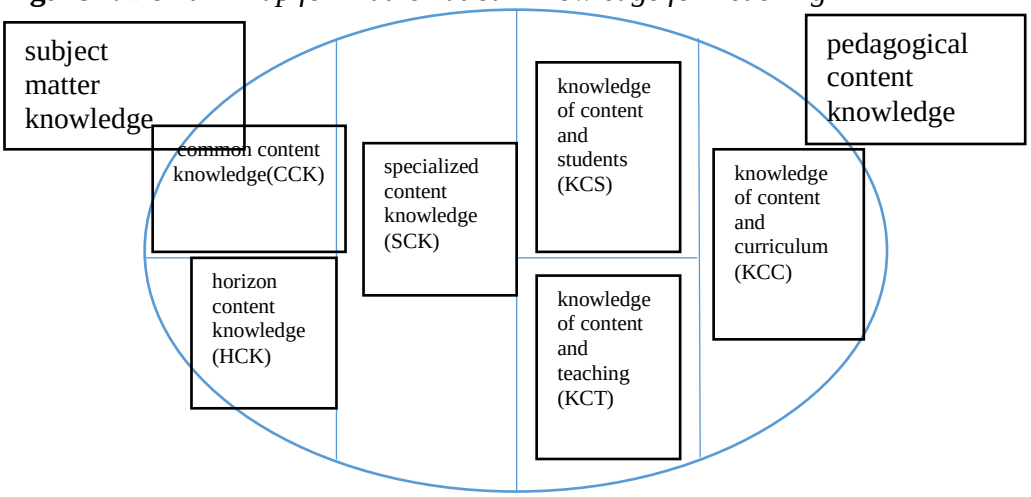
Mathematical Knowledge for Teaching

Shulman (1986, 1987) defines PCK within seven domains including: content knowledge; knowledge of subject matter; knowledge of educational aims; goals and purposes; knowledge of other content; general pedagogical knowledge; knowledge of learners; and curriculum knowledge. PCK was explained in two dimensions. First, it characterizes teacher knowledge containing teachers' representation of ideas and the ability to help students connect mathematics ideas (e.g., Ball 1988, Stein et al. 1990). Second, PCK discusses a teacher's understanding to know students' common preconceptions and misconceptions in different ages and backgrounds. PCK is canonical in developing a deeper understanding of the teacher's content knowledge and pedagogical knowledge.

Ball et al. (2008, p. 399) define MKT as a theory that encapsulates mathematical knowledge needed to perform the recurring tasks of teaching mathematics, noting that they have adopted a flexible conception of "needs" that allows for the perspective, habits of mind, and sensibilities that matter for the effective teaching of the content.

MKT assesses the knowledge by teachers in their teaching process, which includes pedagogical content knowledge and subject matter knowledge in the construct of mathematical knowledge for teaching (Hill et al. 2007) That is, knowledge of how making mathematical understanding of students and knowledge of students' conception and misconceptions (Shulman 1986). The relationship between pedagogical content knowledge and subject matter knowledge can be seen in Figure 1. The concept of MKT appears by studying records in mathematics teaching, and identifying teachers' mathematical knowledge, reasoning, and insight (Ball and Bass 2003, Hill et al. 2005).

Figure 1. *Domain Map for Mathematical Knowledge for Teaching*



Source: Ball et al. 2008.

Loughran et al. (2012) explain that PCK builds on teachers' personal experiences and own conceptions—particularly their expertise with individual idiosyncrasies and important differences that are influenced by the teaching experience, content, and context. Ball et al. (2008) defined MKT as a practice-based theory that encapsulates the mathematical knowledge needed to perform the recurrent tasks of teaching mathematics. There are six portions of the oval that are a proposed standard of MKT. The right side associates with Shulman's (1986) proposed PCK that contains KCS, KCT and KCC. KCS is content knowledge intertwined with knowledge of how students think about, know and learn mathematical knowledge content. The teachers can be diagnosed with students' errors as a partial or a complete explanation for selecting their answer for mathematical reasoning (Hill et al. 2008). KCS is the teacher's ability to know how making lessons better designed and foresee possible alternative conceptions of students and plan how to help them go past those conceptions which requires substantial knowledge of the students. Teachers know what works for students and

support the development of their understanding (Chua, 2018). KCT is the knowledge of content and teaching that is teaching design in practices and combines knowing about students and mathematics. KCT is proof that includes strategies of representing, explaining, or connecting proof ideas and responding to students' contributions (Lesseig, 2016). KCC is the knowledge of content and curriculum that describes somewhat Shulman's conception of curriculum knowledge. The left side is the subject matter knowledge that is divided into common content knowledge (CCK), specialized content knowledge (SCK), and horizon content knowledge (HCK). CCK is intrinsically defined as the mathematical knowledge and skill that is used in many other professions or occupations for mathematics. CCK means pure mathematical knowledge (Carrillo et al., 2011). CCK includes recognizing proof through which mathematical knowledge is verified, established and communicated (Lesseig 2016). SCK allows teachers to work in particular teaching tasks, including how to accurately represent mathematical ideas, provide mathematical explanations for common rules, procedures, examinations and understanding unusual solution methods to solve problems (Hill et al. 2005). HCK means an awareness of the relationship between mathematics topics and the curriculum. The MKT measures teachers' abilities to use mathematical knowledge in practice in the teaching processes. The six domains of the MKT are important tools that allow scholars to study factors of how various professional development activities can help develop it. The research on MKT is used to provide a powerful tool for evaluating knowledge used by mathematics teachers in their practice (Nettles et al. 2011).

Professional Learning Community

The PLC means the core task of formal education that is deep learning, not teaching (DuFour 2004, Hargreaves 2007). Stoll et al. (2006, p. 5) defines the PLC as, "an inclusive group of people, motivated by a shared learning vision, supporting and working with each other, finding ways, inside and outside their direct community, examining on their practice and together learning new and better approaches that will enhance all pupils' learning." Kruse et al. (1995) consider characters of the PLC that include: (1) reflective dialogue that helps teachers improve and promote teaching discussion; (2) focus on student learning that is a goal of PLC's activities to improve students' learning; (3) interaction among teachers or deprivation of practice that can engage teachers in sharing ideas, learning and helping; (4) collaboration that is happening when teachers share their teaching strategies, skills and growth; and (5) shared values and norms: partners reach a consensus for mission, value and specifications to build their professional behavior.

There are seven components of effective learning involved in CTL: constructivism, questioning, inquiry, learning community, modeling, reflection and authentic assessment (Yerizon and Putra 2021). Teachers need appropriate environments for their professional growth that can be used effectively to improve creative thinking, critical thinking and teaching skills (Hord 1997, 2004). PLCs should be a place where the principal and teachers are all learners and distributed

leadership positively (Hargreaves and Fink 2006). Teachers have the responsibility to promote their teaching skills and students' achievement. The shared personal practice contributes to the development of teachers' professional learning and supports a professional learning community (Hord 1997, Pickering and Garrod 2007). Darling-Hammond et al. (2017) identify seven characteristics of effective PD: (1) is content focused; (2) incorporates active learning utilizing adult learning theory; (3) supports collaboration, typically in job-embedded contexts; (4) uses models and modeling of effective practice; (5) provides coaching and expert support; (6) offers opportunities for feedback and reflection; (7) is of sustained duration. To achieve this shared purpose, participants are encouraged to be involved in the process of developing a clear vision how their collaboration must contribute to their students' learning and effective teaching. They build collective leadership and commitments that clarify the responsibility of teachers' contributions to their teaching and students' learning. Stylianides (2007) suggests that teachers' strong mathematical knowledge for teaching proves their ability to structure opportunities through arguments for their students, which helps teachers improve their weak teaching skills and mathematical knowledge understanding. As through the PLC's operation, teachers need to construct mathematical proofs. The PLC is an entire professional continuum system that supports and links to teachers' experiences in preparation and induction, as well as to teaching standards and evaluation (Darling-Hammond et al. 2017). The PLC is a continuous improvement process and helps teachers to continue their growth in teaching. Teachers are not completely alone on this because partners will help each other and solve teaching problems in the classroom.

The broadening research on PLC is used to provide more information about making MKT a powerful tool for evaluating teachers' mathematical knowledge. The element of MKT framework specializes in the work of teaching practices. The MKT measure that represents classroom, school process and teachers' ability to use mathematical knowledge in the classroom practice (Charalambous 2008). The MKT framework may be described in three ways: (1) as open-ended discussion which allow for the exploration of teachers' reasoning about mathematics and students' thinking; (2) as materials that are used to inform teachers' professional development; (3) as examples of what the mathematical knowledge teacher have to use in teaching (Fauskanger et al. 2012). However, there has been little research focused on examining how teachers' MKT is operationalized in the PLC.

Methodology

The study utilized a qualitative study design that described three teachers' knowledge of MKT in the PLC over the last three years. The research subjects were three primary school teachers in Taiwan. Table 1 presents their background information and pseudonyms. All subject teachers earned master's degrees, but no one majored in mathematics or science. Their teaching experiences are ranged from 15 to 18 years. The teacher PLC had operated for three years while a professor was invited to guide partners to improve their teaching. The purpose of

this study discussed participants in the PLC and what teachers' knowledge of MKT over the last 3 years. Subject teachers had dialogue and discussion for teaching 6~8 times and choose to teach a lesson every semester. The study was designed to capture a set of qualitative data of teachers' mathematics knowledge for interviews, lesson observation sheets, reflection and teaching feedbacks.

Table 1. *Background Information of Participants*

Pseudonyms	Gender	Education	Background	Teaching Subject	Teaching Years
AT	Female	M.Ed.	D.P.E	Chinese, Mathematics	18
BT	Female	M.Ed.	Teacher class	Chinese, Mathematics	17
CT	Female	C.A.C.S.	Finance	Chinese, Mathematics	15

Data Collection

Shulman (1986) proposes that teaching requires unique subject-matter-related knowledge, classroom observation became a primary method used to explore this idea. For this reason, the study discussed the participants' professional development for the last three years. The data sources included PLC meeting videos, lesson observation sheets, interviews, and teaching feedback which were analyzed and triangulated by the researchers and other mathematics educators. Before teaching, each teacher in the PLC needed to review lesson design ideas and how to teach and assess students' learning. Other teachers shared their teaching, skills and resources, and advised the teachers with more ideas on how to teach. PLC meeting and classroom observation were video recorded and transcribed verbatim. Semi-structured interviews are widely used in qualitative research. All data can provide limited insight into teachers' MKT, four different types of semi-structured interviews were executed to understand what teachers know and reasons for their teaching actions: (1) background interview- participants ask questions related to their teaching backgrounds, teaching design and mathematical knowledge; (2) pre-observation interview-focus on teachers' planning of the lesson to be observed; (3) post- observation interview-understand each teacher's reflection on the lesson; (4) teaching feedbacks-the participants revisit the lesson and issue the reasons for their teaching decisions and process. The pre-observation and post- observation interviews are carried out in combination with each observation.

Data Analysis

In order to capture the nature and dynamic process of the MKT components in the PLC for the last three years, data were analyzed through two approaches: (1) in-depth analysis of the explicit MKT (Ball et al. 2008); (2) analysis of the MKT elements of teachers' change process. Gencturk (2012) indicates the teachers' MKT improved and increased efficiently change in the quality of their interview, lesson design, mathematical agenda, task choices, and classroom situation.

According to the analysis of interview, observation and PLC meeting data that reveal teachers' beliefs, mathematical knowledge, teaching skills, and instructional practices. In-depth analysis of explicit MKT, was first identified within the documents from the video recordings and interviews, which gave a detailed description of MKT and what the teacher did and how many times the MKT components appeared. The data were used to answer the first research question. Then we analyzed the MKT elements of teachers' change process in the PLC for the last three years. This method assesses the relative extent to which teachers talk about different aspects of the MKT framework within each teacher's data set. In order to integrate the process of the MKT components in a clear way, we adopt an enumerative approach through the in-depth analysis of the explicit MKT (LeCompte and Preissle 1993). Every MKT component was identified in all of the six portions that the mathematical knowledge needed to perform the recurrent tasks of teaching mathematics. The data were coded by two authors to establish the reliability of parsing MKT coding. Inter-reliability was achieved that all agreements were resolved through discussion. This analysis provided direction for further qualitative analysis and supported the identification of the topic through the PLC activities.

Results

Identification of the MKT Domain Classification

Having profiled the theoretical and empirical basis for MKT, we developed the notion further for the proposed measurement. Table 2 shows one to three items from the MKT's six domains that each item was defined (Hill et al. 2008, Ball et al. 2008). Throughout the early conceptualization of these items we discussed how to classify the MKT items. We adopted the classification to measure a teacher's development work and a basis for future discussions about the nature of the teacher's knowledge (Hill et al. 2008). Knowledge of content and students (KCS) combines prior knowledge about students and mathematics. When the teacher chooses the examples, he needs to predict students' ability and assign the task, whether they will find it easy or hard. In order to analyze the teachers' KCS, we define that teachers can intertwine knowledge of how students think about, know, learn mathematical knowledge content (KCS-1), and foresee possible alternative conceptions of students (KCS-2). Knowledge of content and teaching (KCT) combines teaching and mathematics. Teachers design the mathematical task that requires mathematical knowledge for a particular sequence of content for instruction and evaluates the representation used to teach a specific idea and identify different methods and procedures. KCT separate the third components: KCT-1 means the teacher decides to begin the teaching and learning sequence, KCT-2 evaluates the quality of the mathematical presentation, and KCT-3 identifies different mathematical solution. KCC-1 means that a teacher connects the knowledge of content and curriculum. The common content knowledge (CCK) define it as the mathematical knowledge and skills when the teacher writes on the

board that he need to use correctly terms and notations. From our data as shown in Table 2, we indicate that CCK-1 means pure mathematical knowledge and CCK-2 diagnose students' wrong answer. SCK is the mathematical knowledge and skills unique to teach. The teacher looks for the students' error pattern and misconceptions. So SCK-1 is used to analyze students' misconceptions and SCK-2 accurately represents mathematical ideas and provides mathematical explanations for common rules. HCK means an awareness of the relationship in mathematics topics and curriculum.

Table 2. *MKT's Domain Classification*

Mkt	Domain	Items	Content
PCK	KCS	KCS-1	Intertwine with knowledge of how students think about, know, learn mathematical knowledge content
		KCS-2	Foresee possible alternative conceptions of students
	KCT	KCT-1	Decide begin of teaching and learning sequence
		KCT-2	Evaluate the quality of the mathematical presentation
		KCT-3	Identify different mathematical solution
	KCC	KCC-1	Connect the knowledge of content and curriculum
SMK	CCK	CCK-1	Pure mathematical knowledge
		CCK-2	Diagnose students' wrong anwser
	SCK	SCK-1	Analyze students' misconceptions
		SCK-2	Accurately represent mathematical ideas and provide mathematical explanations for common rules
	HCK	HCK-1	Relationship in mathematics topics and curriculum

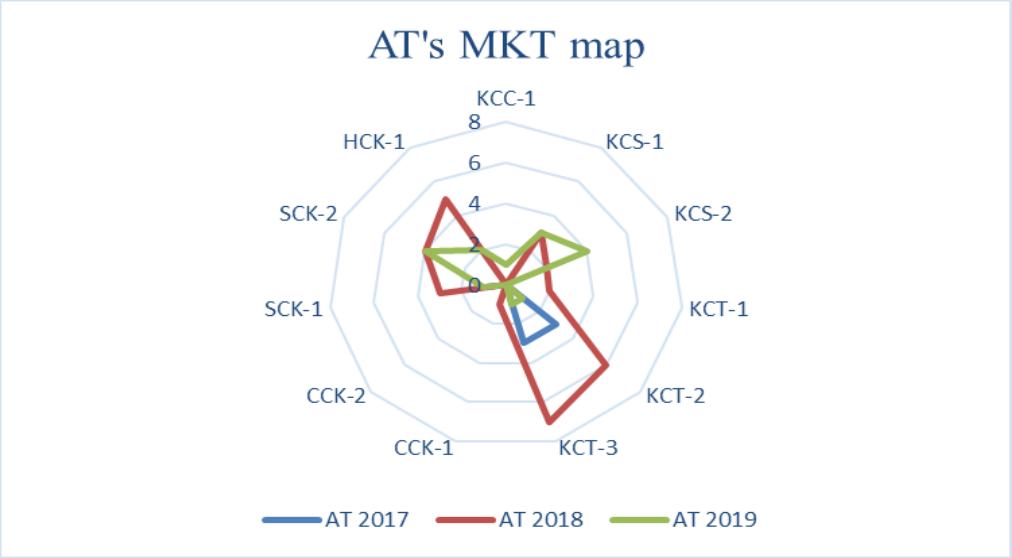
Source: Hill et al. 2008.

Our analysis of the MKT map expressed in the radar chart that revealed the participant's MKT for the last three year and process. The MKT map showed the MKT's domain classification that had a clear vision of the participants. The teachers' MKT map presented their professional development in the PLC that was summarized in Figures 2 to 4. Each teacher's MKT was composed of the frequency for three years. Each item was evident in the subsequent data that we could find out each teacher's teaching change process in the PLC. Each teacher's MKT map differed for their teaching and participation in the PLC. We realized the teachers kept changing through the PLC's sharing and diagnosis of teaching skills and mathematical knowledge to promote the individual teacher's professional development. Besides, we could diagnose the teachers' weak ability and which items could help them to improve their teaching. The analysis was presented to the participants who could realize how to promote their mathematics teaching and correct mathematical misconceptions.

Collecting and Using Data to Prove our Classification

The study collected three participants in the PLC in order to study teachers' mathematical teaching. We argued the six domains of the MKT that could help us to discuss teachers' mathematical knowledge and teaching skills. All data proved whether teachers' growth in our measure is sensitive to their teaching about how students learn mathematics. In the PLC, teachers examined students' computational work for errors, conceptions, explained those errors, and discussed how they remedy them in teaching. They described which problems students used to solve various types of problems and viewed in students solving problems and examined their work.

Figure 2. *AT's MKT Map During the Years 2017-2019*

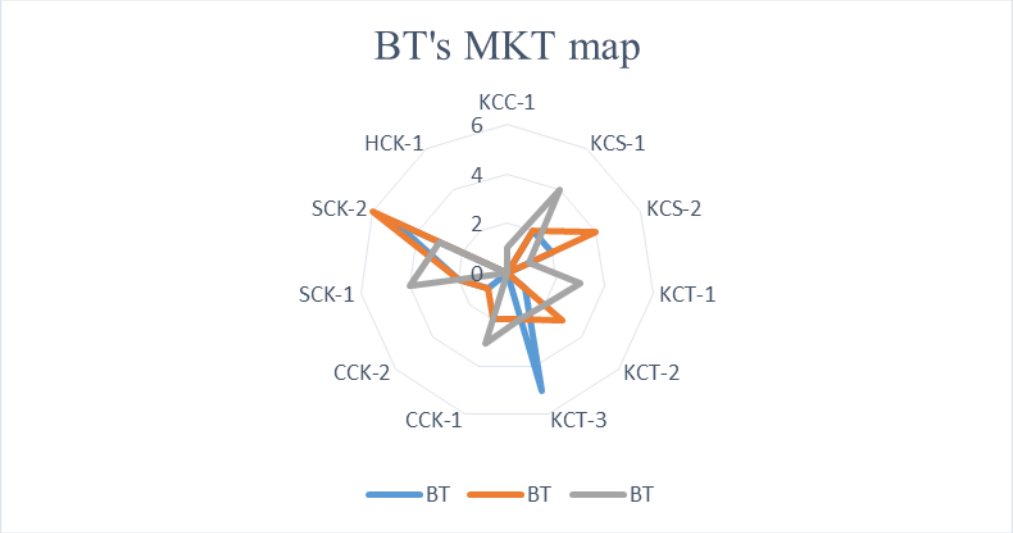


At is a grades 1-2 teacher. At the beginning of the PLC, AT's data was more focused on KCT-2 and KCT-3. KCT is the knowledge of content and teaching that is teaching design in practices and combines knowing about students and mathematics. In 2018, she was aware that her teaching was insufficient that she evaluated the quality of the mathematical presentation (KCT-2), identified different mathematical solutions (KCT-3), analyzed students' misconceptions (SCK-1), accurately represented mathematical ideas and provided mathematical explanations for common rules (SCK-2) and relationship in mathematics topics and curriculum (HCK). AT has a clear vision of the PLC lens that helped her know how to improve her teaching. In the third year, AT focused on intertwining with knowledge of how students think about, know, learn mathematical knowledge content (KCS-1), foresee possible alternative conceptions of students (KCS-2) and accurately represented mathematical ideas and provide mathematical explanations for common rules.

In AT's reflection, because she had mathematics problems in practice, she would find out solutions to help students. AT tried to use more mathematical presentations in practice and students were engaged in activities in which they

made the observation, counting activity, problem posing and compared those results with mathematical conceptions. For example, AT taught the topic of "time" using the real clock and calendar that helped the students to realize the concept of "time". In order to help the students to understand the mathematics of geometry, AT designed to understand the meaning of operations that illustrated in a three-layer box through stacking blocks, stratification and drawing out the picture in their vision. We discussed her teaching progress and students' performance that the result was shown. Most students could draw each layer box and counted the total box that could help the students understand which part of the layer box was not seen. Some students cut different directions in longitudinal sections or cross-sections, but they could find out the same results. The results showed the proofs for KCT-2, KCT-3. Evidence of KCT often took the form of teachers describing specific teaching strategies. AT shared her teaching idea that could make students understanding how to find out the invisible box and try to count every box in the second graders. Those proofs of KCS were shown. AT would like to challenge when she had a difficult task. For example, she shared her ideas in which they measured the classroom's window length in the first grade, explanation by students what they thought and measurement methods. Evidence of AT focused on intertwining the knowledge of how students think about, know, learn mathematical knowledge content (KCS-1), with foreseeable possible alternative conceptions of students (KCS-2) that accurately represent mathematical ideas and provide mathematical explanations for common rules. One student could not find the invisible box that AT used in the stacking blocks example to help her to see and understand how many boxes were in the figure. These discussions elicited both CCK-2 and SCK-1. In the PLC, she discussed the elements of mathematical teaching ideas, skills and students' representation made visible.

Figure 3. *BT's MKT Map During the Years 2017-2019*

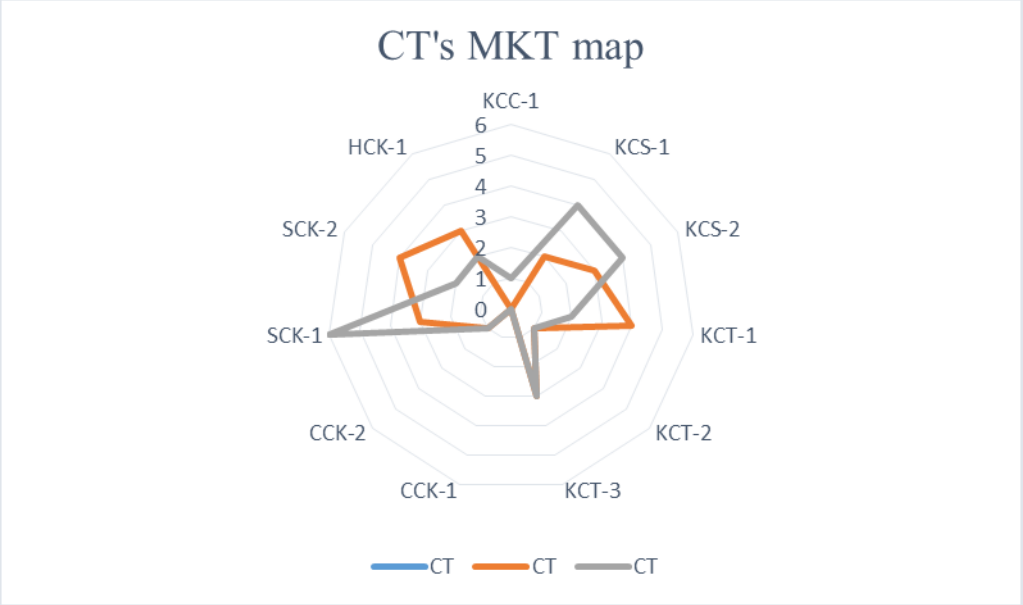


BT was a grades 4~6 teacher. She had positive attitude toward participating in the PLC. She would like to share her mathematical teaching idea and students'

misconceptions to help her solve mathematical teaching problems. BT used more representations in mathematical teaching.

In 2017, BT showed SCK-2, KCT-3, KCS-1 and KCS-2. Before teaching, BT used to consider her students' mathematical conceptions to design curriculum and teaching materials. That matches SCK-2. In the second year, BT invested continuously in foreseeing possible alternative conceptions of students (KCS-2), accurately represent mathematical ideas and provided mathematical explanations for common rules (SCK-2) and evaluated the quality of the mathematical presentation (KCT-2). BT improved her quality of teaching and her students noticed. The students reflected BT's improvement of teaching skills and understood the students' misconceptions and preconceptions. BT's teaching made the students enjoy mathematical learning and promoted their achievement for three years. This conclusion encouraged participants invest in the PLC's activities on their initiative. They realized that teachers must be to understand the problems in students' learning to improve teaching.

Figure 4. *CT's MKT Map during the Years 2017-2019*

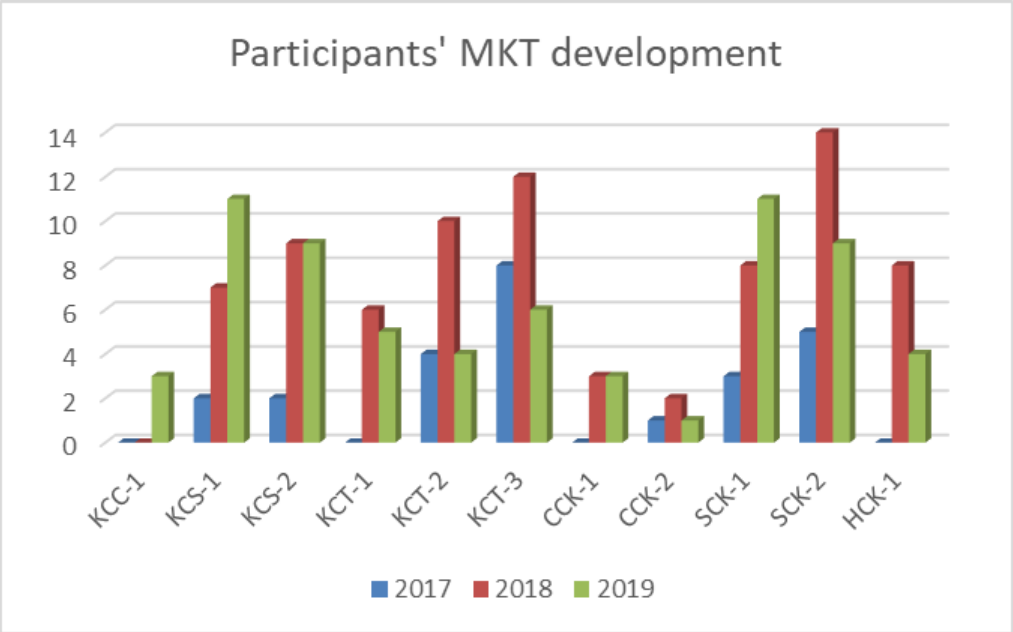


CT was mobilized to this school in 2018, hence she just had two years in the PLC. CT effectively has invested in sharing her teaching, correcting mathematics errors and developing richness of teaching mathematics. CT's map (Figure 4) revealed that CT paid attention to accurately represented mathematical ideas and provided mathematical explanations with common rules (SCK-2), analyzed students' misconceptions (SCK-1), decided to begin teaching and learning sequence (KCT-1), evaluated the quality of the mathematical presentation (KCT-2) and relationship in mathematics topics and curriculum (HCK) in 2018. CT showed more presentations of SCK-1, KCS-1, KCS-2, KCT-3 that revealed CT's understanding of mathematics teaching and willingness to change her teaching mind to prove the teaching practices. SCK-1 had the most amount of the MKT elements. For example, CT analyzed students' misconceptions in counting as

shown below: students counted three numbers forward and backward: 20, □, 22. Someone could not find out □ what the number is. CT used number cards to help the first graders understand counting number forward and backward. The proof showed her KCT-1. CT tried to analyze students' misconceptions (SCK-1) and use different mathematical solutions (KCT-3) to clear students' misconceptions. Those helped her identify correct mathematical knowledge. Before teaching, CT would intertwine with knowledge of how students think about, know, learn mathematical knowledge content (KCS-1) and foresee possible alternative conceptions of students (KCS-2). She prepared to understand students' mathematical knowledge background to choose her teaching style and curriculum. Even though CT had only participated in the PLC for two years, she kept moving on developing her teacher professional growth and changed her mind to improve mathematical teaching.

In teaching progress, we found that teacher's MKT was determined by their mathematical knowledge and students' learning. This present study also empirically supported the assertions by showing those three teachers. As shown in Figures 2 to 4, AT, BT, CT demonstrated a more coherently structured MKT map for three years. According to Figure 5, all of the items of participants' MKT development were increased. Evidenced in codes for PLC meetings, classroom teaching and learning, occurred in HCK-1, SCK-1-2, KCT-1-3, and KCS-1-2.

Figure 5. *Participants' MKT Development*

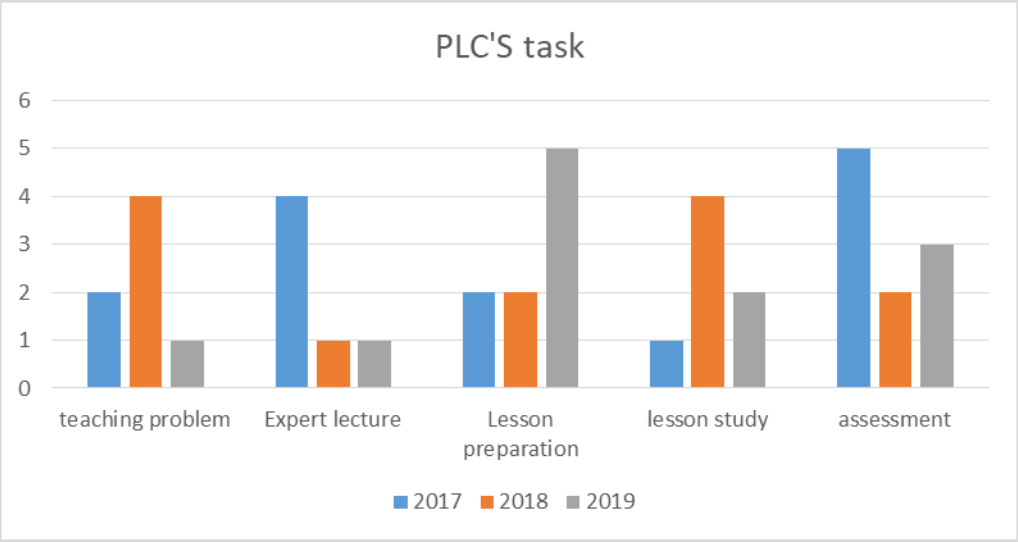


The reason the teachers shared their mathematical problems in the PLC, the expert teacher and professor had advises and resources to help them, they accepted their suggestions then tried those strategies in teaching later. After they tried and tested, the suggestions were proved to be effective. The teachers showed their reflections and the students made progress. The professor and expert teacher encouraged the participants to keep on trying different mathematical knowledge

and teaching skills. Figure 5 shows the participants' MKT development for three years. At the beginning of the PLC, the discourse was mainly related to SCK-1, SCK-2, KCT-2, KCT-3 and CCK-1. It reveals that the participants ought to be energized in SCK, KCT, CCK and the PLC activities should be specially arranged in these aspects. After the continuous professional dialogue and teaching practices, the teacher's KCC-1, KCS-1-2, KCT-1-3, SCK-1-2, HCK-1 are improved most significantly, which also promotes the change of the teachers' teaching skills and student learning achievements. It was contributed to the teacher professional development.

As shown in Figure 6, there were five tasks in the PLC. The tasks included teaching problem; expert lecture; lesson preparation; the lesson study and assessment. Because MKT's framework contains the teachers' teaching idea and mathematical knowledge, so assessment is considered in this study. At the beginning of the PLC, the professor and expert teacher provided expert lectures to enrich the teachers' mathematical knowledge and backgrounds. The teachers' mathematical foundations would be set up, because they did not major in science or mathematics. Then the teachers revealed their mathematical problems in the classroom, professor and expert teacher diagnosed the mathematical errors, corrected mathematical knowledge and presented teaching skills to help the participants to understand how to teach. The participants tried the new methods and corrected their mathematical knowledge in practice. Their students were making more progress and liked mathematics more. The researchers have used MKT framework to assess the teachers' mathematical knowledge during classroom teaching and development in teacher preparation programs (Stylianindes and Ball 2008, Steele and Rogers 2012, Stylianindes and Stylianides 2009). The former study was empirically grounded in PLC and investigated the MKT of proof (Lesseig 2016).

Figure 6. *PLC's Task*



In order to verify the teachers' MKT development, we tried to understand the teacher's ideas and teaching skills through the lesson preparation and the lesson

study. At the beginning of the semester, all participants shared their lesson preparations, curriculum, and mathematical skills. These tasks could help teachers sort out their mathematical knowledge, teaching progress and evaluate students' learning tools. Lesson study is a common method in promoting teacher professional development. Through lesson study, it will prove the effectiveness of teachers' lesson design, teaching and students' learning. More empirical studies in the PLC are needed to understand mathematical teaching orientations concerning MKT components and the whole construct of MKT in the context of teaching practice. Our PLC tasks provided efficient strategies to promote teachers' professional development.

Discussion

This study adopts a qualitative research method to investigate the change of participants' MKT of a primary school teacher PLC. The results show that PLC may help teachers improve their MKT. Shulman introduced that pedagogical content knowledge inflect pupil's learning. PCK assume teachers' ability to design effective instruction and skills to contribute to students' learning (Hill et al. 2008). Utilizing the in-depth discourse within the PLC meetings, collaborative lesson preparation, peer lesson observation, and analyzing exam items, the participants could transfer, the sharing resources to their own teaching practices, and manage to learn actively. In Taiwan, many teachers are not majoring in science and mathematics. They used to use e-book by the curriculum vendor to teach mathematics. Teachers have weak abilities in lesson design and mathematical knowledge.

In order to promote teachers' efficient actions in mathematical teaching, we adopted the tasks including teaching problem, expert lecture, lesson preparation, lesson study and assessment. At the beginning of the PLC, the discourse was mainly related to the KCC and KCT. It reveals that the participants ought to be energized in KCC and KCT, and the PLC activities should be specially arranged in these two aspects. After the continuous professional dialogue and teaching practices, the teacher's KCC, KCS, and SCK are improved most significantly, which also promote the student learning achievements. This suggestion has been supported by other empirical studies (e.g., Hill et al. 2008). The most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations (Shulman 1986, p. 7). As shown in BT's MKT map, she held a strong didactic direction to support Shulman's study. In this issue, the MKT map approach was developed that could explore various research questions about MKT. The MKT map can be used as a reflection tool to identify which components they need to improve for teaching more effectively. Through the PLC, teachers have more partners to share their teaching idea and solve their mathematical teaching problems practice. We have more data to realize teachers' MKT map that can explore more directly concerning mathematical knowledge domains. The result can suggest the orientations to the participants' professional development.

Conclusions

An effective teacher has a sense of the potential that their students possess and encourages their students to excel by providing the motivation to push the student to make sustained efforts when needed (Stronge 2018). In order to improve mathematics teaching from the result of our analysis of the MKT map, we have several conclusions. First, PLC is helpful for teachers to promote their teaching. Through the PLC, teachers were diagnosed by other participants; they focused on teaching skills and correctly mathematical knowledge to help them solve problems in practice. Second, SCK-2 was a max item that reveals the participants would like to accurately represent mathematical ideas and provide mathematical explanations for common rules. Teachers would like to change their minds on mathematics teaching and discuss how to achieve effective teaching, even not in the PLC period that shows collaboration happening to participants. Third, we discuss three teachers participating in the PLC for three years. If there are more participants in the PLC, they share the same vision to improve mathematical teaching that can elevate other primary school teachers. If the research methods can explore more PLC, it must be help for more teachers in teaching mathematics. Forth, the PLC operation will be work that suggests participants including professors or professional except teachers. The professor can provide more resources, mathematical knowledge and theories to help other participants' development. In summary, our study suggests MKT map prove theoretically productive and empirical studies to help more mathematics teachers. The result informs our understanding of the MKT map in practice and influence teacher professional development in the PLC.

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Polycyclic Aromatic Hydrocarbons Concentrations in Soils from Power Plant Stations in Universities in Port Harcourt, Rivers State, Niger Delta, Nigeria

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Soil contamination as a result of human interferences with nature is a common occurrence all over the world. Soil samples were collected from three universities (Ignatius Ajuru University of Education (IAUE), University of Port Harcourt (UNIPORT) and the Rivers State University (RSU) in Port Harcourt, Rivers State. The soils were taken at the points where the different institutions generate electricity with diesel powered generators. The soil samples were collected from the surface to a dept of 30 cm and were put into tightly closed glass containers. They were transported to the laboratory and prepared by standard methods of extraction and purification. The extracts were analyzed with a gas chromatography – mass spectrophotometry instrument to obtain the various fractions of PAHs present in the samples. It was observed that all the 16 priorities PAHs were present in all the samples from the station. The total concentrations of PAHs showed that IAUE>UNIPORT>RSU with respective values of 18.18, 16.64 and 16.53 mg/Kg. Benz(a)anthracene was observed to be the most abundant PAH in all the stations with a value of 2.11±0.14, 2.01±0.51 and 2.10±0.57 mg/Kg for IAUE<UNIPORT and RSU respectively. Fingerprinting and source diagnosis identified only one source of PAHs being pyrogenic sources of PAHs in the three stations. Ring size analysis showed the order 2-3>4>5>6 rings. The concentrations of carcinogenic and non-carcinogenic PAHs were almost in equal proportions in the soils examined. Therefore, the workers involved directly with the electrical generation on these campuses should adequately protected and informed on the consequences of contact with the soil and the gases that come out of the exhaust.

Keywords: *polycyclic aromatic hydrocarbons, soil, fingerprinting, power generating stations, pollution, human influence*

Introduction

The evolution of industrial revolution and subsequent industrialization and mechanization of different human activities has led to serious negative implications in the environment. These activities have resulted in the contamination of different sites which might be within the immediate vicinity or far away from the main point of the activity. Besides, when these manufacturing sites are no more in use, the contaminants and their effects (associated health conditions) are not adequately removed from the environment so contaminate (Guarino et al. 2019).

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Soil being contaminated by chemicals of organic and inorganic contaminants is a fast-rising issue, which is a consequence of increased industrial development, exhaustive agriculture, and general application of xenobiotics into the natural environment (Harms et al. 2011). Contact to these contaminants positions humans and the ecology at very high risk and health imbalance (Singh et al. 2009). The pollution of the surface soil is a well-recognized and grave problematic issue all around the globe. It has been identified to negatively affect food chain and also portend great danger to the already scarce water resources, being a source of its contamination. The contamination of surface soil with tenacious organic chemicals is of utmost concern because of the fact that when they are present in the environment, it takes a very long time before they are abated (Roskam and Comans 2009).

Polycyclic aromatic hydrocarbons (PAHs) are one amongst the different tenacious organic based compounds that has been given serious consideration presently, because of the health challenges and implications associated with this group of compounds (Cai et al. 2017). PAHs are resistant to biological degradation and highly hydrophobic and are composed of fused hydrocarbons of 2-6 benzene rings (Ellenhorn and Barceloux 1988, Ekpete et al. 2019). Their sources of origin are either natural are anthropogenic. In most cases, human influenced sources of PAHs are the major contributors of PAHs in an environmental media (Wick et al. 2011, Edori and Iyama 2019). PAHs are very common in the environment (Zhang et al. 2017). Majority of PAHs found in the environmental are produced from the partial burning or pyrolysis of vestige fuels (Holbrook 1990). Exposure routes of humans to PAHs may be oral (food and water), dermal (skin) and inhalation (air) (EFSA 2008).

In Nigeria, like many other developing countries, electricity to power industrial and research activities are irregular. Therefore, power stations are built and are powered by heavy duty diesel generators. The way of filling the fuel tank and discharging of fuel from the tank is a cause for concern. The soil environment within the immediate vicinity of the generating are at the receiving end of the hydrocarbon waste discharged from the generating house. Pollution rising due to the discharge of the tank content, engine oil and petrol used during servicing and repair works has cause pollution of the immediate soil environment (Odjegba and Sadiq 2002, Edori et al. 2020). Therefore, there is the need to examine the contamination status of the immediate soil environment, using the concentration of polycyclic aromatic hydrocarbons in soil within the immediate vicinity of the power stations in three selected universities in Port Harcourt, Rivers State, Nigeria.

Materials and Methods

Samples were collected from the surface to a depth of 20 cm from soils within the area of heavy-duty generators used to power electricity in three universities in Port Harcourt Rivers State, Nigeria. Soil samples were randomly collected with soil auger and pooled together to form representative sample for each of the sample points. The three universities where samples were collected were; The Rivers State University (RSU), Ignatius Ajuru University of Education (IAUE) and University of Port Harcourt (UNIPORT). The samples were immediately put

into glass containers and well corked and then transported to the laboratory and refrigerated for further treatment.

The determination of the concentrations of PAHs in the soil samples, was achieved by weighing out 8 grams of soil into a Soxhlet extractor and 30 mL of acetone and n-hexane solvent in a 50:50 ratio. The temperature of the extraction system was put at 100^{o}C for 1200 seconds. Then were allowed to cool to 25^{o}C and the extracting solvent were removed and put into an inverted sample vessel. The extraction container was washed three times with n-hexane and thereafter removed to the inverted sample vessel to avoid loss of PAHs present in the original sample. Subsequently (after the extraction), each of the samples were cleansed in the chromatographic column, which contain 10 cm long activated silica gel, 2 cm of anhydrous Na_2SO_4, which compacted with a cotton absorbent. Thereafter the solvent used for the extraction was added to the chromatographic column and eluted using 30 mL of dichloromethane and 30 mL of n-hexane to separate out the PAHs. The solvents were volatilized and the sample concentrated to between 2.0-0.3 mL through a rotary evaporator. The final volume obtain was stored frozen pending time for analysis.

The eluted PAHs were analyzed by a gas chromatographic instrument model Agilent 6890 gas chromatograph **(**GC) furnished with a tube support model HP-5 of length 30 m, whose inner radius is 0.125-mm inner and the film is 0.25 m thick, manufactured by J & W Scientific Inc., Folsom, CA, USA) and a 5975C mass selective detector (MS). The carrier gas used in the gas chromatographic process was helium, which was inserted at a rate of 1 mL/min with care to avoid splitting**.** The operating temperature was set at 60^{o}C and maintained for 60 seconds and thereafter increased to 110^{o}C at 20 C/min. Then, the temperature was increased to 290°C at an increment rate of 4°C/minutes and allowed to stand for 1200 seconds**.** The temperature of the detector was set at 290^{o}C. The individual components were identified by ion selection mode, based on the scan and retention time on the chromatogram. The quantification and confirmation of the ions were read from the chromatogram chart from the mass detector.

The sources and origin of the PAHs were examined using different diagnostic ratios and the sources were identified on the basis of the value obtained for that particular ratio. The ratios used were: (a) low molecular weight/high molecular weight (LMW/HMW), for source identification in this, if the ratio gives a value >1, the probable source is petrogenic, while a value <1 is pyrogenic. (b) anthracene/ anthracene+phenanthrene (An/(Ant+Phe), for source classification and identification, when the ratio value is <0.1, it is petrogenic, but > when >0.1, it indicates pyrogenic source (c) Fluoranthene/Fluoranthene+pyrene (Fl/(Fl+Pyr)), for this grouping, if the value of the ratio is >0.5, then pyrogenic source is suggested, but if the ratio <0.4, then petrogenic source is inferred. (d) benzo (a) anthracene/benzo(a) anthracene+ chrysene (BaA/(BaA+Chr)), for the identification of source and origin in this class, when the ratio <0.2, petrogenic source is inferred, but when >0.35, pyrogenic source is suggested and (e) Indeno(1,2,3-ed) pyrene/ Indeno(1,2,3-ed) pyrene/Benzo (g,h,i) perylene (Ip/(I+Bgp)), when the value of the ratio <0.2, it is proposed petrogenic, values ranging from 0.2-0.5 is proposed to be mixed petrogenic and pyrogenic sources and values >0.5 are termed pyrogenic (Tolosa et al. 2004).

Results and Discussion

Concentrations of PAHs in the Power Generating Stations

The results of polycyclic aromatic hydrocarbons (PAHs) concentrations in the soil samples from the power generating stations are shown in Table 1. The results showed that the total concentrations of PAHs in the selected stations was 18.18, 16.64 and 16.53 mg/Kg at IAUE, UNIPORT and RSU respectively. It was also observed that the most abundant PAH in all the examined stations was Benz (a) anthracene, which was 2.11±0.14, 2.01±0.51 and 2.10±0.57 mg/Kg at IAUE, UNIPORT and RSU respectively, which was followed by the observed values of Dibenz (a,h) anthracene, anthracene, chrysene, Benzo(k) fluoranthene, phenanthrene , naphthalene etc. The least abundant PAH in all the stations was O-terphenyl.

The total concentrations of PAHs observed in the stations in the present is lower than the values observed in soils in Lagos, Nigeria (Fatunsin et al. 2019), higher than the values of PAHs observed in urban and natural forest soils in the Atlantic Forest, (São Paulo State), Brazil (Bourotte et al. 2009) and also lower than the total values of PAHs observed in contaminated sites of Hisar, India (Bishnoi et al. 2009). However, the values observed in the various university stations were higher than the 10 mg/Kg for recreational land use recommended by the Italian legislation (Guarino et al. 2019). The observed concentrations of PAHs in soils of the different stations investigated may be related to the equilibrium amongst contributing and discharge sources and the length of time that the generation has existed (Holoubek et al. 2009). From the continuous discharge of generator emissions in the three universities, it will be expected that the concentrations of PAHs in the soils within the immediate vicinity will be higher than observed, but it was not so. The reason may not be far-fetched from the observation of Nam et al. (2008), that concentrations of PAHs in soils are connected majorly with the nature of the emissions, atmospheric transport and land cover. Looking at the different levels of concentrations of the PAHs in soils in each of the universities, the order is IAUE>Uniport>RSU. Taking into consideration, IAUE generates more electricity, than all the other universities, while RSU gets electricity from the national supply line more than the others, which probably may have emitted less of hydrocarbons than the others.

Table 1. *Concentration (mg/Kg) of Polycyclic Aromatic Hydrocarbon (PAHs) in Soil from Power Generating Stations in the Universities*

Concentrations of PAHs (mg/Kg)	**University Location**		
	IAUE	**UNIPORT**	**RSU**
Naphthalene	1.10±0.12	1.09±0.01	1.00±0.00
Acenaphthylene	0.55±0.02	0.40±0.01	0.42±0.01
Acenaphthene	0.28±0.00	0.25±0.01	0.20±0.00
Fluorene	0.68±0.03	0.66±0.00	0.67±0.19
Phenanthrene	1.50±0.10	1.39±0.13	1.36±0.58
Anthracene	1.81±0.04	1.75±0.25	1.72±0.07
O-Terphenyl	0.05±0.00	0.03±0.00	0.01±0.00
Fluoranthene	0.70±0.01	0.61±0.03	0.58±0.02
Pyrene	0.56±0.02	0.54±0.02	0.50±0.00
Chrysene	1.75±0.11	1.74±0.16	1.74±0.14
Benz(a) anthracene	2.11±0.14	2.01±0.51	2.10±0.57
Benzo(b) fluoranthene	0.65±0.00	0.65±0.03	0.68±0.06
Benzo(k) fluoranthene	1.86±0.21	1.54±0.20	1.46±0.00
Benzo(a) pyrene	0.80±0.09	0.67±0.02	0.60±0.00
Dibenz (a,h) anthracene	2.01±0.31	1.60±0.14	1.47±0.16
Benzo(g,h,i) perylene	0.81±0.00	0.81±0.06	1.10±0.14
Indeno (1,2,3-cd) pyrene	0.96±0.06	0.90±0.02	0.92±0.05
Total	18.18	16.64	16.53

PAHs do occur in soils in a diverse fraction which are related to appropriation and maturing developments that increases with time (Harmsen 2007). Also, owing to the excessive sorption and ability of the soil to retain the absorbed PAHs. Thus, coarse soils have low capacity to retain pollutants which are easily leached to inner depth of the soil or quickly washed away.

The contamination of the environment with PAHs have different health effects on both humans and the environment. The effects depend on the degree of contact, dosage, distinctive toxicity characteristics and the exposure pathway (Ekpete et al. 2019). Although, the effects might not be noticed on the workers now, both the chances of being affected later may be there. On the other hand, the present health condition and the age of the workers in this unit can enhance or promote the effects of PAHs on them (Adedosu et al. 2015, Edori and Iyama 2019). In other words, taking into consideration the levels of PAHs in the soil, not considering the amount inhaled during the period at work, the artisans are at a risk of acute and chronic effects due to exposure (ATSDR 1995). The most notable and considered effects of PAHs is related to their carcinogenicity and teratogenicity, inducing of dioxin-like activity and weak estrogenic response (Villeneuve et al. 2002, Nwineewii and Marcus 2015).

The PAHs observed from the sites examined in this research majorly originated from the partial burning of diesel, spills during refueling of the generator, precipitation of discharged fumes by rain, engine oil and petrol used during maintenance and servicing of the generators. This observation is in agreement with an earlier one by Korosi et al. (2013) who observed that PAHs in soils originated majorly from fume waste and dumps within that particular point. When PAHs is present in soil, it

possesses the ability to contaminate ground water through percolation down the soil profile and also surface water through running water after heavy down pour of rain (Al-Delaimy et al. 2014). The consequences of incidence of PAHs in water to living organisms is an issue that demands utmost concern because the direct and indirect effects either through individual personal contact of through food chain transmission (Ifemeje et al. 2014).

Fingerprinting and Diagnosis of PAHs from the Power Stations

The results of the different analytical ratios and sources of the PAHs is shown in Table 2. Different tools have been used to judge the origin of Polyaromatic hydrocarbons in environmental media by different authors (Jiao et al. 2017, Zeng et al. 2019, Ekpete et al. 2019, Edori et al. 2020). The outcome is used to apportion the supposed causes and the particular origin of the source type, whether natural or anthropogenic. The ratios of LMW/HMW in the different sites were 0.48, 0.5 and 0.48 at IAUE, UNIPORT and RSU respectively. All the values observed in the examined stations were less than 1, which signifies that the PAHs origin were of pyrogenic or combustion sources. This observation is in consonance with the observation of Jiao et al. (2017), where they observed that concentrations of the ratio of LMW/HMW revealed pyrogenic sources of PAHs in soils around a chemical plant in Shanxi, China. However, this observation is at variance with the observation of Ekpete et al. (2019), that observed values of the ratio LMW/HMW higher greater than 1 at dumpsites situated at psychiatric Road and Rumuokwuta in Obio/Akpor Local Government Area, Port Harcourt, Rivers State, Nigeria, which was ascribed to petrogenic sources of PAHs.

The ratio of An/(Ant+Phe) in the stations showed that in IAUE, UNIPORT and RSU were 0.55, 0.56 and 0.56 respectively. All the ratio values from the stations were >0.1, which suggested pyrogenic sources of PAHs. This observation corroborates the findings of Jiao et al. (2017), where they observed that PAHs sources from a chemical plant sited in Shanxi, China, originated from combustion of organic materials such as coal, wood, grass and petroleum. Also, Cao et al. (2019), while investigating the concentrations of PAHs in reconstructed land from a coking plant, Beijing, China, observed that finger printing analysis for source identification of PAHs using An/(Ant+Phe) gave values >0.1 and concluded that the PAHs present in the top soil in the coking area were principally from incineration that resulted from the burning of coal and biomass burning, but little contribution came from petroleum source.

The ratio of Fl/(Fl+Pyr) in the stations showed that in IAUE, UNIPORT and RSU were 0.56, 0.53 and 0.54 respectively. All the ratio values from the stations were >0.50, which suggested that pyrolytic sources were responsible for the observed PAHs. The observations from this work is in agreement with those of Ekpete et al. (2019) in selected dumpsites within Obio/Akpor local Government Area, Rivers State, whose Fl/(Fl+Pyr) values were all greater than 0.5. According to Yunker et al. (2002), when ratios of Fl/(Fl+Pyr) falls within the value range of 0.40-0.50, the PAHs origin are chiefly a consequence of petroleum combustion,

but less than 0.40 is an indication that the sources are from oil origin, while values that are >0.50 are alluded to the burning of coal and biomass sources.

The ratio of BaA/(BaA + Chr in the stations showed that in IAUE, UNIPORT and RSU were 0.55, 0.54 and 0.55 respectively. All the ratio values were >0.35, which a consequence of pyrogenic sources (Salih et al. 2015). Cao et al. (2019), observed that the classifications of the origin of PAHs based on BaA/(BaA + Chr) ratio are; values between 0.2-0.35 is due to petroleum combustion, if it is less than 0.2, then the source is from lower petroleum fractions, but greater than 0.35values is due to biomass combustion from grass, wood and coal.

The ratio of Ip/(Ip+Bgp) in the stations showed that in IAUE, UNIPORT and RSU were 0.54, 0.53 and 0.46 respectively. Guarino et al. (2019), suggested that Ip/(Ip+Bgp) ratio above 0.50 is a result of biomass and coal incineration. Whereas, pyrolytic products that originated from gas, petrol, paraffin, diesel and crude oil produces ratios that are less than 0.50 and discharges from automobiles fall within 0.24 and 0.40.

Table 2. *Diagnostic Ratios and Source Apportionment of PAHs in Power Stations*

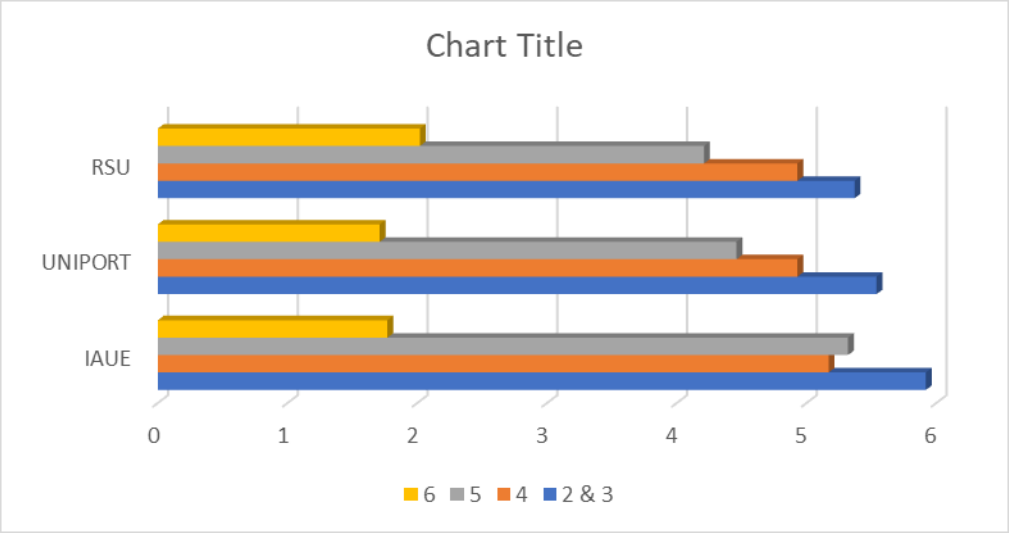
Power Generating Stations	LMW	HMW	LMW/ HMW	An/(Ant+Phe)	Fl/(Fl+Pyr)	BaA/(BaA+Chr)	Ip/(Ip+ Bgp)
IAUE	5.92	12.26	0.48	0.55	0.56	0.55	0.54
UNIPORT	5.54	11.10	0.5	0.56	0.53	0.54	0.53
RSU	5.37	11.16	0.48	0.56	0.54	0.55	0.46

Ring Size Analysis of PAHs in the Power Generating Stations

The concentrations of the PAHs ring types in the various power generating stations is shown in Figure 1. The results from the stations revealed that in IAUE, the values were 5.92, 5.17, 5.32 and 1.77 mg/Kg for 2-3 rings, 4, 5 and 6 rings respectively. At the UNIPORT station, the values were 5.54, 4.93, 4.46 and 1.71 mg/Kg for 2-3 rings, 4, 5 and 6 rings respectively and at the RSU station, the values were 5.37, 4.93, 4.21 and 2.02 mg/Kg for 2-3 rings, 4, 5 and 6 rings respectively. The stations values showed the predominance of 2-3 membered rings in all cases, which was followed by the 4-membered rings, then the five membered rings and the least was the six membered rings. The high levels of the LMW PAHs is due to the continuous use of generators to supply electricity to the various units of the universities' establishments. Highly contaminated soil with LMW PAHs as was observed in the present work is an indication of recent deposition. This because they are highly hydrophobic, hydrophilic, volatile and soluble, therefore can easily be removed under slight environmental changes (Wu et al. 2019, Edori et al. 2020). Despite the volatility of the LMW PAHs yet they were still present in very high proportions. The HMW PAHs were probably formed due to combination reactions of the LMW PAHs under very high temperature. They are not easily biodegradable nor volatile, so the fairly high proportions of 4 and five membered rings in the soils might be a result of deposition or accumulation over a long time, putting into considerations the length of time generators have been used to supply energy needs of the universities. It is and established fact that LMW PAHs are primarily formed from petroleum contamination, whereas HMW PAHs are chiefly

due to partial pyrolysis of coal at high temperatures (Li and Duan 2015). This is the case with the observations made in the present work, where the presence of the PAHs is linked to the use of diesel-powered generators (heavy duty generators), which operate at very high temperatures. Further to this is the nature of discharge of spent oil by the staff and the nature of solvents used during servicing, which is gasoline.

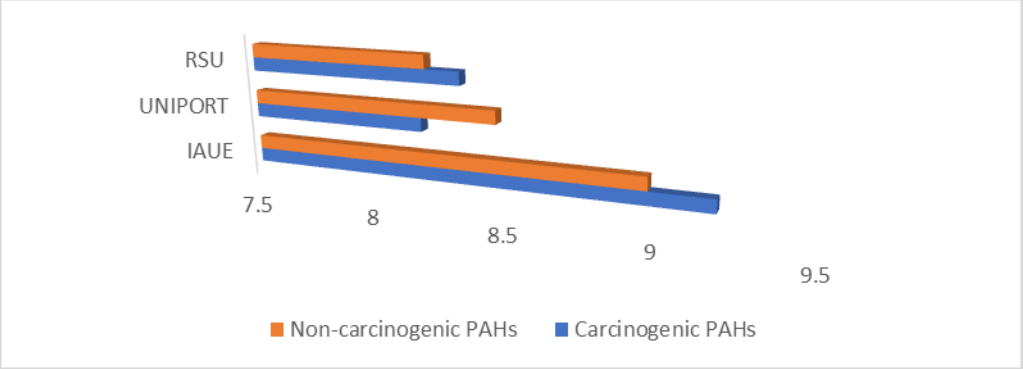
Figure 1. *Ring Size Analysis of PAHs in the Power Generating Stations*



Carcinogenic and Non-Carcinogenic PAHs in Soils from Power Generating Stations

The concentrations of the carcinogenic and non-carcinogenic are shown in Figure 2. The assessment of the values of non-carcinogenic and carcinogenic PAHs in the examined stations revealed that at IAUE the values were 8.98 mg/Kg and 9.20 mg/Kg for non-carcinogenic and carcinogenic PAHs respectively. At UNIPORT, the respective values for non-carcinogenic and carcinogenic PAHs were 8.46 and 8.18 mg/Kg, while that of RSU were 8.20 and 8.33 mg/Kg for non-carcinogenic and carcinogenic PAHs. The values of carcinogenic PAHs were slightly higher than the non-carcinogenic PAHs in soils from IAUE and UNIPORT, but slightly lower in soil from RSU. Highest values for both medically classified categories were observed at the IAUE station. This means that staff from the IAUE institution are more likely predisposed to health effects that might be associated with the work when compared to the other institutions. Although all the examined sixteen priority PAHs have negative health consequences on man, yet, six PAHs have been identified as having constituted highest risk when contacted for a very long period. All in this category fall within four to six membered rings. These six PAHs are namely benzo(a)anthracene, chrysene, benzo(b)fluoranthrene and benzo(k) fluoranthrene are known to be carcinogenic in nature (Obini et al. 2013). The implication of the high values of these PAHs on the workers is exposure to cancer causing agents which have a negative toll on them after protracted exposure through contact with the soil (ATSDR 1999) and inhalation of gases which are released from the generators exhaust.

Figure 2. *Concentrations (mg/Kg) of Carcinogenic and Non-Carcinogenic PAHs in the Power Generating Stations*



The nature of toxicity of PAHs are categorized and the basis of benzo[a] pyrene because its toxicological profile and cancer-causing characteristics have been well understood (Lee and Shim 2007). The carcinogenicity and mutagenicity of benzo [a]pyrene is mostly pronounced when it is converted to its metabolites at very high temperatures ranging from 300-600^{o}C (Aygün and Kabadayi 2005).

Conclusions

Due to the educational development and the energy requirements of universities, power stations were built to meet up with such requirements seeing the failure of the national grid to supply electricity. This has resulted in some sort of environmental pollution of the soils within the immediate environment. This study is on the level of pollution and the origin of PAHs in the soil surface of power stations in three universities in Port Harcourt Rivers State, Nigeria. The total concentrations of 16 priority PAHs in the stations ranged from 16.53-18.18 mg/Kg. The profiling of the different ring types showed that the low-ring aromatics (2-3 rings) were most dominant, which was followed by the 4 membered rings, then 5 membered rings and the least was 6 membered rings, which indicated that fuel combustion was the major sources of PAHs. The finger printing and diagnosis of the origin of the PAHs indicated anthropogenic pyrolytic sources in all the stations, which assessment of the total carcinogenic and non-carcinogenic PAHs revealed that almost equal proportions of the two types, although carcinogenic PAHs dominated at the IAUE and RSU stations. The level of PAHs in the soils examined is alarming and therefore caution should be taken to avoid further increase so as to stem any emergence of health effects in the near future.

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