Investing the Impact of Microchip Shortage on the Supply Chain of the Egyptian Automotive Industry

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Abstract

The worldwide shortage of microchips is one of the concerns related to raw materials that impact the inbound supply chain (SC). Undoubtedly, the semiconductor scarcity has influenced a multitude of businesses; nonetheless, the automotive industry has borne the impact of this crisis to the greatest extent. The worldwide microprocessor crisis can be attributed to a confluence of many factors. The snowball effect of COVID-19 and the Russian-Ukrainian war caused several chip facilities to temporarily close or run at lower levels, causing a microchip manufacturing shortage that affected the entire semiconductor sector. The aim of this study is to investigate the causes and consequences of microchip shortage within the automobile sector with insight into Egypt. To provide potential solutions for mitigating the adverse impact of the microchip shortage, a series of semi-structured interviews were conducted with seven companies operating in the automotive sector and chip manufacturing industry in Egypt. The purpose were these interviews was to investigate the phenomenon and gain a

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deeper understanding of the crisis and its consequences. Thematic analysis was employed to evaluate the data obtained from the interviews followed by adopting the Analytic Hierarchy Process (AHP) to prioritize the factors that had a role in and led to the microchip shortage. Based on the findings of this research, the most significant determinant affecting the microchip shortage is the demand fluctuations as one of the fundamental reasons behind this was the rising demand for electronics and portables since COVID-19.

Keywords: Supply Chain, Egypt, COVID-19, Microchip Shortage, Automotive Industry.

دراسة تأثير نقص الرقائق الدقيقة على سلسلة التوريد لصناعة السيارات في مصر

الملخص

يعد النقص العالمي في الرقائق الدقيقة أحد المخاوف المتعلقة بالمواد الخام التي تؤثر على سلسلة التوريد الداخلية (SC). مما لا شك فيه أن ندرة أشباه الموصلات أثرت على العديد من الشركات؛ ومع ذلك، تحملت صناعة السيارات تأثير هذه الأزمة إلى أقصى حد. يمكن أن تعزى أزمة المعالجات الدقيقة في جميع أنحاء العالم إلى التقاء العديد من العوامل. تسبب تأثير كرة الثلج لـCOVID-19 والحرب الروسية الأوكرانية في إغلاق العديد من منشآت الرقائق مؤقتًا أو تشغيلها عند مستويات أقل، مما تسبب في نقص في تصنيع الرقائق الدقيقة مما أثر على قطاع أشباه الموصلات بأكمله. الهدف من هذه الدراسة هو دراسة أسباب وعواقب نقص الرقائق الدقيقة في قطاع السيارات مع إلقاء نظرة ثاقبة على مصر. ولتوفير حلول محتملة للتخفيف من الأثر السلبي لنقص الرقائق الدقيقة، تم إجراء سلسلة من المقابلات شبه المنظمة مع سبع شركات تعمل في قطاع السيارات وصناعة الرقائق في مصر. وكان الغرض من هذه المقابلات هو التحقيق في الظاهرة والحصول على فهم أعمق للأزمة وعواقبها. تم استخدام التحليل الموضوعي لتقييم البيانات التي تم الحصول عليها من المقابلات تليها اعتماد عملية التسلسل الهرمي التحليلي (AHP) لتحديد أولويات العوامل التي كان لها دور وأدت إلى نقص الرقائق الدقيقة. بناءً على نتائج هذا البحث، فإن العامل الأكثر أهمية الذي يؤثر على نقص الرقائق الدقيقة هو تقلبات الطلب، حيث كان أحد الأسباب الأساسية وراء ذلك هو الطلب المتزايد على الإلكترونيات والأجهزة المحمولة منذ فيروس كورونا.

الكلمات المفتاحية: سلسلة التوريد، مصر، كوفيد-19، نقص الرقائق الدقيقة، صناعة السيارات.

1. Introduction:

The global shortage of microchips inbound supply has resulted in increased prices for a variety of goods and led to a reduction in manufacturing across a variety of industries, including the automotive sector (Casper et. al, 2021). Inbound supply chain management (SCM) refers to the systematic approach employed by organizations to acquire raw materials, parts, components, and other goods and services from a broad spectrum of suppliers, to facilitate their operational activities (Prajogo et al., 2016; Muñoz-Villamizar et al., 2021). This part of the supply chain (SC) encompasses several potential hazards often known as the probable possibility of an incident related to the failure of individual suppliers or the supply marketplace, resulting in the purchasing firm's inability to meet consumer demand (Lochan et al., 2021). Moreover, the occurrence of SC failures carries substantial financial implications and has the potential to cause substantial delays in customer deliveries (Wu et al., 2006; Wicaksana et al., 2022). Likewise, the effective management of supply-related risks is a crucial component in the overall management of the SC. Nevertheless, a wide range of factors, including low supplier reliability, inefficient inbound transportation, and shortages of materials, can cause disruptions, making today's inbound SC risks more varied than ever (da Costa, 2021; Ganguly & Kumar, 2019).

The automotive industry in Egypt had a fall of 25-30% due to the global scarcity of microchips which then triggered a series of repercussions, leading to a more than 30% increase in automobile expenses (El-Ghamry, 2021). it can be observed that chips, also known as semiconductors or microchips, are the brains behind an ever-increasing range of products, from smartphones to computers, even vacuum cleaners, refrigerators, and space shuttles (Capri, 2020). Compared to other industries, such as computer manufacturing, automobile manufacturers have minimal leverage to obtain chip supplies due to their 10% share of the total semiconductor volume (Casper et al., 2021). As a result, throughout the COVID-19 pandemic, automotive manufacturers struggled to get chips, causing delays in manufacturing and several facility shutdowns across the globe (Pennisi, 2022). Furthermore, Russia and Ukraine export essential components for microchip manufacturing, such as neon, palladium, and platinum, but the extended supply disruptions caused by the war cause negatively impact microchip output (Ngoc et al., 2022).

The importance of these microchips to manufacturers and their usage in plenty of products is obvious, however, based on the literature reviewed, some gaps have not been discussed yet, as there has been no research conducted that specifically highlights the reasons for microchip shortages in the automotive industry, especially in developing countries such as Egypt. Thus, this research aims to investigate and prioritize the causes of the microchip shortage and identify how these shortages impacted the automobile industry in Egypt. Likewise, this research attempts to contribute to several managerial implications to help solve the microchip shortage and reduce the negative effect of the microchip shortage on the Egyptian automotive industry in Egypt.

2. The Challenging SC of the Automotive Industry

SCs have been significantly elevated in response to the challenging and dynamic environment of the automotive industry (Zhu, 2018). Besides, the automobile industry has had a significant impact on the global economy. Based on a study published by the International Labor Organization (2020), more than 95 million automobiles and trucks are manufactured annually. Furthermore, Europe produces about 20 million cars each year, and the automotive industry supports 14.6 million jobs (ACEA, 2020).

The automobile industry's aggressive competition has provoked companies to streamline their SC operations and implement lean thinking, as an example, to reduce inventory costs, Toyota invented lean thinking, which has been widely applied in the sector since the 1990s by reducing waste and any redundant, non-value-adding processes (Ciano et al., 2020). Additional strategies to simplify SCs include just-in-time (JIT) distribution and moving the manufacturing process to developing countries, which in turn expose the SCs to further dangers and weaknesses across the complex network of different tiers of original equipment manufacturers (OEM) and suppliers (Zhu, 2018). One approach adopted by the industry to mitigate these risks is a change in emphasis from cost reduction to enhancing SC robustness and agility. This is achieved by the utilization of varied sources and the maintenance of a certain level of safety stock (Thun & Hoenig, 2011; Zhu, 2018). To effectively respond to and mitigate the effects of adverse occurrences, SCs must possess a robust nature that enables them to be proactive and resistant (Dwaikat et al., 2022). Furthermore, the SC must possess sufficient adaptability to effectively manage unforeseen circumstances that may potentially hinder its ability to perform (Wieland and Wallenburg, 2012).

Throughout the years, the automotive industry has seen substantial changes which have had a notable adverse impact on the functioning of businesses. Under some conditions, the industry has experienced challenges (Ivanov, 2020). The occurrence of the 2011 Tsunami in Japan, which resulted in significant damage to SCs globally and incurred a daily loss of

$72 million for Toyota, serves as one instance of substantial disruptions that have had a profound influence on the automotive industry (Ho et al., 2015). One such event is the terrorist assault that occurred in New York in 2001. This incident led to significant disruptions at Ford and Toyota factories in the United States, since the timely delivery of supplies from external sources was impeded (Thun and Hoening, 2011).

3. Semiconductor Manufacturing and SC

Semiconductors hold a crucial position in contemporary technology, facilitating the advancement of technologies that have revolutionized our society in terms of their potential, efficiency, and safeguarding capabilities (García de Arquer, 2021). These components are widely recognized as essential elements in a diverse range of devices, spanning from smartphones and laptops to automobiles and advanced military systems, which have significantly influenced several aspects of our everyday existence (Casper, 2021). Furthermore, the emergence of a sophisticated and interconnected high-technology microchip industry has been driven by the growing need for technical advancements and the guarantee of semiconductor supply for various public and commercial organizations (enabling progress in several fields May & Abdullah, 2020; Gao et al., 2023).

Semiconductors are frequently produced using several manufacturing methods. Khan et al. (2021) described the process of semiconductor manufacturing to be under three major steps: design, fabrication, and assembly; testing; and packaging (ATP) (Khan et al., 2021). Ruberti (2023) added that manufacturing semiconductors requires a wide variety of specialized machines, such as those used for deposition, laser engraving, and photolithography. A further element in

semiconductor manufacturing is fundamental intellectual property (IP), and computer software to be used in the chip design process, known as electronic design automation (EDA) (Khan et al., 2021; Huang et al., 2021).
Electronics manufacturing plants are prevalent, and they design and market semiconductor chips while outsourcing the manufacturing process to independent outsourced semiconductor assembly and testing (OSAT) businesses for undergoing assembly, testing, and packaging (Khan et al., 2021). The development of specialized production plants was motivated by substantial obstacles to entry and discontentment with outsourcing to integrated device manufacturers (IDMs). According to Wang & Lin (2021), the adoption of the fabless-foundry model has resulted in a notable reduction in the barriers to entry, hence facilitating the rapid expansion of fabless enterprises.

On the other hand, globalization has sped up the growth of microchip companies. This is because companies can take advantage of the low costs of making things in Asia and then bring the finished products back to the US (Dachs et al., 2023). However, IDMs' use of a vertically integrated model limits their ability to manufacture cutting-edge technology, as keeping up with the latest technology requires big capital investments, which are hard to find in a company that designs and makes things (Ganichev & Koshovets, 2021).

The complex and interconnected nature of this SC renders it vulnerable to a range of hazards, such as geopolitical conflicts, natural calamities, and disruptions in the SC. This emphasizes the importance of implementing effective robust strategies and contingency plans (Chu et al., 2020). Moreover, the need for electronics has grown as safety, self-driving cars, and networking have improved. Thus, to accommodate forthcoming advancements, an average of 3,500 semiconductors are included in each new automobile. According to analysts' projections, the advent of completely autonomous driving is anticipated to result in a yearly sales rise of automotive semiconductors by 6%, which represents a 4% augmentation compared to the average growth rate seen between 1995 and 2015. Nonetheless, the implementation of pandemic-related shutdown measures has resulted in a significant reduction in output, rendering it unable to meet the prevailing demand (Mohamed et al., 2022).

4. COVID-19 and Automotive SC Performance

There have been numerous previous instances of pandemic outbreaks in various regions affecting SCs. Notable examples include the Severe Acute Respiratory Syndrome (SARS) outbreak that occurred from 2002 to 2003 (Tan & Enderwick, 2006), as well as the Hemagglutinin Type 1 and Neuraminidase Type 1 (H1N1) outbreak, commonly referred to as the Avian Flu, in 2009 (Paul & Chowdhury, 2020). These outbreaks had a detrimental impact on the performance of the SC. However, the COVID-19 pandemic has had unparalleled ramifications in the present day, leading to significant concerns over the impact on trade and the economy (Chowdhury et al., 2021; Shardeo et al., 2022; Münch & Hartmann, 2023).

Moreover, the COVID-19 pandemic has given rise to a multitude of challenges that are concurrently impacting all members of the SC and various regions (Chowdhury et al., 2021; Fonseca and Azevedo, 2020).

Chowdhury et al. (2021) conducted a literature assessment of SC studies about the COVID-19 pandemic and acknowledged that the pandemic has influenced eight sectors within the SCM, namely; demand management, supply chain-wide impacts management, transportation and logistics management, relationship management, financial sustainability management, and supply chain-wide impacts management. All of these affected sectors caused alterations in demand, scarcities of materials, interruptions in manufacturing, delays in transportation, and extended lead times (Münch & Hartmann, 2023; Raj et al, 2022).

The global automotive industry has experienced a decline in demand for new automobiles as a result of the COVID-19 pandemic, mostly owing to the increased viability of vehicle sharing as an option among the younger demographic (Belhadi et al., 2021). The profitability and cash flow of automakers faced a significant decline in light of the widespread impact of the pandemic (Chowdhury et al., 2021). During the period spanning from April 1st to June 30th, 2020, Toyota faced a significant reduction in manufacturing levels, resulting in a 53 percent fall. Toyota had a decline in revenues of 43% over the corresponding time frame. Similar outcomes have been observed among other multinational automobile manufacturers (Ishikawa, 2023). For instance, Volkswagen saw a significant decline in car production, sales, and income, with reductions of 32.5%, 30%, and 23% respectively, during the initial six months of 2020 (Bai, 2021).

Likewise, the automotive industry saw significant adverse effects as the COVID-19 epidemic led to a substantial decrease in transportation capacity, thereby causing substantial increases in air, train, and marine transportation fares (Shardeo et al., 2022). The shortage of materials and components among manufacturers was a consequence of the current situation,

wherein prices experienced a significant increase, reaching many orders of magnitude (Pato and Herczeg, 2020).
Hence, the technology industry has started to take significant action to reduce the shortages by investing in new and existing chip production facilities. To do so, many firms have embraced offshoring manufacturing to lower their manufacturing costs and curtail supply lead times (Ishak, 2023).

In conclusion, the automotive industry has encountered significant interruptions and difficulties as a result of the consequences brought forth by the COVID-19 pandemic. In light of the lack of pre-existing predictions and preparedness strategies due to the pre-discussed challenges facing SCs, microchip output shortages are anticipated to persist. Therefore, the identified research gap pertains to the absence of comprehensive answers and alternative approaches in addressing the problem, along with its significant ramifications on the automobile industry in developing countries, specifically in Egypt .

The remainder of this research attempts to investigate the factors that contribute to the shortage of microchips and their implications on the automobile industry in Egypt. In addition, the research will investigate the significance of these factors to bring up possible recommendations that could help assist decision-makers in overcoming such shortages.

5. Research Methodology

This research utilizes a combination of inductive and deductive methodologies to investigate the causes and consequences of the microchip shortage on the automotive sector in Egypt. The study used an inductive approach to investigate the causes and effects of this scarcity. Following this, a deductive methodology is utilized to further refine and prioritize each of the factors which lead to the shortage .

The research methodology consists of two phases, the conceptual phase and the empirical phase. The conceptual stage of the research is to gain an extensive understanding of the contextual background of the problem. Thus, a systematic review of the existing literature was conducted. Consequently, the second stage of the research involves the empirical part, which seeks to collect data from a diverse group of participants, including automotive manufacturers and dealers.

Likewise, the empirical stage comprises two phases. Semi-structured interviews were conducted during the initial phase while using the thematic analysis to analyze the collected data. The thematic analysis involved the identification, description, and linkage of relevant data concerning the causes and consequences of microchip shortages in the Egyptian automotive industry. Consequently, AHP was adopted in phase two to assess and establish a hierarchy of the aforementioned factors, taking into account their respective levels of significance.

During the initial phase of the empirical stage, the data was collected using face-to-face, semi-structured interviews. The research employed non-probability sampling techniques, namely purposive and snowball sampling, to ascertain both the amount and quality of interviews conducted. The individuals chosen were prominent figures in the automobile industry, holding significant market share in the Egyptian market. Additionally, they have a minimum of five years of professional experience. The research methodology evolved to incorporate chain referral sampling, commonly referred to as the "snowball" sample approach, since it effectively serves the objectives of this study. The sample comprises individuals from several stakeholders throughout the microchip's supply chain, including those involved in manufacturing and buyers. These individuals possess a high level of awareness of the sourcing process of the microchip and the reasons for such shortage.

Finally, the AHP was adopted to define the comparative significance of these factors. This can be achieved by the establishment of objectives or the assessment of options according to predetermined criteria to achieve a certain objective (Ishizaka, 2019). Gaudenzi & Borghesiet al. (2006) argued that including data obtained from interviewers who were questioned at phase one can enhance the evaluation of criterion significance and aid in the identification and evaluation of the criteria relevance by allocating of relative scores using a scale of nine-point, as introduced by Saaty (1990; 2012).

6. Empirical analysis findings

Stage one: Findings of the semi-structured interviews

A total of 15 semi-structured interviews were conducted with 15 distinct companies to facilitate a comprehensive examination of the data. A set of questions was formulated and the discourse was facilitated by directing it based. The interviews that were recorded were transcribed word for word and subjected to thematic analysis, a method employed to identify and build a set of themes. The process of identifying and selecting related exact quotations was initiated during the thematic analysis. The sub-themes of the problem addressed were identified by assigning an appropriate code that aligns with the primary meaning of the quote. The codes that were classified under the same category were systematically organized, and afterward assigned a suitable nomenclature (Nowell et al., 2017). Thus, thematic analysis was used to gain insight into why microchips are in short supply and how that affects automotive production in Egypt by coding and checking existing themes in the transcripts. Finally, the results of this stage were summarized, labeled, and linked to the previously discussed literature, as shown in Table 1, including 5 main themes, namely COVID-19, demand fluctuations, supplier priority, lack of know-how, and pricing strategy.

Table 1: Findings of stage (1)

Covid-19	Demand Fluctuation	Supplier Priority	Lack of know-how	Pricing Strategy
Closures	New technology trends	Economic war	High-cost technology	Compensate down payments
Demand shift	Environmental initiatives	Rising demand fulfillment	Obsolete infrastructure	Inactive market
Logistics delays	Governmental directives	Payment terms	Limited workforce	Resourcing
Health restrictions	Product Life Cycle	High consumption	Political considerations	Inflation
	Over price	Strategic importance	Enormous investments	Supply / Demand equation

Source: Authors' Own

On a global scale, COVID-19 had an impact on all aspects of sustainability, including social, environmental, and economic problems. Several studies acknowledged that the COVID-19 pandemic had a substantial impact on the worldwide automotive industry. Chowdhury et al. (2021) confirmed that the progression of the pandemic will lead to a precipitous drop in the profit margins and cash flow of automobile manufacturers. Moreover, the desire for electronic gadgets grew more than that for automotive as a result of the complete lockdown and homeschooling. Likewise, all automobile industry stakeholders developed crisis management teams (CMTs) on all scales to handle the supply shortfall of microchips. Yet, the automobile industry was impacted by the lockdown's poor productivity and the decrease in imports, with several brands facing comparable sales declines. Moreover, there were also problems with the workforce in the industry because of COVID-19 health restrictions, which made it more difficult to address the crisis.

On the other hand, as a consequence of current improvements in automotive safety, autonomous driving, and electronic vehicles, the need for semiconductors has expanded to accommodate new autonomous driving technologies. The high demand affected both sides, which are the microchip manufacturers and the automobile manufacturers. Additionally, according to the interviewees, the automotive market's high demand and low supply have forced dealerships to raise prices in an effort to reduce demand, which is the main cause of the overprice phenomenon today. According to Enterprise interviewees, prices in the second-hand market have experienced an increase ranging from +30 to +200 thousand Egyptian pounds and are expected to rise more. This encouraged dealers to procure vehicles from local suppliers and subsequently sell them at a higher price, capitalizing on the significant demand for automobiles. Furthermore, the new car replacement initiative in Egypt encouraged local production and reduced the demand for imported vehicles.

There is a list of priorities with varying requirements for each supplier, as the size and volume of customers have a significant impact, as larger clients tend to receive preferential treatment owing to their higher order amounts. Nevertheless, based on the interviewees' feedback, the priority was producing chipsets for electronics rather than cars because suppliers prefer customers who offer high quantities with a high frequency of orders, such as electronics, as they consume more microchips than the automotive industry.

The know-how in the microchip industry is significant, as it is a very high-tech industry that requires many factors for the production process, such as a complex manufacturing environment. The interviewees declared that the current supply problem has resulted in production disruptions across microchip manufacturing and is confronted with the possible challenge of becoming unable to meet rising demands owing to a deficiency in expertise. Furthermore, they declared that Egypt, as a developing country, does not have the know-how, which requires huge investments. Also, one of the reasons was political; as acknowledged by the interviewees, Egypt cannot build a microchip foundry for political reasons and the lack of high technology. On the other hand, the used car market in Egypt is inactive because people do not prefer to sell their cars if they are not able to upgrade them due to the increase in prices and long waiting times. Additionally, resourcing affected prices significantly, as many companies shifted their source of supply to overcome shortages from their suppliers.

Stage two: Ranking factors and causes of microchip shortage using AHP.

The AHP, developed by Saaty (1990; 2012), is widely used by decision-makers and researchers. The definition of criteria and the calculation of their weight are central to this method of assessing the alternatives. The AHP was adopted to rank the factors causing the microchip shortage and their consequences. These factors were based on the main themes from the earlier thematic analysis. An average of all the survey responses was taken to conduct the AHP. The wide applicability of AHP analysis is due to its simplicity, ease of use, and great flexibility. It can be integrated with other techniques, such as software that helps analyze both qualitative and quantitative factors and real-world resource limitations (Ho, 2008). Moreover, the AHP consists of three main operations: hierarchy construction, priority analysis, and consistency verification. To perform these three operations, nine steps need to be addressed.

Step 1: Develop the hierarchy

The AHP A hierarchical problem-solving model is being developed to facilitate decision-making. As seen in Figure 1, the aim is situated at the top of the hierarchical structure. The criterion and sub-criteria are positioned at lower hierarchical levels, with the sub-criteria being at the lowest tier of the model. The AHP framework is constructed hierarchically to prioritize the causes of microchip shortages. The main criteria, as concluded from the previous phase, are COVID-19, demand fluctuation, supplier priority, lack of know-how, and pricing strategy. For each main criterion, there are several sub-criteria that was generated, based on the data analyzed in the previous stage, as shown in **Figure** 1. All these elements affect the automotive industry, leading to a global shortage of semiconductors microchips.

Criteria	COVID-19	Demand Falctuation	Supplier Priority	Lack of Know-How	Pricing Strategy
sub-criteria	Closures	New Technology Trends	Economic War	high-cost Technology	Compansate Down Dayments
	Demand Shift	Environmental Initiatives	Rising Demand Fullfillment	Obsolete Infrastructure	Inactive Market
	Logistics Delays	Governmental Directions	Payment Terms	Limited workforce	Resourcing
	Health Restrictions	Product Life Cycle	High Consumption	Political Considerations	Inflation
		Over Price	Strateic Importance	Enormous investments	Supply / Demand Equation

Figure 1: AHP Hierarchy
Source: Author's won

Step 2: Conduct pairwise comparisons with a numerical scale of 1 to 9.

The fundamental component of the AHP is the process of making pairwise comparisons to establish priorities for a set of five criteria. This entails the interviewee explaining the relative importance of each criterion to the other criteria (Anderson, 2019).

The respondent assigns numerical rankings to the paired criteria, ranging from 1 to 9. A rating of 9 indicates the highest level of importance, signifying the most significant relationship between the two criteria. Conversely, a value of 1 signifies that both criteria are equally essential.

Step 3: Deciding on a level of priority among criteria through pairwise comparison.

Table 2: Pairwise assessment of criterion priority

Main Criteria					
Item Description	**Demand Fluctuation**	**Lack of Know-how**	**Pricing Strategy**	**COVID-19**	**Supplier Priority**
Demand Fluctuation	1	5.00	6.00	7.00	5.00
Lack of Know-how	0.200	1.00	3.00	3.00	4.00
Pricing Strategy	0.167	0.33	1.00	6.00	2.00
COVID-19	0.143	0.33	0.17	1.00	2.00
Supplier Priority	0.200	0.25	0.50	0.50	1.00

Source: Author's own

The equation utilized to determine the maximum number of comparisons in a matrix for the AHP analysis is as follows: n (n-1)/2.

Within every matrix, the variable "n" denotes the quantity of items that are being subjected to comparison. Given that the value of n is equal to 5 in this particular scenario, it can be determined that the maximum number of pairwise comparisons required is 10. The numbers indicated in blue for 10 pairwise comparisons were obtained from the interviews. As an example, when comparing demand fluctuations, it is equally crucial to consider the impact of demand fluctuations. Hence, it can be observed that there are a total of five elements that have been emphasized with the color orange in the matrix depicted above. The remaining 10 values may be obtained by taking the inverse of the corresponding 10 values obtained from the interviews. For example, the correlation between demand fluctuation and demand fluctuation in the first row and first column holds similar significance.

Nevertheless, the significance of COVID-19 to demand fluctuation is observed in row 1, column 4. Consequently, in row 4, column 1, the importance of demand fluctuation is inversely proportional, with a magnitude of 1/7, to that of COVID-19. The remaining values can be obtained by dividing one by the corresponding scale value.

Step 4: Integration

The fourth step in the process is incorporation. the pairwise comparisons matrix to determine the relative importance of each criterion to the overarching theme including demand volatility, pricing strategy, lack of know-how, COVID-19, and supplier priority.

Table 3: Step 4.1: Compute the totals for each column's values.

Main Criteria					
Item Description	**Demand Fluctuation**	**Lack of Know-how**	**Pricing Strategy**	**COVID-19**	**Supplier Priority**
Demand Fluctuation	1	5.00	6.00	7.00	5.00
Lack of Know-how	0.200	1.00	3.00	3.00	4.00
Pricing Strategy	0.167	0.33	1.00	6.00	2.00
COVID-19	0.143	0.33	0.17	1.00	2.00
Supplier Priority	0.200	0.25	0.50	0.50	1.00
Sum	**1.710**	**6.917**	**10.667**	**17.500**	**14.000**

Source: Author’s own

Table 4: Step 4.2: Generate an adjusted pairwise comparison matrix by dividing each matrix value by the total of the column.

Item Description	Demand Fluctuation	Lack of Know-how	Pricing Strategy	COVID-19	Supplier Priority
Demand Fluctuation	0.585	0.723	0.563	0.400	0.357
Lack of Know-how	0.117	0.145	0.281	0.171	0.286
Pricing Strategy	0.097	0.048	0.094	0.343	0.143
COVID-19	0.084	0.048	0.016	0.057	0.143
Supplier Priority	0.117	0.036	0.047	0.029	0.071

Source: Author's own

Table 5: Step 4.3: Using the average of the data in a row to establish the priority

Item Description	Demand Fluctuation	Lack of Know-how	Pricing Strategy	COVID-19	Supplier Priority
Demand Fluctuation	0.585	0.723	0.563	0.400	0.357
Lack of Know-how	0.117	0.145	0.281	0.171	0.286
Pricing Strategy	0.097	0.048	0.094	0.343	0.143
COVID-19	0.084	0.048	0.016	0.057	0.143
Supplier Priority	0.117	0.036	0.047	0.029	0.071

Source: Author's own

AHP indicates that the most essential feature is the influence of demand fluctuation, which has a priority of 52.55%. The second most significant criterion, with a priority of 20%, is a lack of know-how .

Pricing strategy is ranked third in significance with a priority of 14.5% and COVID-19 is ranked fourth with a priority of 6.95%, while supplier priority is ranked the lowest with a priority of 6%.

Step 5: Calculating Consistency

The importance of maintaining consistency in paired evaluations, whether conducted during interviews or by decision-makers, cannot be neglected. As an example, if the evaluation of criterion A in comparison to B results in a score of 3, and the evaluation of B in comparison to C generates a score of 2, then a fully consistent score for A in comparison to C would be calculated as 3 multiplied by 2, resulting in a score of 6. However, if the assigned rating falls within the range of 4 or 5 for grades A to C, it suggests a degree of discrepancy in the ratings. Attaining absolute uniformity in many pairwise assessments poses a significant challenge, and it is common to see slight disparities in such comparisons.

The AHP provides a means to assess the consistency of pairwise comparisons through the calculation of a consistency ratio (CR) or an inconsistency ratio (IR). When these ratios exceeds 0.10, it indicates a disparity in the pairwise comparison (Saaty & Vargas, 2012).

Table 6: Step 5.1: Calculating consistency

Item Description	Demand Fluctuation	Lack of Know-how	Pricing Strategy	COVID-19	Supplier Priority	SUM
Demand Fluctuation	0.525	0.940	0.844	0.480	0.286	**3.07**
Lack of Know-how	0.094	0.200	0.422	0.206	0.229	**1.15**
Pricing Strategy	0.078	0.063	0.145	0.411	0.114	**0.81**
COVID-19	0.067	0.063	0.023	0.069	0.114	**0.34**
Supplier Priority	0.094	0.047	0.070	0.034	0.060	**0.31**

Source: Author's own

The consistency of the pairwise comparison delivered by the interviewers is a crucial aspect of this procedure. As acknowledged by Jayawickrama (2015), if the level of consistency is deemed unsatisfactory, it is advisable for the interviewers to thoroughly examine and modify the pairwise comparisons before advancing to subsequent stages.

Table 7: Step 5.2: Dividing the elements of the weighted total by the relevant priority for each criterion.

Item Description	SUM/WEIGHT
Demand Fluctuation	5.851
Lack of Know-how	5.749
Pricing Strategy	5.595
COVID-19	4.846
Supplier Priority	5.086

Source: Author's own

After calculating the (sum/weight) by dividing the sum by the weight for each criterion, the total average for all criteria, which is the maximal eigenvalue, will be computed, as shown in **Table 8**.

$\lambda max = (5.851 + 5.749 + 5.595 + 4.846 + 5.086) / 5 = 5.425$

Table 8: Step 5.3: Calculating the maximal eigenvalue, the consistency index (CI), and the inconsistency ratio (IR)

Maximal eigenvalue (average)	5.425
CI	0.106
IR	0.095

Source: Author's own

The AHP employs a consistency ratio (CR) or inconsistency ratio (IR) to quantitatively assess the level of consistency in paired comparisons. This ratio serves as a metric for evaluating the degree of consistency in the decision-making process .

Accordingly, the ratio has been established in a manner that any value beyond 0.10 signifies a lack of consistency in paired assessments (Saaty & Vargas, 2012).

As a result, the AHP approach's ability to improve acquired data resilience is a distinct feature. Due to an incorrect appraisal by a decision-maker, it is relatively uncommon to acquire contradictory judgments during pairwise comparisons. With a numerical range of [0.0 to 0.1], CR acts as a monitor, adjusting any inconsistencies in the data. If the CR is more than 0.1, it is also necessary to ask the decision-maker or respondent to re-rank the pairwise comparison until the CR is less than 0.1.

Calculating the consistency index (CI) is CI = $\lambda max - n / \ n - 1$ $= (5.425–5)$ / (5-1) = 0.106
Finally, computing IR, which is calculated as IR= CI / random index (RI)
The RI is contingent on how many objects are being compared.

Table 9: Average Random CI

n	3	4	5	6	7	8	9	10
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Source: Saaty & Vargas, 2012

Based on the given data, the IR = 0.106 / 1.12 = 0.074

Step 6: *Ranking factors using each criterion.*

In this step, the relative importance of all criteria will be calculated, which are demand fluctuations, pricing strategy, lack of know-how, COVID-19, and supplier priority. To do so, the interviewees were asked to indicate their preferences for the attributes using each criterion concurrently to determine each criterion's priority. In addition, interviewees were required to select the criterion that they believe to be the most important and evaluate the extent to which that criterion influences the other. The following tables (Tables 10, 11, 12, 13, and 14) synthesize the pairwise comparisons for each criterion to rate the five primary themes.

Table 10: Demand Fluctuation Criterion

Demand Fluctuation					
	New Technology Trends	**Over-price**	**Environmental Initiatives**	**Governmental Directions**	**Product Life Cycle**
New Technology Trends	1.00	6.00	3.00	5.00	5.00
Over-price	0.17	1.00	2.00	4.00	3.00
Environmental Initiatives	0.33	0.50	2.00	2.00	2.00
GovernmentalDirections	0.20	0.25	0.50	1.00	4.00
Product Life Cycle	0.20	0.33	0.50	0.25	1.00

Source: Author's own

Table 11: Lack of Know-how Criterion

Lack of Know-how					
	High-cost Technology	**Obsolete Infrastructure**	**Enormous Investments**	**Limited workforce**	**Political Considerations**
High-cost Technology	1	5	8	8	4
Obsolete Infrastructure	0.200	1	6	3	7
Enormous Investments	0.13	0.17	1.00	2.00	4.00
Limited workforce	0.13	0.33	0.50	1.00	2.00
Political Considerations	0.25	0.14	0.25	0.50	1.00

Source: Author's own

Table 12: Pricing Strategy Criterion

Pricing Strategy					
	Compensate Down Payments	**Inactive Market**	**Resourcing**	**Inflation**	**Supply-Demand Equation**
Compensate Down Payments	1.00	3.00	5.00	6	7
Inactive Market	0.33	1.00	4.00	7	5
Resourcing	0.20	0.25	1.00	5	4
Inflation	0.17	0.14	0.20	1	2
Supply-Demand Equation	0.14	0.20	0.25	0.50	1

Source: Author's own

Table 13: Supplier Priority Criterion

Supplier Priority					
	Economic War	**Rising Demand Fulfillment**	**Payment Terms**	**High Consumption**	**Strategic Importance**
Economic War	1	3	2	5	4
Rising Demand Fulfillment	0.333	1	6	4	6
Payment Terms	0.50	0.17	1.00	3.00	4.00
High Consumption	0.20	0.25	0.33	1.00	2.00
Strategic Importance	0.25	0.17	0.25	0.50	1.00

Source: Author's own

Table 14: COVID-19 Criterion

COVID-19				
	Imports Reduction	**Demand Shift**	**Logistics Delays**	**Health Restrictions**
Closures	1	6	7	5
Demand Shift	0.17	1	3	3
Logistics Delays	0.1428571429	0.33	1	2
Health Restrictions	0.2	0.333	0.5	1

Source: Author's own

Step 7: *Develop pairwise comparisons in each decision alternative matrix*

AHP combines each of the five main criteria matrices to establish each criterion's priority to establish the importance for each criterion. The results of 5 comparisons, which yield the five sets of criteria, are shown in the next table. In the table below, the weights of each sub-criterion and the weight of the main criteria were placed at the bottom of the table.

Table 15: Priorities for each factor using each criterion

Sub-Criteria (Main Criteria)	**Sub-Criteria 1 (Demand Fluctuation)**		**Sub-Criteria 2 (Lack of Know-how)**		**Sub-Criteria 3 (Pricing Strategy)**		**Sub-Criteria 4 (Supplier Priority)**		**Sub-Criteria 5 (COVID-19)**	
Demand Fluctuation	47.70 %	New technology trends	52.46 %	High-cost technology	47.01 %	Compensate Down Payments	38.14 %	Economic War	62.71 %	Closures
Lack of Know-how	19.76 %	Over-price	24.90 %	Obsolete infrastructure	28.07 %	Inactive Market	32.79 %	Rising Demand Fulfillment	19.36 %	Demand Shift

Pricing Strategy	15.68 %	Environmental initiatives	10.45 %	Enormous Investments	14.51 %	Resourcing	16.34 %	Payment terms	10.17 %	Logistics delays
COVID-19	10.94 %	Govern-mental directions	6.71%	Limited workforce	5.94%	Inflation	7.37%	High Consumption	7.76%	Health restrictions
Supplier Priority	5.92%	Product life cycle	5.49%	Political Considerations	4.47%	Supply-Demand Equation	5.36%	Strategic importance		
WEIGHT	**52.55%**		**20.00%**		**14.50%**		**6.95%**		**6.00%**	

Source: Author's own

Step 8: *Multiply weights to establish priority ranking*

In the subsequent table (**Table 16**), a multiplication operation was performed wherein each sub-criterion weight was multiplied by the weight located at the bottom of the column, representing the weight of the major criteria. This enabled for computing the total of each main criterion and thereafter rank them, determining the relative importance of each primary theme. For example, the sub-criteria inefficiency has a priority of 47.70%, multiply it by the main criteria weight which is 52.55% (47.70% x 52.55%) = 25.07%.

Table 16: Sum values of each row

Sub-Criteria (Main Criteria)	Sub-Criteria1 (Demand Fluctuation)		Sub-Criteria2 (Lack of Know-how)		Sub-Criteria3 (Pricing Strategy)		Sub-Criteria4 (Supplier Priority)		Sub-Criteria5 (COVID-19)		SUM
Demand Fluctuation	25.07 %	New technology trends	10.49 %	High-cost technology	6.8%	Compensate Down Payments	2.65 %	Economic War	3.76 %	Closures	**48.79%**
Lack of Know-how	10.38 %	Over-price	4.98%	Obsolete infrastructure	4.07 %	Inactive Market	2.28 %	Rising Demand Fulfillment	1.16 %	Demand Shift	**22.87%**
Pricing Strategy	8.24 %	Environmental initiatives	2.09%	Enormous Investments	2.10 %	Resourcing	1.14 %	Complex Production	0.61 %	Logistics delays	**14.18%**
Supplier Priority	5.75 %	Govern-mental directions	1.34%	Limited workforce	0.86 %	Inflation	0.51 %	High Consumption	0.47 %	Health restrictions	**8.93%**
COVID-19	3.11 %	Product life cycle	1.10%	Political Considerations	0.65 %	Supply-Demand Equation	0.37 %	Focused Production	0.00		**5.23%**

Source: Author's own

Step 9: *Develop overall priority ranking*

The results revealed from the AHP, as shown in **Table 17**, showed that demand fluctuation is the most important factor (48.79%), then the second most important factor is lack of know-how (22.87%); following it is the pricing strategy (14.18%), and the fourth most important is Supplier Priority by (8.93%) and finally and the least important was COVID-19 priority with (5.23%).

Table 17: Overall Priority Rankings

Main Criteria	SUM	Rank
Demand Fluctuation	48.79%	1
Lack of Know-how	22.87%	2
Pricing Strategy	14.18%	3
COVID-19	8.93%	4
SupplierPriority	5.23%	5
	100%	

Source: Author's own

The result from the AHP, presented in **Table 17**, prioritizes the significance of the factors that led to the microchip shortages in the automotive industry in Egypt. The Demand Fluctuations were identified as the most significant factor, with 48.79%, meaning that the changes and variability in the demand were accused the most significant factor that led to this shortage.

7. Conclusions and Recommendations

The COVID-19 pandemic has exerted a substantial impact on global SCs, hence disrupting the distribution and transit of products and services across many locations. The emergence of the pandemic in early 2020 resulted in significant disruptions in supply networks, revealing vulnerabilities in the supply systems of many enterprises and underscoring the importance of enhanced flexibility. Similarly, because of the COVID-19 pandemic and an increasing scarcity of semiconductors in the automotive industry, companies have encountered challenges related to the availability of supplies. The semiconductor scarcity has had a discernible influence on several businesses. The primary objective of this study was to ascertain the effects of the microprocessor shortage on the automotive sector and thereafter prioritize these elements based on their significance by employing the AHP. Moreover, this research endeavored to provide a valuable contribution towards addressing the microprocessor scarcity within the automobile industry of Egypt. The study's contributions are derived from the formulation of three research questions designed to address the existing gaps in the literature that were previously highlighted. (1) What were the contributing factors that precipitated the global microchip shortage? (2) What was the impact of the microprocessor shortage on the automotive industry in Egypt? (3) What approaches may be employed to mitigate the adverse impact of the worldwide microchip shortage?

The findings of this research have uncovered several theoretical and managerial consequences, which will be discussed in the subsequent propositions. The research findings revealed the key determinants contributing to the worldwide microchip shortages and assessed their impact on the automotive sector in Egypt. Furthermore, establishing and nurturing a robust connection between the firm and its supplier confers a competitive advantage by positioning the enterprise at the forefront of the supplier's hierarchy of priorities. To achieve this aim, SC managers operating within the Egyptian automotive industry needs to implement a range of strategic measure, First, it is important for the companies to promote the diversification of the supply base by actively working with several chip manufacturers and distributors. This strategic approach aims to mitigate the risks associated with overreliance on a single source. Second, the development of skilled labor who can repair and reuse existing chips, in collaboration with local educational institutions and technical training programs, thereby mitigating the need for new chip production or purchase. Third, developing partnerships with governmental bodies and agencies might enhance the ability to obtain resources during the crisis, as they can have the power to allocate necessary resources, provide financial aid, or grant regulatory flexibility to overcome problems that are specific to a certain industry. Finally, a well-coordinated, flexible, and effectively managed SC is essential for firms to ensure the longevity of their operations, particularly considering prevailing business risks while keeping the industry competitive and resilient. This necessitates comprehensive visibility into SC, collaborative forecasting, and precise lead time management.

In conclusion, it is important to acknowledge that no research study can be considered entirely faultless or comprehensive in its coverage of all potential factors. The empirical study's conclusions are limited in scope to the automobile sector in Egypt, rather than being applicable internationally. Therefore, the research focused on examining the impact of the microchip shortage on the Egyptian automotive market and analyzing the strategies employed by local enterprises to address this global problem. Consequently, its applicability to other industries within the same region or to the automobile industry in a distinct geographical area can be limited. Consequently, doing an inquiry and delving into the determinants that precipitated the scarcity of microchips inside either an alternative or the same sector in a different geographical area. Semi-structured interviews can be used to analyze and contrast the findings with this research using a similar structure. Moreover, the rankings may also be analyzed based on findings obtained through investigating various locations or countries.

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