Evolution of Technology and the Demand for Cybersecurity Professionals

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Abstract

This research paper explores the importance of cybersecurity in today's digital era. With the rapid growth of technology, the need for secure networks and the protection of sensitive information has become increasingly important. The paper highlights the rise of computer and mathematical occupations, as well as the increase in demand for cybersecurity professionals. It also emphasizes the need for cybersecurity awareness and education, as many individuals lack the knowledge to identify and prevent cyber-attacks. Additionally, this essay discusses the potential consequences of not taking cybersecurity seriously, including significant monetary losses. It also discusses the rise of monetary loss due to cyber-crime throughout the years, and what this fact suggests for the long-term view.

Introduction

In today's fast-paced, technology-driven world, cybersecurity has become a critical concern for individuals and organizations. As the world exponentially moves into the digital era, cyber threats continue to grow in complexity and frequency, making it more important than ever for individuals and organizations to take measures to guard themselves against cyber-crimes.

As technology continues to evolve, the demand for cybersecurity professionals is on the rise. One of the possibles explanations for the demand, according to Libicki in the book "Hackers Wanted", is the "growth in computer and connectivity" [1]. In other words, the increasing number of new technologies is a potential explanation for the rise in the demand. It suggests the rate of technological innovation is outpacing the rate at which people are trained to handle it. And so, creating a significant gap in the number of skilled cybersecurity professionals needed to defend against cyber-crime.

Further on, as more people gain access to technology, the need for cybersecurity awareness among the general population has become increasingly important. The rise of social media, online shopping, and other digital platforms has made people more vulnerable to cyber-attacks, with black hat hackers constantly looking for new ways to exploit vulnerabilities in these platforms.

Considering these ideas, it is essential to understand the relationship between the demand for cybersecurity professionals and the evolution of technology. This research paper aims to explore this relationship by analyzing data sets that show trends and patterns related to the demand for cybersecurity professionals in the market. By examining the factors that contribute to this demand, such as the growth of the technology industry and the increasing number of cyber threats, the study will shed light on the current state of cybersecurity and provide insight into future trends.

In addition to exploring the demand for cybersecurity professionals, this paper will also investigate the importance of educating the general public on cybersecurity practices to prevent from falling prey to cyber-crimes. Cybersecurity awareness among the general population is an essential topic as humankind moves further into the digital era.

Section 1

The data mentioned in this section is from the U.S Bureau of Labor Statistics [2]. The data sets collected are classified as Occupational Employment and Wage Statistics from the year 2008 to 2021. The information contained is about the US national number of jobs in each occupation by industry, the median hourly, and annual wages for each occupation. For the purposes of this section, the data has been filtered, and it utilizes only information from the "Computer and Mathematical Occupations" field. Which is characterized in these data sets as everything under the occ_title 15-xxxx code.

An important observation about the data sets collected is the difference between the number of occupations under the code 15-xxxx throughout the years. In 2008, there are sixteen different occupations in the field. Now, in 2021, there are twenty-one different occupations listed under the field of "Computer and Mathematical Occupations". This difference is a potential indicative of the evolution in the area. As new technologies are developed and adopted, new job roles are created to support them,

leading to a higher number of different occupations.

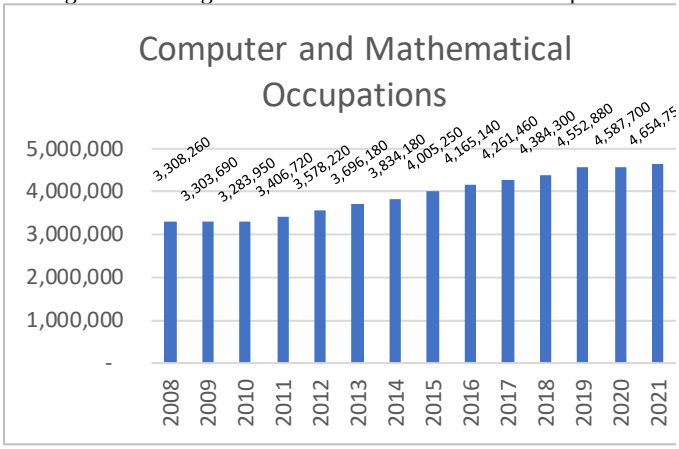

Figure 1: 15-0000-Computer and Mathematical Occupations - The total number of employees in the whole "Computer and Mathematical Occupational" field from the years 2008 to 2021.

The graph above represents the total number of employees in the whole "Computer and Mathematical Occupational" field from the years 2008 to 2021. In 2008, there were over three million and three hundred thousand employees. And in 2021, there were over four-million and six hundred thousand employees in the area. It means, from 2008 to 2021, over one million and three hundred thousand individuals were hired to work in the field.

It is possible to see a slight decrease in the occupation from 2008 to 2010. More precisely, there is a variation of -0.14% from 2008 to 2009, and a variation of -0.60% from 2009 to 2010. Now, from 2010 to 2021, it can be noted a constant increase in the occupation. The average growth in the area for the years 2010 to 2021 is 3.2%, having the highest variation of 5.03% from 2011 to 2012, and the lowest variation of 0.76% from 2019 to 2020. The average variation growth for all the years in scope is 2.6%.

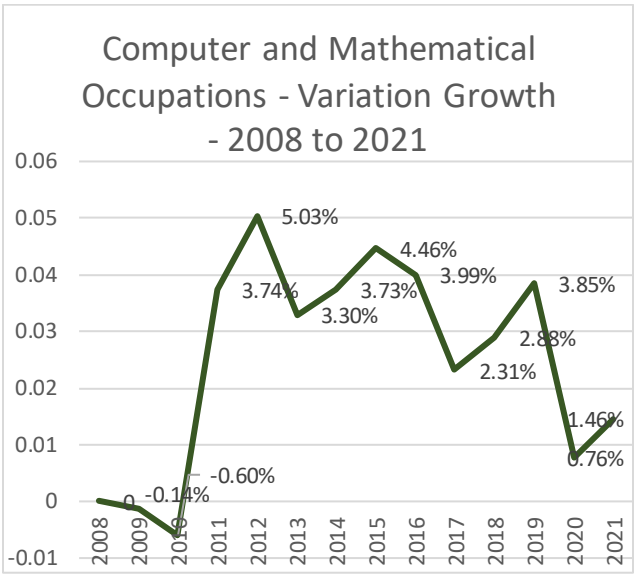

Figure 2: Computer and Mathematical Occupations – Variation Growth – 2008 to 2021.

The slight decrease from 2008 to 2010 could be due to both the burst of the U.S housing bubble and the global financial crisis that occurred during that period. Both happenings had a significant impact on the job market. However, the average growth rate of 3.2% from 2010 to 2021, and the overall average growth of 2.6%, is a testament to the growing importance of technology in the economy. The fact that the lowest variation in growth, apart from 2008 to 2009 and 2009 to 2010, was only 0.76% from 2019 to 2020, during a global pandemic, is a further indication of the resilience of this industry.

Section 1.1

For the purpose of this section, the data sets utilized are from 2012 to 2021. The data has been divided between "Computer Occupations" and "Mathematical Science Occupations", both represent occupations under the "Computer and Mathematical Occupations" domain. "Computer Occupations" is the subtotal of the sum of employees working on computer related jobs. And "Mathematical Science Occupations" is the subtotal of the sum of employees working on mathematic science related jobs. For the sake of facilitating reading, "Computer Occupations" and "Mathematical Science Occupations" are going to be abbreviated to "CO" and "MO" respectively.

Computer Occupations and Mathematical Science Occupations

Year	Computer Occupations	Mathematical Science Occupations	Total
2012	3.456.500	121.720	3.578.220
2013	3.573.120	123.070	3.696.190
2014	3.692.980	141.200	3.834.180
2015	3.853.860	151.380	4.005.240
2016	3.997.370	167.770	4.165.140
2017	4.094.930	166.530	4.261.460
2018	4.214.820	169.480	4.384.300
2019	4.358.410	194.460	4.552.870
2020	4.368.000	219.700	4.587.700
2021	4.389.910	264.840	4.654.750

Figure 3: Computer Occupations and Mathematical Science Occupations.

The table above shows the total number of employees in both CO, and MO. An important observation is the extreme difference from the total number of CO to the total number of MO. CO represents the absolute largest part of the "Computer and Mathematical Occupations" field. In 2012, CO represents 96.6% of the field, whereas only 3.4% represents MO. However, in 2021, there was a decrease of 2.29% in the percentage of CO, and an increase of 2.29% percentage of MO compared to the first year.

Percentual of Total Occupations

Year	Computer Occupations -CO- percentual of total	Mathematical Science Occupations - MO - percentual of total
2012	96,60%	3,40%
2013	96,67%	3,33%
2014	96,32%	3,68%
2015	96,22%	3,78%
2016	95,97%	4,03%
2017	96,09%	3,91%
2018	96,13%	3,87%
2019	95,73%	4,27%
2020	95,21%	4,79%
2021	94,31%	5,69%

Figure 4: Percentual of total Occupations.

The table above makes reference to the findings of the previous paragraph concerning the total representation percentage of CO and MO in the Computer and Mathematical Occupations field.

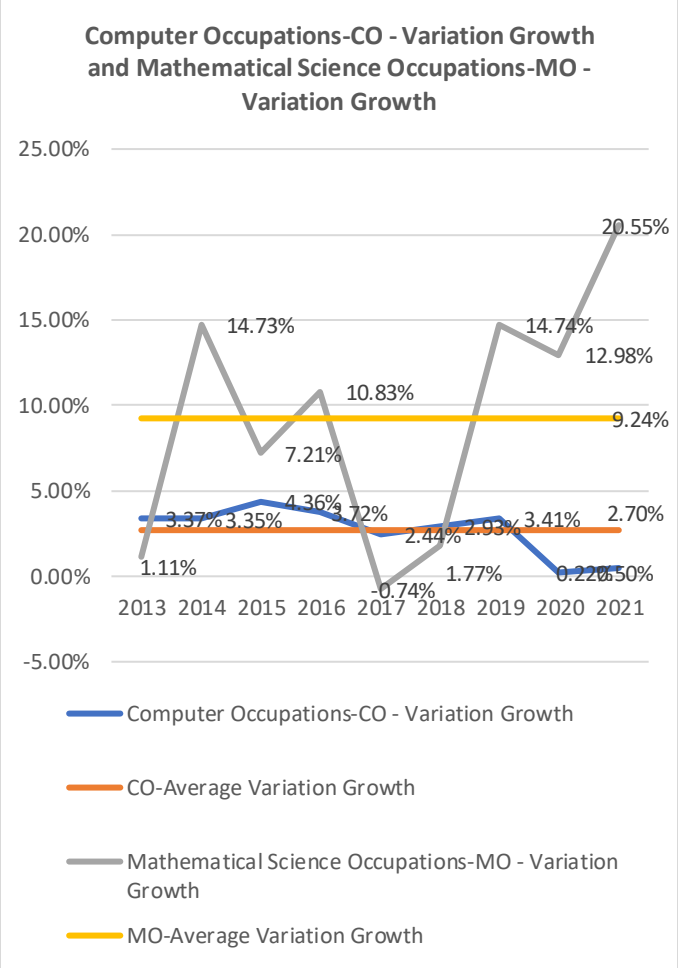

Figure 5: Computer Occupations-CO – Variation Growth and Mathematical Science Occupations-MO – Variation Growth.

The average variation growth for CO is 2.7% as shown in the graph above. The highest variation growth is 4.36% from 2014 to 2015. And the lowest variation growth is 0.22% from 2019 to 2020. Now, the average variation growth for MO is 9.24%, where

the highest and lowest variation growth are 20.55% from 2020 to 2021, and -0.74% from 2016 to 2017 respectively.

Further on, the difference between the total CO number of employees from 2012 to 2021 is over nine hundred thousand. It means that from 2012 to 2021 there were over nine hundred thousand individuals hired to work in the area. Also, the difference between the total MO number of employees from the years in scope is over one hundred and forty thousand. Both are quite impressive number of hiring for a spam of nine years.

A crucial observation is that even though CO does not have a high variation growth, it represents such a large portion of the "Computer and Mathematical Occupations" field that even a small percentage of increase can still result in a significant number of new hires. In other words, 1% variation growth on top of three million is thirty thousand, while 1% variation growth on top of one-hundred thousand is one thousand. Although both are 1% variation, the 1% under the three million is a much bigger group than the other one. So, even if CO variation growth does not seem that impressive, the number of hirings per year is quite large. CO's lowest variation growth of 0.22% from 2019 to 2020 suggests there were over nine thousand and four hundred employees hired in 2020, whereas MO's lowest non-negative variation growth of 1.11% from 2012 to 2013 suggests there were over one thousand and three hundred hirings for that year.

One possible explanation for MO increase is due to the growing need of data analytics and statistics in industries. The more business recognizes the value of data-driven decisions, the more job positions on MO are created to support the businesses. Leading to a higher need for MO in the market, increasing the hired number in the area.

Section 1.2.1

For this section, the data sets analyzed are from 2012 to 2021. It is an occupation under the "Computer Occupations" field, and it is classified as "Information Security Analyst". Which falls under the "Computer and Mathematical Occupations" domain. For the sake of better reading, "Information Security Analyst" and "Computer and Mathematical Occupations" are going to be abbreviated to "ISA" and "CMO" respectively.

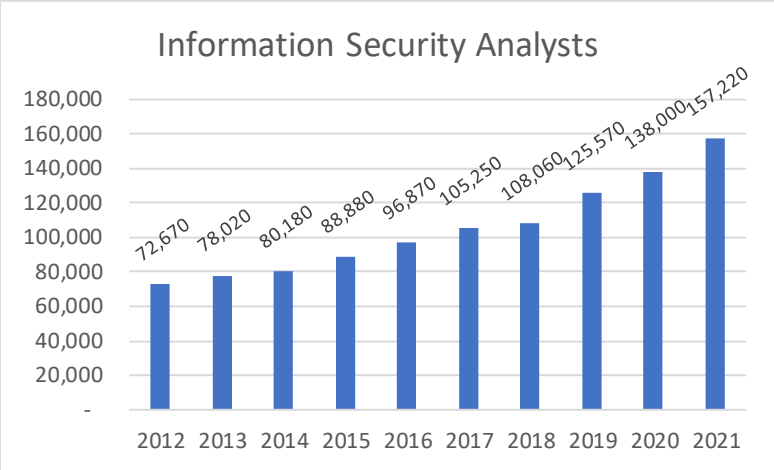

Figure 6: 15-1212-Information Security Analysts.

The graph above represents the total number of employees working under the ISA job description from 2012 to 2021. In 2012, there were approximately seventy-two thousand and five hundred employees working in this occupation. Now, in 2021, there were over one hundred and fifty-seven thousand employees working in the area. It represents an increment of more than 100% from the first year in the area. Which is impressive for a span of 10 years.

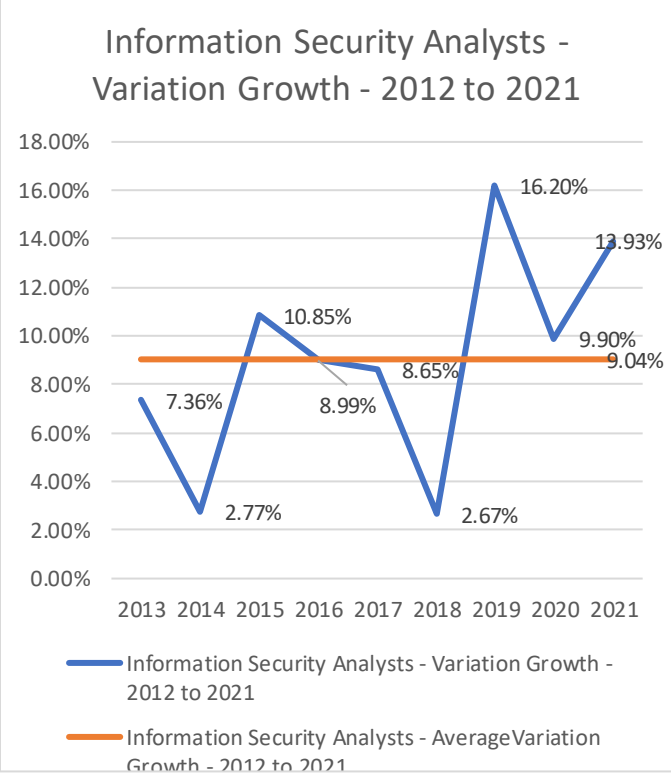

Figure 7: Information Security Analysts – Variation Growth-2012 to 2021.

The average variation growth is 9.04% as shown in the graph above, having the lowest variation growth of 2.67% from 2017 to 2018, and the highest variation growth of 16.2% from 2018 to 2019. Also, it is possible to observe an increase of how much ISA represents in the total variation growth of CMO field. From 2012 to 2013, ISA represented 2.11% of CMO's total variation growth. Now, from 2020 to 2021, ISA represented 3.38% of CMO's total variation growth for the same respective years. It suggests that the demand for ISA is increasing at a faster rate than other occupations within CMO field. Which, potentially, could be due to the growing importance of cybersecurity in business models.

Section 1.2.2

Still under the "Computer Occupations" field, the data sets analyzed in this section are from 2008 to 2021. The occupation is classified under the name "Computer and Information Research Scientist", which also falls under CMO's domain. For the sake of better reading, "Computer and Information Research Scientist" is going to be abbreviated as "CIRS".

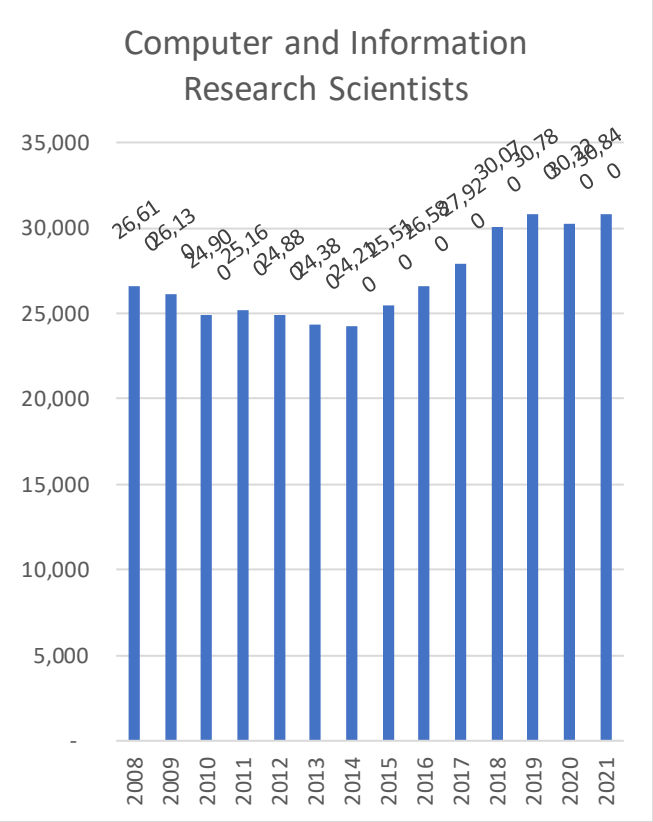

Figure 8: 15-1221-Computer and Information Research Scientists.

The graph shows the total number of employees in CIRS from 2008 to 2021. In 2008, there were roughly twenty-six thousand and six hundred employees working in the area. Now, in 2021, there were approximately thirty thousand and eight hundred employees in the area. Which is a small increase for the span of fourteen years.

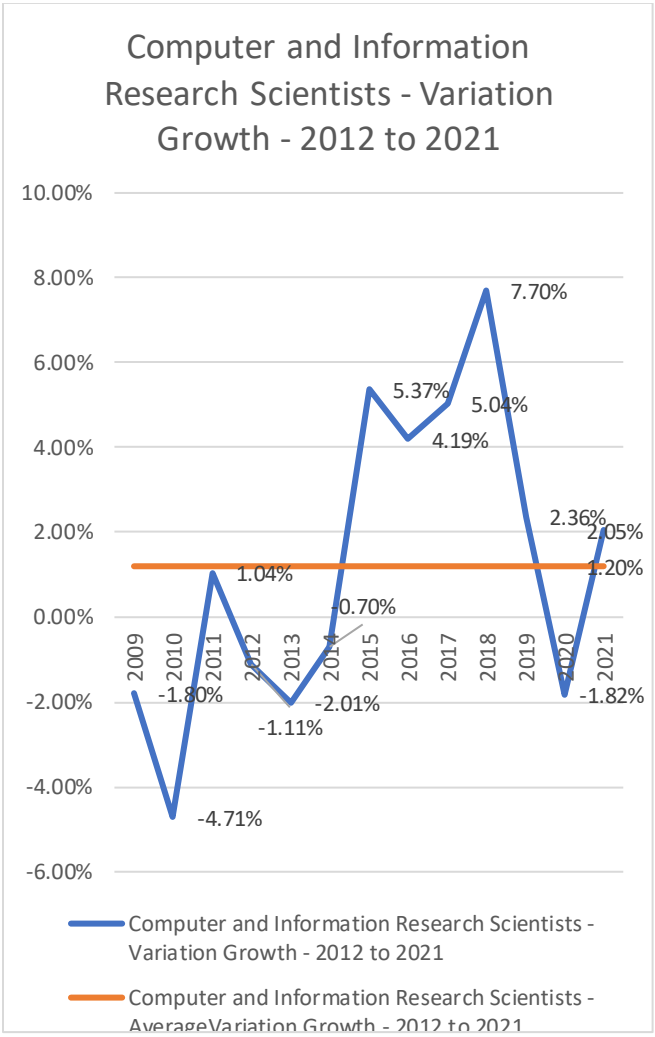

Figure 9: Computer and Information Research Scientists – Variation Growth-2012 to 2021.

The average variation growth is 1.2% as shown in the graph above. The highest variation growth is 7.7%, and the lowest is -4.71%. Comparing CIRS trends with ISA's trends is possible to notice their drastically difference. While ISA has an increase of over 200% on the number of employees from 2012 to 2021, CIRS has an increase of 115.9% from 2008 to 2021.

One possible explanation for such an event is the lack of interest in business to withhold CIRS jobs.

Section 1.2.3

The data sets utilized are from 2008 to 2021. The occupation analyzed is classified under the name "Computer

System Analysts". For the sake of better reading, "Computer System Analysts" is going to be abbreviated as "CSA".

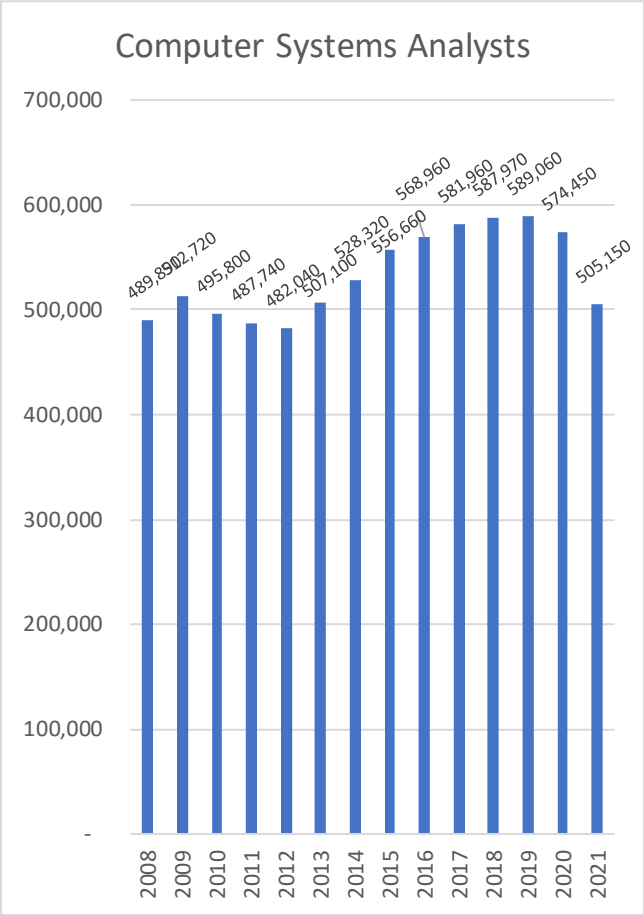

Figure 10: 15-1211-Computer Systems Analysts.

The graph represents the total number of CSA employees from 2008 to 2021. In 2008, there were over four hundred and eight-nine thousand employees. Now, in 2021, there were over five hundred and five thousand and one hundred employees working jobs under the CSA description. It is a slow increase in the area for the span of fourteen years.

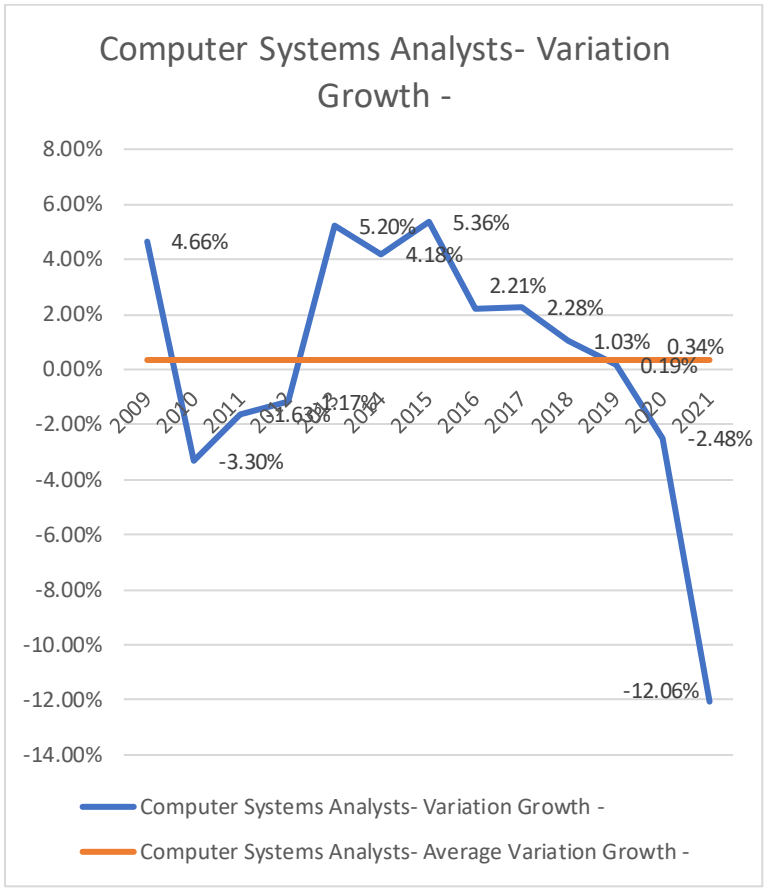

Figure 11: Computer Systems Analysts- Variation Growth.

The average variation growth is 0.34% as shown in the graph above. The highest variation growth is 5.36% from 2014 to 2015, and the lowest variation growth is -12.06% from 2020 to 2021. There is also a decrease from 2009 to 2010, and it is potentially due to the fact that from 2009 to 2010 there was an increase in number of occupations under CMO field, which branched out to other occupations what before was defined as CSA. The same occurs from 2011 to 2012, it is possible to note a decrease of -1.17% in CSA from one year to the other. In 2011, there were sixteen occupations under CMO field, and in 2012 it branched out to nineteen occupations for the field, which could be reason for the decrease in the area.

Section 2

For this section, the data utilized is from Statista [3]. The data set analyzed refers to the internet crimes disclosed to the Internet Crime Complain Center (IC3). It shows the amount of monetary damage from 2001 to 2022, excluding 2010, worldwide.

Amount of monetary damage caused by reported cyber-crime to the IC3 from 2001 to 2022 (in million U.S. dollars)

Year	Milion U.S. dollars	Annual Growth
2001	17,80	0
2002	54,00	203%
2003	125,60	133%
2004	68,10	-46%
2005	183,10	169%
2006	198,40	8%
2007	239,10	21%
2008	264,60	11%
2009	559,70	112%
2011	485,25	-13%
2012	581,44	20%
2013	781,84	34%
2014	800,49	2%
2015	1.070,71	34%
2016	1.450,70	35%
2017	1.418,70	-2%
2018	2.710,00	91%
2019	3.500,00	29%
2020	4.200,00	20%
2021	6.900,00	64%
2022	10.300,00	49%

Figure 12: Amount of monetary damage caused by reported cyber-crime to the IC3 from 2001 to 2022 (in million U.S. dollars).

The table above shows the amount of money lost to cyber-crime from 2001 to 2022 in millions of US dollars. In 2001, the total damage was seventeen million and eight hundred thousand dollars. Now, in 2022, the total damage was ten billion and three hundred thousand dollars. There was an increase of 57,865.16% from 2001 to 2022.

The average variation growth is 48.7%. The lowest variation growth is -46% from 2003 to 2004, and the highest variation growth is 203% from 2001 to 2002. It is important to note the largest difference of loss is from 2021 to 2022, where the difference adds up to three thousand and four hundred million dollars from the first year to the next one. In 2021, the total damage was six thousand and nine hundred million dollars. In the following year, the total damage added up to ten thousand and three hundred million dollars.

The information suggests that there is a dramatic increase in the amount of money lost to cyber-crime. The average variation growth of 48.7% shows a consistent upward trend in losses. Even though there is an increase in the number of employees working in the cybersecurity area, the losses are growing at such a rate that suggests a lack of cybersecurity professionals.

Section 3

For this section, the data utilized is from Statista [4]. It was published by Pew Research Center and conducted by Knowledge Networks. The data set represents the results of a survey from June 17th to June 27th of 2016 that included one thousand and fifty-five respondents. It was realized in United States, and the objective of the survey was to assess American's understanding of a few cybersecurity terms and problems. There were thirteen questions related to cybersecurity and the individuals were asked to answer them. The characteristics of the scope of the survey was the age group eighteen and over, and it was interested in internet users.

Knowledge of various cybersecurity topics among adults in the United States as of June 2016

Questions	Incorrect	Correct	Not sure
Can identify most secure password (from a list of four options)	8%	75%	17%
Public Wi-Fi (even if password protected) is not always safe for sensitive activities	7%	73%	20%
Can identify a "phishing" attack (set of descriptions)	21%	54%	24%
Turning off smartphone GPS function does not prevent all location tracking	22%	52%	26%
Americans can legally obtain one free credit report yearly from each of the three credit bureaus	21%	49%	30%
Ransomware involves criminals encrypting and holding users' data hostage until paid	9%	48%	43%
Email is not encrypted by default	10%	46%	43%
Wi-Fi traffic is not encrypted by default on all wireless routers	11%	45%	44%
Browser programs' "private browsing" mode does not prevent ISPs from monitoring subscribers online activity	12%	39%	49%
https:// in a URL means that information entered into the site is encrypted	12%	33%	54%
A botnet is a networked set of computers used for criminal purposes	10%	16%	73%
A VPN minimizes the risk of using insecure Wi-Fi networks	16%	13%	70%
Can identify only example of multi-factor authentication screen (set of images)	71%	10%	18%

Figure 13: Cybersecurity topic awareness among U.S. adults 2016.

The above table represents the thirteen questions and the percentage of incorrect, correct, and uncertain individuals by column respectively. It is possible to notice that for more common subjects, as picking the strongest password out of a list, the greatest majority understand how to make a password secure, but as the questions get more difficult, it is possible to see a higher quantity of people being unsure, as well as less corrected people.

For questions related to almost all employees in the 21st century, as identifying a "phishing" attack, 48% were either uncertain or wrong. Which is a concerning result from the survey. Phishing attacks can lead to serious consequences such as data breaches and financial losses. Even though the experiment was done in a small percentage of the US total population, this result highlights the necessity of increasing awareness and education on cybersecurity.

Related Work

The article "Priority #4: Cybersecurity Workforce Challenges" by Tim Maurer and Arthur Nelson discusses the challenges that contribute to the gap between the demand for cybersecurity professionals and the supply [5]. One of the challenges identified in the article is the difficulty in retrieving and retaining qualified candidates. This is related to the point that there is a need for cybersecurity education and awareness, as there are not enough qualified professionals to meet the growing demand for cybersecurity roles.

Another relevant article is "The Cyber Workforce Retention" by Willian E. Parker. He says, "Cybercrime is now estimated to suck at least $400 billion from the global economy. This staggering figure is more than the gross domestic product (GDP) of many nations' economies, and it is estimated that these losses will only increase in future years" [6]. He talks about an increase in the cybersecurity area due to the increasing monetary loss to cyber-crimes. Which relates to the findings, because it is possible to note from the analysis of the data the increase in the cybersecurity area while there is a larger increase in the amount of money lost to cyber-crimes.

Also, in the article "Cybersecurity: Current Deficiency" by Franklin D. Kramer and Robert J. Butler, they suggest that "The need for significant change is especially demonstrated by the regularity of successful cyberattacks, as well as the persistence of well-known vulnerabilities and related deficiencies" [7]. The "regularity of successful cyberattacks" can also be noted by the increase in the monetary loss to cyber-crime, as suggested in the data published by IC3 mentioned in this research.

Further, on, as Rahman says in the article "The importance of cybersecurity education in school", "the growing world of cyberspace may also have negative effects on internet users, such as through cybercrime. Such issues should therefore be contained early so they do not have a major impact. In this context, cybersecurity implementation among internet users is very important. Cybersecurity education is necessary because cybercrime cases can occur anywhere regardless of individuals, organizations, and places" [8]. He notes the crucial need for cybersecurity awareness and education among the general public. As the world turns digital, it is essential that people understand the threats involved and how to safely use the technology available.

Borka J. and Andrej J. talk about the importance of cybersecurity education in the article "Cybersecurity Skills among European High-School Students: A new Approach in Design of Sustainable Education Development in Cybersecurity". They say, "the education of cybersecurity within high schools was not addressed at all. More studies in this area were carried out by US researchers that found that one of the main bottlenecks in building awareness about cybersecurity and adopting relevant knowledge later within the undergraduate programs is in the inequities of the computer science education for K-12 students" [9]. They see the lack of cybersecurity education among the students. Their idea is

that cybersecurity education should be taught in high schools as well. They argue that there is specific knowledge that is essential to be taught, but so far education programs have failed to do so.

Finally, in the article "The Economics of the Cybersecurity Labor Market" by Martin C. Libicki, he argues that "it takes time to develop more cybersecurity professionals in response to the heightened demand. Training and education can take years; even if individual workers in other occupations have the right set of skills to become cybersecurity professionals, they may not immediately switch occupations" [10]. In other words, the rate of the demand for cybersecurity professionals is exceeding the rate at which people are educated and trained to fulfill the jobs in the area. Which also suggests that technology is evolving at a higher rate than the one where people are being prepared to handle technology.

Conclusion

As the findings suggest, the rise in computer and mathematical occupations, as well as the increase in demand for cybersecurity professionals, can be seen as a result of the evolution of technology. Not only in the analysis of the field as whole, but in the analysis of individual occupations as information security analysts as well. In addition, the need for secure networks and protection of sensitive information is clear to the light of the large increase in monetary loss throughout the years. With that in mind, it is important for business to start taking measures to prevent such happenings. Cybersecurity professionals are responsible for protecting networks, systems, and data from unauthorized users. The area plays a crucial role in the economy as the world increasingly migrates to digital. It is essential now for businesses and organizations to prioritize cybersecurity and invest in the necessary resources to prevent cyber-attacks. It includes hiring qualified professionals, implementing effective security measures, and providing training and education to employees. By doing so, businesses can help protect their reputation, financial stability, and the privacy of their customers.

Also, there is a need for better cybersecurity awareness and education. The fact that almost half of the participants in the survey published by Pew Research Center were either wrong or unsure on identifying phishing attacks sheds light on a significant gap on the knowledge in cybersecurity. Such lack of awareness can leave individuals and organizations vulnerable to cyber threats. In addition, cybersecurity education should not only be limited to individuals working in the technology industry. With the increasing digitalization of the world, all people should have a basic understanding of cybersecurity and the risks involved with the use of technology.

REFERENCES

[1] LIBICKI, MARTIN C., et al. "Why Has Demand Risen Sharply?" *Hackers Wanted: An Examination of the Cybersecurity Labor Market*, RAND Corporation, 2014, pp. 5–12. *JSTOR*, http://www.jstor.org/stable/10.7249/j.ctt7zvzmj.9. Accessed 23 Mar. 2023.

[2] BLS. "Occupational Employment and Wage Statistics." *U.S. Bureau of Labor Statistics*, U.S. Bureau of Labor Statistics, 19 July 2022, https://www.bls.gov/oes/tables.htm. Accessed 23 Mar. 2023.

[3] "Amount of Monetary Damage Caused by Reported Cyber Crime to the IC3 from 2001 to 2022." *Statista*, IC3; FBI, https://www.statista.com/statistics/267132/total-damage-caused -by-by-cyber-crime-in-the-us/. Accessed 23 Mar. 2023

[4] "Cybersecurity Topic Awareness among U.S. Adults 2016." *Statista*, Pew Research Center, 7 July 2022, https://www.statista.com/statistics/807380/united-states-cybersecurity-topics- awareness/. Accessed 26 Mar. 2023.

[5] MAURER, TIM, and ARTHUR NELSON. "PRIORITY #4: CYBERSECURITY WORKFORCE CHALLENGES." *International Strategy to Better Protect the Financial System Against Cyber Threats*, Carnegie Endowment for International Peace, 2020, pp. 111–26. *JSTOR*, http://www.jstor.org/stable/resrep26915.10. Accessed 20 Mar. 2023.

[6] Parker, William E. "Rising Demand for Private-Sector Cyber Skills." *Cyber Workforce Retention*, Air University Press, 2016, pp. 1–8. *JSTOR*, http://www.jstor.org/stable/resrep13818.8. Accessed 27 Mar. 2023.

[7] Kramer, Franklin D., and Robert J. Butler. "CYBERSECURITY: CURRENT DEFICIENCIES." *CYBERSECURITY: CHANGING THE MODEL*, Atlantic Council, 2019, pp. 2–4. *JSTOR*, http://www.jstor.org/stable/resrep20932.4. Accessed 22 Mar. 2023.

[8] Rahman, Nurul Amirah Abdul, et al. "The importance of cybersecurity education in school." *International Journal of Information and Education Technology* 10.5 (2020): 378-382.

[9] Jerman, Borka, and Andrej Jerman. *Cybersecurity Skills among European High-School Students: A New Approach in the Design of Sustainable Educational Development in Cybersecurity.* Sustainability, 2022,pp. 3.

[10] LIBICKI, MARTIN C., et al. "The Economics of the Cybersecurity Labor Market." *Hackers Wanted: An Examination of the Cybersecurity Labor Market*, RAND Corporation, 2014, pp. 41–54. *JSTOR*, http://www.jstor.org/stable/10.7249/j.ctt7zvzmj.12. Accessed 23 Mar. 2023.