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Working Capital Management Model for Listed Companies on the Tehran Stock Exchange

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Abstract

This study aims to develop a working capital management model for companies listed on the Tehran Stock Exchange. The proposed model determines the expected level of working capital for a company, enabling it to create the highest possible value. Additionally, this model can be used to assess the efficiency of working capital management. The discrepancy between the

actual level of working capital and the expected level serves as an indicator of inefficiency in working capital management. Initially, based on theoretical foundations and expert opinions, 28 variables affecting working capital were selected. Then, using the operational working capital index, the research models were estimated using multiple regression and genetic algorithm techniques for data from 156 companies over the period from 2011 to 2022. Influential variables were identified and filtered. Finally, suitable working capital management models were identified based on two criteria: (1) the strong correlation between the errors of the fitted models and the working capital efficiency of the company, and (2) the model's accuracy in identifying companies prone to excess or shortage of working capital. In total, after estimating 119 different models using regression and genetic algorithm methods, four suitable working capital management models were determined. The regression method resulted in models with an average accuracy of 77.27% and 79.54% for the dependent variable of working capital and the cash conversion cycle, respectively. The genetic algorithm method resulted in models with an average accuracy of 89.03% and 82.08%. The final model, with the cash conversion cycle as the dependent variable, was identified as the best model. It includes the variables of the previous year's cash conversion cycle, company-specific risk, gross profit margin, trade credit, growth opportunities, operating cycle, economic policy uncertainty, and exchange rate changes.

Keywords: Optimal working capital, Excess working capital, Working capital shortage, Working capital efficiency, Cash conversion cycle

Introduction

The term "working capital" generally refers to short-term balance sheet items, including current assets and short-term liabilities (Brealey et al., 2011; p. 856). Both theoretically and operationally, depending on which short-term item balance is ultimately considered, there are often varying definitions of working capital. Working capital management (WCM) is a crucial aspect in developing corporate strategies and policies, typically focusing on "emphasis on components of current assets and liabilities" and "operational cash flow." According to Caballero et al. (2014), the most important issue in working capital management is the effective use of its components: inventory, cash conversion cycle, accounts receivable, and accounts payable. In this context, Yadav (1986), Arnold (2008), and Beasley and Brigham (2007) state that working capital management is a state where a balance between current assets and current liabilities is maintained. On the other hand, researchers such as Gill et al. (2010), Chiang et al. (2019), Mang and Jang (2015), and Tachapilly

(2019) focus on operational cash flow. Chiang et al. (2019) state that working capital management is considered the level of capital necessary to maintain a company's ability to convert assets into cash, conduct daily operations, cover operating expenses, and quickly access cash. Mang and Jang (2015) assert that efficient working capital management is often defined as the ability to effectively and efficiently control current assets and liabilities in a way that maximizes the return on assets and minimizes debt repayment, with the aim of improving cash flows, profitability, and ultimately increasing the company's value.

The way working capital management is defined typically determines how it is measured and evaluated through related proxies; among the most common metrics are inventory turnover (Arsa et al., 2021; Gill & Biger, 2013; Mahdian & Noravesh, 2017), accounts receivable period and accounts payable period (Arsa et al., 2021; Badavar et al., 2016; Vadie and colleagues, 2016), cash conversion cycle (CCC) (Kiymaz et al., 2024; Hong et al., 2019; Deloof, 2003; Badavar et al., 2016; Vadie and colleagues, 2016), and net trade cycle (NTC) (Hong et al., 2019). From a theoretical perspective, multiple factors can influence decisions regarding the appropriate levels of current assets and current liabilities. According to the pecking order theory by Myers and Majluf (1984), due to the costs of adverse selection, firms prioritize their financing sources. Thus, companies prefer short-term debt over long-term debt and debt over equity financing. This hierarchy results from the informational asymmetry between managers and external investors. On the other hand, in firms with low levels of oversight and few mechanisms for disciplining managerial decisions, the source of agency problems is excess free cash flow, defined by Jensen (1986) as cash flow beyond what is necessary to fund all current positive net present value projects. Jensen asserts that the presence of significant free cash flow leads managers to invest in projects with negative net present value. Consequently, for investment purposes, managers might emphasize operational cash flow through aggressive working capital policies, such as reducing inventory levels and tightening customer credit terms (Palombini & Nakamura, 2021), or they might make investment decisions carelessly by adopting more flexible working capital policies with higher inventory levels or lenient credit policies (Kengatharan et al., 2023). Additionally, the presence of informational asymmetry between the firm and the market, resulting in the market's undervaluation of the firm and increased financing costs, can affect the appropriate levels of working capital (Caballero et al., 2014; Surta, 2019).

Clearly, the goal of working capital management is to optimize the volume and duration of investments. In recent years, the importance of focusing on

working capital management has increased due to rapid changes in the economic environment and the need for companies to respond appropriately. This importance is particularly pronounced due to the consequences of deviating from the appropriate level of working capital, impacting the company's value, profitability, and risk. Although the motivation for companies to maintain excess working capital usually relates to factors such as competitive advantage and achieving differentiation by strengthening long-term customer relationships (Petersen & Rajan, 1997), reducing informational asymmetry between the company and the buyer (Emery, 1984), settling debts by reducing accounts payable levels (Caballero et al., 2014), and preventing production stoppages and lost sales due to stock shortages (Caballero et al., 2014), excess working capital levels can negatively affect potential cash flows, profitability, risk, company value, shareholder profits, and the company's vulnerability. This occurs due to overinvestment in working capital, a shortage of funds for investing in positive NPV projects (Hong et al., 2019), the need for additional financing for high levels of working capital, increased financial costs, and the bearing of higher credit risk (Kieschnick et al., 2013). Additionally, the probability of encountering financial problems and bankruptcy and the costs associated with holding high inventory levels, such as maintenance, insurance, and rent, increase (Caballero et al., 2014). Conversely, a deficiency in working capital indicates that the company is currently using a very aggressive working capital policy, which potentially increases the likelihood of supply chain disruption (Arsa et al., 2021), lesser benefit from trade discounts as a cheaper source of financing (Arsa et al., 2021), and the risk of losing sales mainly due to potential stockouts and aggressive collection of receivables (Aktas et al., 2015). Thus, when companies do not have sufficient working capital, financial aspects (such as the level of operational cash flow), operational aspects (such as accounts receivable, inventory, and accounts payable), or both negatively impact performance (Mun & Jang, 2015). Therefore, determining the appropriate level of working capital that balances the benefits and risks associated with it is essential. Adequate funds enable the company to embark on new paths of sustained growth (Ding et al., 2013). Given the recent global economic developments and companies' efforts to explore various methods of financing their activities and consequently their profitability and risk (Smith, 1980), the importance of effective working capital management, which previously was low on the list of entrepreneurial priorities, is now more evident. The management of a company's operational cash flow is becoming increasingly complex due to digital transformation, changing market conditions, globalization, and geopolitical uncertainty (Kıymaz et al., 2024). Reduced external financing opportunities, high interest rates, and cautious

financial providers all highlight the importance of maintaining cash (Panigrahi, 2024). Therefore, effective management of this cycle is essential for maintaining operational cash flow, supporting daily operations, and ultimately impacting the financial health of the company (Berg et al., 2024). Aside from the reasons and effects of undesirable levels of working capital, several factors influence the efficient levels of working capital. Theoretical and empirical background indicates the influence of factors such as age (Chow et al., 2006; Howorth & Westhead, 2023), size (Howorth & Reber, 2003), the level of operational cash flow (Chow et al., 2006; Hill et al., 2010), ROA (Panigrahi, 2024; Chow et al., 2006), financial leverage (Kıymaz et al., 2024; Niskanen et al., 2006), financial flexibility, gross profit margin (Kıymaz et al., 2024; Teruel & Solano, 2020), company growth (Kıymaz et al., 2024; Adelowo et al., 2018), corporate governance (Wasiuzzaman & Arumugam, 2023), sales level (Khokhar, 2019), informational asymmetry and book-to-market value (Nakamura & Palombini, 2009), fixed asset growth (Wasiuzzaman & Arumugam, 2023), sales volatility (Sharma et al., 2020), GDP, interest rates, and more. However, the results of such empirical studies range from having an effect to having no effect, indicating the need for further research, especially in the domestic capital market.

From an academic perspective, unfortunately, the topic of working capital management has been limitedly examined. Most studies in this area have been conducted in developed countries with different economic conditions from Iran. Naturally, the results of these studies, which have mostly been estimated in recent years using nonlinear regression (second degree), are specific to the sample and period under review. Moreover, the existing research primarily explores the relationship between working capital management and company performance variables. However, the question of what model should determine the appropriate level of working capital for a company to steer it towards success and the goal of maximizing value still needs to be answered. This study addresses this research gap using a systematic methodology that combines appropriate methods (DEA, linear regression, and optimization algorithms such as Genetic Algorithm). Given that the second part of the dissertation (not included in this article) examines how the extracted model functions based on real data from Tehran Stock Exchange companies, this research makes a significant contribution to both theoretical and practical academic foundations.

Moreover, in capital markets, particularly in markets with lower efficiency levels, companies' understanding of the importance of working capital management is often limited to a simple economic equation: current assets minus current liabilities (Khokhar, 2019). Such behavior often entails a

conditional problem-solving approach, where companies delay payments to suppliers or pressure customers for faster payments. Even if these efforts manage to control limited liquidity temporarily, suppliers typically adjust their terms and conditions accordingly, and customers often distance themselves. The effects of this, particularly in unstable economies (with stagflation) and the resulting impact on inventory levels (due to rapidly declining sales), increased receivables turnover (due to economic challenges and inability to repay debt) (Tsuruta & Uchida, 2013), reduced purchasing activity, and subsequently, trade payables, and ultimately, increased likelihood of default during economic downturns (Boissay & Gropp, 2013), are more pronounced. Clearly, the findings of this study, in addition to advancing theoretical literature and outlining an appropriate model for working capital management for companies operating in the domestic capital market, are valuable and relevant in determining the appropriate levels of working capital, avoiding excess investment, and improving resource management by managers.

Therefore, to achieve the objectives of this research, the main question is: What is the working capital management model for companies listed on the Tehran Stock Exchange? The proposed model determines the expected level of working capital for a company in such a way that it can create the highest value. Additionally, this model can be used to assess the efficiency of working capital management by measuring the discrepancy between the actual level of working capital and its expected level, which will serve as an indicator of inefficiency in working capital management.

Literature Review

In theoretical literature, efficient working capital management is often defined as the ability to effectively and efficiently control current assets and current liabilities in a way that maximizes asset returns and minimizes debt payments. The aim is to improve cash flows and profitability and ultimately increase the value of the business entity (Mang & Jang, 2015). In other words, the efficiency of working capital management refers to the level of working capital adopted by managers that maximize shareholder value by balancing the benefits and costs of investing in working capital (Aktas et al., 2016). In this context, excess working capital indicates that the company is over-investing in working capital. This suggests that there is an opportunity for the company to enhance its working capital management efficiency over time by adopting a relatively more aggressive working capital policy, such as reducing inventories and delaying debt settlements. Additionally, a deficit in working capital

indicates that the company is currently using a very aggressive working capital policy, potentially increasing the risk of losing sales mainly due to possible inventory shortages and aggressive collection of receivables. In this case, additional investment in working capital is expected to be important as higher inventories can prevent input shortages and production process interruptions. Moreover, increasing credit sales can stimulate sales because it allows price differences to act as a guarantee of product quality and strengthen long-term relationships with customers (Aktas et al., 2016). Reviewing theoretical and empirical studies reveals the impact of various factors on the efficiency of working capital management. Some of the most common factors are discussed below:

Chiu et al. (2006) state that "the larger the company, the worse the working capital management," as the high growth rates in the early years of a company, which force management to control working capital efficiency, tend to slow down over time. The researchers also found empirical evidence suggesting a positive relationship between age and working capital requirements (WCR). Berger and Udell (1998) found that older firms have better access to financing under more favorable conditions, meaning that investing in working capital is less costly. On the other hand, Dodge and Robbins (1992) assert that the organizational life cycle consists of four sequential stages: formation, early growth, slow growth, and stability. They found that inventory control and cost issues increase from the formation stage through early growth to slow growth. When firms reach the final stage of stability, these issues diminish. However, Howorth and Westhead (2003) also show that "Companies that focus on stock management practices have been younger." In this context, a study by Baños-Caballero et al. (2010) confirms a positive relationship, indicating that older companies tend to have longer cash conversion cycles (CCC). Additionally, Teruel and Solano (2020) found that younger companies use less credit from suppliers compared to older companies. However, they did not find a clear relationship between age and accounts receivable. Nevertheless, empirical evidence from Yakti (2019), Nyadi et al. (2018), and Lefort and Hamelin (2022) supports a significant positive effect of age on working capital. Another factor is company size. The impact of size as a determinant of working capital management is influenced by four factors: access to capital markets and credit costs (financial credit), bargaining power, reputation, and economies of scale (Boschker, 2011). The cost of trade credit (trade discounts) is higher than financial credit (interest), so companies with access to financial credit should use it (Molina & Preve, 2007). This is why a study by Meltzer (1960) showed that companies with good access to capital markets share capital with companies with poor access to these markets through trade credit. Some

reasons for this are that smaller companies have to deal with larger asymmetric information problems (Berger & Udell, 2001) and are generally not followed by analysts. Additionally, smaller companies often have less diversification compared to larger companies, which increases the initial risk (Preve & Sarria-Allende, 2020). Therefore, the use of trade credit, which leads to longer accounts receivable conversion periods, can give larger companies a competitive advantage over smaller companies (Howorth & Reber, 2023). Additionally, when transaction costs are added to interest costs, trade credit can be cheaper than financial credit for small companies. This is because small companies face relatively high costs and time in obtaining financial credit (Howorth & Reber, 2023). Howorth and Reber (2023) also note that: "Small companies with low levels of financial management skills may also overlook the high cost of trade credit embedded in discounts." Hashemi (2024) states that company characteristics such as size, level of competition, and level of oversight have a positive impact on the predictive power of current operating cash flow and profitability in forecasting future operating cash flows. According to Long et al. (1993), large firms usually have a reputation, and more information is available about the quality of their products, so they do not need to extend much trade credit. However, smaller companies may lack a reputation and need to offer trade credit to guarantee product quality. A logical consequence of poor access to capital markets is found by Jaffe (1968), which shows that smaller firms are more dependent on the use of trade payables (or trade credit) to finance their operations. Research indicates that working capital management is more crucial for SMEs than for larger companies (Banos-Caballero et al., 2010; Peel & Wilson, 1996). Moreover, the findings of Lefort and Hamelin (2022), considering a large sample of private companies in Germany, France, and Italy, show that business groups play a crucial role in the working capital management of small companies, as they alleviate financial constraints for their affiliated firms.

Another influential variable is the level of operating cash flow. The presence of operating cash flow leads to increased investment in working capital (Chiu et al., 2006; Hill et al., 2010). For instance, Fazzari and Petersen (1993) argue that investment in working capital is sensitive to cash flow. Hill et al. (2010) show that companies with internal cash flow capacity and access to capital markets invest more in working capital. As argued by Baños-Caballero et al. (2014), a positive level of working capital requires financing, and therefore, the availability of cash flow plays a crucial role in the relationship between working capital management and firm performance. In this context, the results of Afrifa's (2016) study indicate a strong concave relationship

between net working capital and performance in the absence of operating cash flow. However, this relationship becomes convex when cash flow is considered. Further results indicate that companies with operating cash flow below the sample average show lower investment in working capital, while companies with cash flow above the sample average invest more in working capital. Another variable that can influence working capital management is a company's financial leverage. After securing financing, creditors (often banks) monitor the company as closely as shareholders do. This means that companies using external financial resources may invest more time and energy in managing their working capital to meet the requirements of these overseers. Typically, this can lead to the appropriate use of working capital (Niskanen et al., 2022).In recent years, a company's gross profit margin (GPM) has been identified in academic literature as a determinant of trade credit (Turel & Solano, 2020) and as a factor influencing working capital management (Hill et al., 2010). Turel and Solano (2020) found that "the weight of trade credit as a portion of sales is positively related to gross profit margins in European countries." This aligns with empirical evidence from Petersen and Rajan (1997), who stated, "The larger a company's gross profit margin, the greater its incentive to increase sales, potentially through the use of additional units of credit." Companies with higher GPMs are expected to be more motivated to use trade credit as a form of price differentiation to increase sales and, consequently, their profits. Panda and Nanda (2024) identified a convex relationship between working capital financing and profitability in companies within the chemical, construction, and consumer goods sectors, while a concave relationship was noted for firms in the machinery, metals, and textiles industries. Additionally, companies with high financial flexibility and high price-cost margins (excluding textiles) can enhance profitability by financing a larger portion of their working capital through short-term debt. Sustained risk-taking in working capital financing can also boost profitability.

Arsa et al. (2021) showed an inverse U-shaped relationship between the Days Sales Outstanding (DSO) and economic profitability. Initially, the relationship between Return on Assets (ROA) and DSO is positive, indicating that granting trade credit positively influences the attraction of new customers. However, this positive impact only lasts for a while. The relationship between the Inventory Conversion Cycle (ICC) and company profitability is U-shaped. Initially, increased inventory investment negatively affects economic profitability due to higher costs (maintenance or obsolescence costs), which reduces profitability. This negative impact is valid for a period (approximately 187 days), after which the benefits of avoiding potential price volatility and breaking costs outweigh the additional inventory costs. Lee (2024) indicates

that working capital management is crucial for companies with limited access to capital, especially those trying to expand their investments as economic conditions improve. The next variable influencing working capital management is the return on assets (ROA). A company's profitability, measured by ROA, not only results from effective working capital management but also serves as an independent variable affecting it. The theoretical literature presents two contrasting views on the impact of proper working capital management on profitability levels. One perspective suggests that a longer cash conversion cycle and a lenient receivables collection period enhance sales and company performance (Deloff, 2023; Charito et al., 2022; Sharma & Kumar, 2010). In contrast, another view indicates a negative relationship between higher working capital and profitability, arguing that excess working capital requires additional financing, thereby increasing financing and opportunity costs (Alipour, 2021; Ren et al., 2019; Kiani et al., 2019a; Banerjee & Deb, 2023; Kamlesh et al., 2023). Excessive working capital can reduce a company's financial performance due to the high cost of carrying surplus working capital. From the perspective of profitability affecting proper working capital management, it is argued that more profitable companies have better access to external capital (Berg et al., 2024; Chiu et al., 2016). Consequently, these companies extend more trade credit to customers to gain competitive advantages. Similarly, Molina and Pro (2019) state that companies facing profitability challenges use trade credit to increase sales or market share. On the other hand, companies with higher profits are likely to reinvest these profits into long-term projects with positive NPV. Conversely, Nazir (2019) suggests that more profitable companies pay closer attention to efficient working capital management, thus acquiring more current assets.

The findings of Lyngstadaas et al. (2023) show that the working capital management package in companies with high ROA features a different configuration of operational and financial working capital management compared to other samples. A common feature among these companies is that operational working capital management accounts for 14% to 27% of net sales, while financial working capital management ranges from -15% to -25% of net sales. This indicates that these companies have found a suitable balance between risk, operational cash flow, and return. Additionally, out of the six components that make up working capital management, inventory, receivables, other current assets, and current liabilities are the most common components that managers need to pay special attention to. Another variable is company growth. While companies experiencing rapid sales growth may be highly profitable, they often face higher risks than slower-growing companies due to

potential operational cash flow issues that can lead to bankruptcy. This heightened risk arises because growing companies need additional capital to invest in inventories and receivables, which take time to liquid (Al-Taleb et al., 2010). Chiu et al. (2016) assert that companies with high sales should pay more attention to working capital management. An example of this increased focus in growing companies is that managers might raise inventory levels to anticipate future sales growth. Another variable is sales volatility. Revenue volatility is associated with fluctuations in sales, making income prediction challenging due to these sales variations. This financial parameter indicates operational risk (Sharma et al., 2020). Organizations with higher sales volatility tend to invest less in working capital. Therefore, a negative relationship is observed between income/sales volatility and investment in working capital (Wasiuzzaman & Arumugam, 2013). However, Hill et al. (2010) present different findings regarding the relationship between working capital management and sales volatility. They argue that with greater sales volatility or significant deviations in demand, achieving the optimal inventory level can be difficult, prompting companies to increase their inventory levels to be on the safe side. Another influential variable is fixed asset growth. Empirical evidence from Sharma et al. (2020) supports a negative and significant relationship between fixed asset growth and working capital management, suggesting that organizations, due to financial resource constraints, choose to invest in areas with higher returns. Organizations prefer long-term investments, consequently reducing their investment in working capital. In this regard, Banerjee and Deb (2023), utilizing data from 12,637 US firms between 1988 and 2018, found a significant relationship between fixed asset growth and the efficiency of working capital management. They observed that higher growth rates lead to better working capital efficiency, which in turn enhances company performance.

Another variable is technological changes. Technological advancements, especially those related to production processes, significantly impact the level of working capital. For instance, if a company acquires machinery that prepares raw materials for production faster than before, the continuous need for inventory might change. If faster preparation of materials requires more raw materials for efficient production flows, the permanent inventory needs to be increased (Kordi, 2013). Additionally, the findings of Alvarez et al. (2021) indicate that in emerging economies, low political and economic stability, moderate development, and financial market instability create an uncertain environment that complicates investment and financing decisions for companies. Furthermore, these choices are often heavily dependent on the involvement of the banking system as the sole source of corporate financing. In

another study, Kiymaz et al. (2024) found that while companies in developed economies show higher firm performance with longer inventory days, companies in developing economies with longer inventory days, longer collection periods, and longer payable periods register lower firm performance. In the realm of domestic studies, the following research has examined the determinants of optimal working capital levels. Ghodrati Zavarm and colleagues (2022) investigated the impact of variables such as economic boom and recession on the types of working capital policies adopted by managers, such as aggressive and conservative policies. Company size, board ownership, institutional ownership, and company age were used as control variables. The research results showed that managers adopt conservative working capital policies during economic recessions and aggressive policies during inflationary periods.

The findings from the study by Nikzad and Ghaheri Ahi (2022) indicated that two indicators, CEO expertise, and tenure, have a significant impact on working capital management. However, this research did not find significant evidence regarding the impact of the CEO's educational level on working capital management. The results of the study by Aflatouni and colleagues (2022) showed that, compared to other business units, companies with greater access to external financial resources and stronger bargaining power in commercial negotiations adjust their working capital more quickly. The supplementary tests, which confirmed the initial findings, align with the trade-off theory (balancing the costs and benefits of debt). Therefore, understanding the role of external financial resources and bargaining power in accelerating working capital adjustment to achieve an optimal level can provide valuable information to business managers and investors. The findings of Jokar and Hedayati (2022) indicated a positive and significant relationship between market value added and working capital, as well as between cash value added and working capital. However, there was no significant relationship between economic value added and working capital. Azizi and Jokar's (2021) study investigated the optimal level of working capital management, the critical point of inflation, and its impact on cash holdings. The results showed that with increasing inflation, initially, the amount of cash held by companies increases; however, when inflation reaches a certain level, the amount of cash held by companies decreases with further inflation. The study found that the critical point of inflation for Iranian companies is 16%, but companies with positive working capital have a higher tolerance threshold for inflation, with a critical point around 19%. Additionally, the results indicated that as working capital increases, the level of cash held by companies increases, but when working

capital reaches a certain level, the amount of cash held decreases with further increases in working capital. In other words, the relationship between working capital and cash holdings is an inverted U-shape.

The findings of Khodabakhshi and Soleimani Amiri (2021) revealed that the most significant factor influencing working capital management stems from the country's economic and political conditions and the role of the government. By developing long-term economic plans and considering the country's political and economic conditions, the groundwork for improving working capital management can be established. This study examined both external and internal factors affecting working capital management. External factors included global commodity prices, macroeconomic conditions, political conditions, the role of the government, suppliers, and the industry. Internal factors included financial aspects, corporate governance mechanisms, the board of directors, company credit, the type of goods, sales strategies, dividend policies, production volume, company credit policies, unsystematic risk, company age, and geographic location. The outcomes of optimal working capital management, such as improved operational cash flow, increased profitability, greater market share, enhanced company credit, and company survival, were also considered. Furthermore, strategies for improving optimal working capital management were discussed, including management practices, board structure, forming a risk committee, budget forecasting, developing financial regulations for each industry, conducting internal and operational audits, fostering industry collaboration with universities and research centers, and engaging in analytical work.

Maleki and Molaei (2021) examined the reciprocal relationship between working capital management, financial leverage, and performance indicators. The results of their model estimation indicated a significant positive relationship between current period working capital and profitability for companies listed on the Tehran Stock Exchange. Additionally, the second model's test demonstrated a significant positive relationship between profitability and companies' working capital. The variable coefficient for size indicated that larger companies have higher working capital and profitability, suggesting that companies can increase profitability through optimal asset utilization. The findings from lagged periods of profitability and working capital showed a significant negative relationship between the previous periods of working capital and profitability, although the magnitude was small. Conversely, past profitability had a significant positive relationship with current working capital. Nabavi Chashmi and Asadi (2021) found that managerial ability increases the cash conversion cycle of a company.

Moreover, there is a negative relationship between managerial ability and the cash conversion cycle. Additionally, a significant negative relationship exists between managerial ability and the accounts payable period, while managerial ability leads to an increase in the inventory turnover period. Baradaran Hasan Zadeh et al. (2020) conducted a study titled "The Impact of Working Capital Management on the Profitability of Companies Listed on the Tehran Stock Exchange during business cycles based on the output gap." They assessed working capital management using metrics such as the cash conversion cycle, accounts receivable period, accounts payable period, and inventory turnover period. Profitability was measured using return on assets (ROA), return on equity (ROE), and return on operating profit. Business cycles were evaluated using the output gap. The results indicated a significant negative impact of working capital management components on profitability in Iranian companies. Additionally, during economic booms compared to recessions, the components of working capital management had a more pronounced effect on return on assets.

Khodabakhshi and Amiri (2020) found that external factors such as gross domestic product (GDP), inflation rate, and exchange rate have the most significant impact on working capital management. Furthermore, hypothesis testing revealed that several internal factors, including the current ratio, capital expenditures, financial leverage, return on assets (ROA), operating cycle, return on operating profit, percentage of institutional ownership, and board independence, also affect working capital management. Mohammadi and Yousofvand (2020) examined nine main factors influencing working capital behavior: operational cash flow, growth opportunities, performance, firm value, age, size, leverage, economic conditions, and industry type. The results from multivariate regression analysis of company data indicated that working capital behavior is affected by various factors related to company characteristics, economic conditions, and industry type. Kavousi Kalashmi and Khaliq Khiyavi (2018) investigated the relationship between the components of working capital management and operational cash flow. The results showed a statistically significant negative relationship between the current debt-to-total assets ratio and operational cash flow. Conversely, there was a statistically significant positive relationship between the current assets to total assets ratio and operational cash flow. Additionally, there were no statistically significant relationships between the current assets to current liabilities ratio and the total debt to total assets ratio with operational cash flow.

Mahdian and Noravesh (2018) first measured working capital management (a latent variable) using observable variables (average collection period,

average inventory turnover period, average payment period, cash conversion cycle, cash holding level, current ratio, and cash conversion cycle efficiency). Financial performance and profitability were measured based on return on assets (ROA) and return on equity (ROE), respectively. After confirming the acceptable fit of the measurement and structural models, the results indicated that working capital management reduces financial performance. Furthermore, the structural equation results showed that working capital management, considering the conservative policy of managers, leads to reduced company profitability. Badavar Nahandi and Taghizadeh Khangah (2016) explored the relationship between working capital management and investment inefficiency in companies listed on the Tehran Stock Exchange during the fiscal years 2006-2012. The results indicated a significant negative relationship between the accounts receivable period, accounts payable period, and cash conversion cycle efficiency with investment inefficiency, while no significant relationship was found between the inventory turnover period and investment inefficiency. Additionally, the study showed a significant positive relationship between the cash conversion cycle, cash holding, and current ratio and investment inefficiency. Overall, efficient working capital management reduces deviations from the optimal investment level.

Rahimi et al. (2016) found an inverse and significant relationship between working capital management indicators and their components with the profitability of small and medium-sized non-listed economic firms. The study suggested that companies can have an optimal level of working capital that maximizes their value. Ample inventory and a generous credit policy can lead to increased sales. A large inventory reduces the risk of stockouts and trade credit by allowing customers to assess product quality before payment, which can increase sales. Dolou and Mahmoudi (2016) investigated the functional relationship between working capital management and company performance, as well as the impact of financial constraints on this relationship. The study utilized panel data regression analysis on a sample of 90 companies listed on the Tehran Stock Exchange during 2007-2013. Various criteria were used to determine financial constraints, revealing that these constraints significantly affect the relationship between working capital management and financial performance. Specifically, the optimal level of working capital is lower for companies facing greater financial constraints. The findings suggest that managers should consider the optimal level of working capital due to the costs associated with deviating from it. Samaei Rahni et al. (2016) aimed to optimize working capital management in the pharmaceutical industry using intelligent systems. The study employed radial basis function neural networks to model and determine suitable values for independent variables through

comprehensive range searches. The results indicated that in the pharmaceutical industry, an appropriate accounts receivable turnover period ranges from a minimum of 10 days to a maximum of 45 days. The suitable accounts payable turnover period is between 40 and 54 days, while the optimal inventory turnover period for achieving adequate profitability lies between 252 and 273 days.

Vaez et al. (2014) examined the impact of certain governance components, such as ownership concentration (percentage of shares held by the five largest shareholders) and board structure (size and independence), on the efficiency of working capital management. The findings indicated that due to the lack of a significant relationship between board structure and the cash conversion cycle (considered as the combined effect of three other indicators), board structure does not have a meaningful impact on the efficiency of working capital management. This might suggest weakness and inefficiency in the board of directors' control and supervision over working capital policies in Iranian companies. Anvari Rostami et al. (2014) found an inverse and significant relationship between debt ratio, return on assets (ROA), and investment in fixed assets with working capital management. Conversely, there is a direct and significant relationship between operational cash flow and working capital management. The study showed that companies with longer lifespans and better cash flows have longer cash conversion cycles compared to other companies. Moreover, companies with higher ROA, debt ratio, growth opportunities, and investment in fixed assets tend to have more comprehensive and better policies for managing working capital.

Research Methodology

To provide an appropriate model for working capital management, 28 variables influencing working capital were initially selected based on theoretical foundations and expert screening. These variables are listed in Table (1). The experts (21 in total) were all university faculty members specializing in accounting (15 members, constituting 71% of the expert panel) and financial management (6 members, constituting 29% of the expert panel). They were selected in a chain and entirely purposive manner, considering the nature of the research. The final screening of the influential variables by the expert panel was conducted using the Delphi technique and a five-point Likert scale. Ultimately, after the second round of the Delphi method, achieving Kendall's coefficient of concordance as shown in Table (2) at 0.816 (with significance at a 5% error level), the final influential variables were determined for the next phase.

Subsequently, using dependent variables such as working capital (WC_{it}) and cash conversion cycle (CCC_{it}) as indicators of operational working capital, the research models were estimated using multiple regression and genetic algorithms, identifying the impactful variables. To determine the appropriate model, the efficiency of companies' working capital was first calculated using Data Envelopment Analysis (DEA). Then, to choose the suitable model, two criteria were considered: first, selecting an appropriate working capital management model with a strong correlation between the residual errors of the fitted models and the efficiency of companies' working capital, and second, the accuracy of the model in identifying companies prone to excess or shortage of working capital. Thus, initially, by calculating the residuals (errors) of the regression models, the absolute value of the correlation coefficient of the model residuals with the working capital efficiency calculated using DEA (Sorta, 2019) is measured. In this part, the correlation coefficient should be negative; in other words, if the absolute value of the residuals decreases, the efficiency level of the companies should increase. Subsequently, the selected model serves as the basis for predicting companies prone to excess and shortage of working capital, and the accuracy of the models is compared.

Table 1. Influential Variables on Working Capital Management Based on Literature, Theoretical Foundations, and Expert Opinions

Variable	Measurement Method	Source
Company Age	Natural logarithm of the number of years since the founding	(Caballero et al., 2010)
Company Size	Natural logarithm of total assets	(Wan Mohammad et al., 2018)
Operational Cash Flow Level	Operating cash flows $= \frac{Cash\ flows\ from\ operating\ activities}{Total\ assets}$	(Moshkin et al., 2014)
Cash Flow Volatility	The standard deviation of cash flow over the past three years	(Zarani et al., 2010)
Financial Leverage	Total debt / total assets ratio	(Abdolvahab et al., 2018)
Capital Expenditures	Capital expenditures extracted from financial statements, scaled by total assets	(Mashayekhi et al., 2010)
Asset Turnover	Net sales / total assets ratio	(Chiou et al., 2006)
Cost of Debt Rate	Financial cost divided by the sum of average current liabilities and average non-current liabilities	(Chiou et al., 2006)
Gross Profit Margin	Gross profit of company i in period t divided by total sales revenue of the company	(Hill et al., 2010)
Return on Assets	Operating profit divided by total assets	(Chiou et al., 2006)
Operating Cycle	Sum of inventory turnover period and receivables collection period for each company in the given year	(Lee, 2019)

Growth Opportunity (Tobin's Q)	(Book value of debt+(Market value per share × The number of shares held by shareholders)) / Book value of total assets	(Esradher, 2017)
Sales Volatility	The deviation of each year's sales from the systematic growth trend of sales during the review period	Lou & Kionitzki (2017)
Fixed Asset Growth	Changes in fixed assets in the current and previous year relative to the previous year	Dalvail et al. (2008)
Company-specific Risk	Variations in stock returns in past periods, equal to the standard deviation of returns	Castena & Habib (2020)
Dividend Policy	Dividend payout ratio to net sales	Esradher (2017)
Company Credit Policy	Average collection period divided by 365	Dalvail et al. (2008)
Financial Health	Z = 1.2A + 1.4B + 3.3C + 0.6D + 1.0E A: Working capital to total assets ratio B: Retained earnings to total assets ratio C: Earnings before interest and tax to total assets ratio D: Market value of equity to total debt ratio E: Total sales to total assets ratio	Salehi Nia & Tamoradi (2019).
Trade Credit	The ratio of trade payables to the cost of goods sold	Costa & Habib (2020)
Operational Efficiency	The ratio of operating profit to the difference between shareholders' equity and debt with cash and short-term investments	Navidi et al. (2018).
Technological Changes	Ratio of investment in equipment (amount of equipment and machinery) over the past five years	Kordi (2013)
Competition Level	Herfindahl-Hirschman Index to calculate the company's competitive share from the industry (sum of the squares of market shares of all active firms in the industry)	Dalvail et al. (2008)
Depreciation Policy	Discretionary part of depreciation (subtracting the non-discretionary part with regression of changes in sales revenue, changes in receivables and properties to total accruals, and calculating the relevant coefficients) normalized by total assets	Salari (2011)
Economic Policy Uncertainty	Fluctuations in the inflation rate over the past ten years	Nozari (2021)
Business Cycle	Dummy variable for positive change in gross domestic product (growth indicator, value 1) and negative change (recession indicator, value 0)	Mehrgan et al. (2022)
Gross Domestic Product	The absolute value of changes in the logarithm of gross domestic product	Navidi et al. (2018)
Exchange Rate	Changes in the exchange rate during the review period	Salari & Bahari Moghadam (2011)
Interest Rate	Annual bank interest rate	Nozari (2021)
Economic Growth	The ratio of economic value added to total assets	Nozari (2021)

Table 2. Kendall's Correlation Coefficient

Test Statistics	
N	21
Kendall's W[a]	.816
Chi-Square	224.407
Asymp. Sig.	.000
a. Kendall's Coefficient of Concordance	

Results

Calculation of Working Capital Efficiency of Companies

In this section, the efficiency of working capital for companies is calculated following Sorta (2019). The calculation is based on Data Envelopment Analysis (DEA), with the input variables including current assets and current liabilities (as components of working capital management), the operational cycle (comprising accounts receivable period and inventory turnover period), and the output variable being return on assets (ROA). For data analysis and computation of working capital efficiency, the R-4.0.5 software, known for its powerful programming and statistical computation capabilities, was utilized. In this software, the working capital efficiency of companies was calculated using the dea function from the rDEA package. Additionally, the writexl and readxl packages were used. Given the large number of sample companies, Figure 1 illustrates the efficiency changes for five companies over the years 2011 to 2022. As observed, for example, the working capital efficiency of Barez Industrial Company increased from 2011 to 2016 and remained stable from 2016 to 2022.

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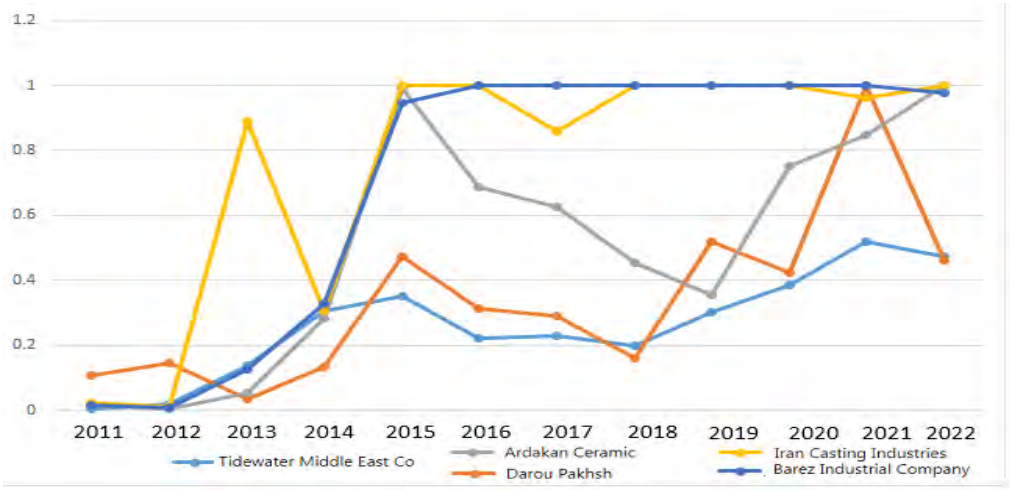

Figure 1. Changes in Working Capital Efficiency of Sample Companies

Descriptive Statistics

To better understand the variables in the population, descriptive statistics of the research variables are presented in Table 3. For example, the average product market competition of companies is 0.6750. The average company size is 14.8579. The minimum and maximum values of the company size variable are 10.5046 and 21.5717, respectively. These figures indicate that the sample companies vary significantly in size. The average return on assets is 0.1515, indicating that the profitability of the companies is around 15%.

Table 3. Descriptive Statistics of Research Variables

Symbol	Variables	Mean	Median	Standard Deviation	Maximum	Minimum	Skewness	Kurtosis
HHI	Market competition	0.6750	0.7237	0.2256	0.9276	0.0000	-1.4426	5.0067
DDP	Discretionary depreciation	0.0000	-0.0002	0.0086	0.0458	-0.0453	0.1672	6.5830
Age	Age	3.6227	3.7612	0.4030	4.2767	2.0794	-0.8660	3.1623
Risk	Specific risk	0.1686	0.1534	0.0999	0.9240	0.0002	1.9202	10.5113
Size	Company size	14.8579	14.6047	1.8299	21.5717	10.5046	0.5859	3.2961
OCF	Operating cash flow level	0.1143	0.0948	0.1443	0.8725	-0.4601	0.6605	5.0839
Cfov	Cash flow volatility	0.0886	0.0760	0.0577	0.4147	0.0055	1.6603	7.0020

Lev	Financial leverage	0.5765	0.5749	0.2456	1.8745	0.0254	0.7067	5.2939
ATO	Asset turnover	0.9741	0.7999	0.7170	5.7762	0.0034	2.3414	11.0184
CoD	Debt cost rate	0.0561	0.0466	0.0470	0.3157	0.0000	0.8867	3.5302
GPM	Gross profit margin	0.1787	0.1437	0.3131	2.1727	-1.6832	0.1869	10.0150
DIV	Dividend distribution	0.0823	0.0291	0.1283	0.8954	0.0000	2.6663	11.7761
Pc	Operational efficiency	0.1753	0.1361	0.2014	1.5641	-0.5449	1.4994	8.5560
DT	Technological changes	0.0112	0.0105	0.0416	0.2096	-0.0938	0.7693	4.9738
Z	Financial health	0.2846	0.2846	0.8080	7.8873	-4.7281	-0.2870	13.0811
TC	Trade credit	0.3514	0.2346	0.4496	4.0874	0.0005	3.9714	23.9918
Roa	Return on assets	0.1515	0.1273	0.1568	0.7999	-0.5356	0.4427	3.8564
Cp	Credit policy	0.3626	0.2490	0.3755	2.8823	0.0001	2.4097	10.6932
Ssale	Sales volatility	0.1614	0.1302	0.1265	0.9215	0.0006	1.9984	8.5977
GPP	Fixed asset growth	0.3498	0.0566	1.0220	8.9971	-0.9182	4.8492	31.0731
CapEx	Capital expenditures	0.0430	0.0086	0.1181	0.9724	-0.6109	2.9875	17.5450
Oc	Operating cycle	0.6499	0.5026	0.5101	4.5631	0.0012	2.3449	11.8872
Ccc	Cash conversion cycle (working capital management)	0.4015	0.3146	0.4863	3.6700	-2.7563	0.5373	12.0165
Wc	Working capital	0.1373	0.1588	0.3165	0.8402	-2.9181	-2.5651	19.5057
Q	Growth opportunities	2.8018	1.9055	2.5114	18.1115	0.1649	2.9479	13.6577
Epu	Economic policy uncertainty	0.0966	0.0860	0.0306	0.1537	0.0461	0.4323	2.3037
Exr	Exchange rate fluctuations	0.4656	0.2315	0.5019	1.6320	-0.1140	0.9330	2.9097
Ir	Interest rate	0.1808	0.1800	0.0229	0.2200	0.1500	-0.0606	1.7561
DEA	Working capital efficiency	0.1962	0.1341	0.2226	1.0000	0.0005	2.1372	7.7482
RGDP	Economic growth	0.0108	0.0315	0.0054	0.125	-0.077	0.000988	0.0266

Table 4. Descriptive Statistics for the Dummy Variable Business Cycle

Business Cycle	Frequency	Percentage
0 (Recession)	780	41.7%
1 (Expansion)	1092	58.3%
Total	1872	100%

Stationarity of Research Variables

Before estimating the regression models using the research variables, it is necessary to examine the stationarity of the variables using Levin, Lin, and Chu statistics in panel data studies (a combination of time series and cross-sectional data, which in this study are companies). According to the information provided in Table (5), this statistic for all variables except for the variables "Company Size" and "Economic Policy Uncertainty" is less than the error level of 0.05. Therefore, the stationarity of these variables is confirmed. For the variables "Company Size" and "Economic Policy Uncertainty," the first-order differencing yields a significance level less than the error level of 0.05, indicating these variables are also stationary.

Table 5. Stationarity Test

Symbol	Variable	Statistic	Significance Level
HHI	Product Market Competition	-16.189	0.0000
DDP	Discretionary Depreciation	-7.506	0.0000
Age	Age	-111.353	0.0000
Risk	Specific Risk	-31.409	0.0000
Size	Company Size (First-order diff.)	-15.078	0.0000
OCF	Operating Cash Flow Level	-28.422	0.0000
Cfov	Cash Flow Volatility	-12.323	0.0000
Lev	Financial Leverage	-11.660	0.0000
ATO	Asset Turnover	-11.812	0.0000
CoD	Cost of Debt	-109.494	0.0000
GPM	Gross Profit Margin	-17.927	0.0000
DIV	Dividend Distribution	-50.631	0.0000
Pc	Operating Efficiency	-12.000	0.0000
DT	Technological Changes	-16.648	0.0000
Z	Financial Health	-9.741	0.0000
TC	Trade Credit	-17.389	0.0000
Roa	Return on Assets	-11.969	0.0000
Cp	Company's Credit Policy	-18.094	0.0000
Ssale	Sales Volatility	-25.581	0.0000
GPP	Fixed Asset Growth	-36.068	0.0000
CapEx	Capital Expenditures	-22.712	0.0000
Oc	Operating Cycle	-16.061	0.0000

Ccc	Cash Conversion Cycle	-24.175	0.0000
Wc	Working Capital	-16.689	0.0000
Oc	Operating Cycle	-16.061	0.0000
Q	Growth Opportunities	-14.396	0.0000
Epu	Economic Policy Uncertainty (First-order diff.)	-17.505	0.0000
Exr	Exchange Rate Changes	-11.294	0.0000
Ir	Interest Rate	-3.552	0.0002
Rgdp	Economic Growth	-31.027	0.0000
BC	Business Cycle	-33.893	0.0000
DEA	Working Capital Efficiency	-17.757	0.0000

Normality of Dependent Variables

In this research, the Jarque-Bera test is used to assess the normality of the distribution of the dependent variables. The significance level of the Jarque-Bera test for the dependent variables is 0.0000, which is less than the 0.05 error level, indicating that the normality of the dependent variables' distribution is not confirmed. Therefore, a transformation is applied for normalization. The bestNormalize function from the bestNormalize package (Petersen, 2021) in R software is used to select the best transformation method. The orderNorm transformation was automatically selected as the best transformation for this research. The results of the Jarque-Bera test for the dependent variables after applying the transformation are shown in Table (6). The significance levels for the Jarque-Bera test for the variables "Cash Conversion Cycle" and "Working Capital" after applying the transformation are 0.9885 and 0.9894, respectively. Since these are greater than the 0.05 error level, the normality of these variables is confirmed.

Table 6. Normality Test of Dependent Variables

Transformation	Symbol	Variable	Statistic	Significance Level
Before	Ccc	Cash Conversion Cycle	6431.21	0.0000
	Wc	Working Capital	23303.17	0.0000
After	Ccc	Cash Conversion Cycle	0.0231	0.9885
	Wc	Working Capital	0.0212	0.9885

Extracting the Appropriate Working Capital Management Model

As previously mentioned, using the dependent variables Working Capital (WC_it) and Cash Conversion Cycle (CCC_it) as indicators of operational working capital, the research models are estimated using multiple regression and genetic algorithms to identify the influential variables. The regression and genetic algorithm models (Model 1 and Model 2) initially include all

significant independent variables. Then, by screening and gradually eliminating non-significant variables and selecting a combination of significant independent variables in different models, the appropriate research model is established by considering the best estimation of companies prone to excess and shortage of working capital. Models 1 and 2 are as follows:

$$\begin{aligned} \mathrm{WC}_{it} = \beta_0 &+ \beta_1 \mathrm{WC}_{it-1} + \beta_2 \mathrm{WC}_{it-2} + \beta_3 \mathrm{AGE}_{it} + \beta_4 \mathrm{RISK}_{it} + \beta_5 \mathrm{SIZE}_{it} + \beta_6 \mathrm{OCF}_{it} \\ &+ \beta_7 \mathrm{CFOV}_{it} + \beta_8 \mathrm{LEV}_{it} + \beta_9 \mathrm{ATO}_{it} + \beta_{10} \mathrm{COD}_{it} + \beta_{11} \mathrm{GPM}_{it} + \beta_{12} \mathrm{DIV}_{it} \\ &+ \beta_{13} \mathrm{PC}_{it} + \beta_{14} \mathrm{DT}_{it} + \beta_{15} \mathrm{Z}_{it} + \beta_{16} \mathrm{TC}_{it} + \beta_{17} \mathrm{ROA}_{it} + \beta_{18} \mathrm{CP}_{it} \\ &+ \beta_{19} \mathrm{SSALE}_{it} + \beta_{20} \mathrm{GPP}_{it} + \beta_{21} \mathrm{CAPEX}_{it} + \beta_{22} \mathrm{HHI}_{it} + \beta_{23} \mathrm{DDP}_{it} \\ &+ \beta_{24} \mathrm{Q}_{it} + \beta_{25} \mathrm{EPU}_{it} + \beta_{26} \mathrm{EXR}_{it} + \beta_{27} \mathrm{IR}_{it} + \beta_{28} \mathrm{RGDP}_{it} + \beta_{29} \mathrm{BC}_{it} \\ &+ \beta_{30} \mathrm{OC}_{it} + \varepsilon_{it} \end{aligned} \quad (1)$$

$$\begin{aligned} \mathrm{CCC}_{it} = \beta_0 &+ \beta_1 \mathrm{CCC}_{it-1} + \beta_2 \mathrm{AGE}_{it} + \beta_3 \mathrm{RISK}_{it} + \beta_4 \mathrm{SIZE}_{it} + \beta_5 \mathrm{OCF}_{it} + \beta_6 \mathrm{CFOV}_{it} \\ &+ \beta_7 \mathrm{LEV}_{it} + \beta_8 \mathrm{ATO}_{it} + \beta_9 \mathrm{COD}_{it} + \beta_{10} \mathrm{GPM}_{it} + \beta_{11} \mathrm{DIV}_{it} + \beta_{12} \mathrm{PC}_{it} \\ &+ \beta_{13} \mathrm{DT}_{it} + \beta_{14} \mathrm{Z}_{it} + \beta_{15} \mathrm{TC}_{it} + \beta_{16} \mathrm{ROA}_{it} + \beta_{17} \mathrm{CP}_{it} + \beta_{18} \mathrm{SSALE}_{it} \\ &+ \beta_{19} \mathrm{GPP}_{it} + \beta_{20} \mathrm{CAPEX}_{it} + \beta_{21} \mathrm{HHI}_{it} + \beta_{22} \mathrm{DDP}_{it} + \beta_{23} \mathrm{Q}_{it} \\ &+ \beta_{24} \mathrm{EPU}_{it} + \beta_{25} \mathrm{EXR}_{it} + \beta_{26} \mathrm{IR}_{it} + \beta_{27} \mathrm{RGDP}_{it} + \beta_{28} \mathrm{BC}_{it} \\ &+ \beta_{29} \mathrm{OC}_{it} + \varepsilon_{it} \end{aligned} \quad (2)$$

It is evident that in each regression model fitting, essential statistics to ensure the validity of the model estimates include the F-Limer test (to determine whether a pooled or panel model is appropriate), the Hausman test (to decide between fixed effects or random effects models), the significance level of the F-Fisher statistic (to assess the overall significance of the fitted Model), the Durbin-Watson statistic (to check the independence of regression errors), the Breusch-Pagan-Godfrey test (to identify heteroskedasticity in regression errors), the VIF statistic (to determine multicollinearity among independent variables), the coefficient of determination (to evaluate the explanatory power of the independent variables), and the t-statistic (to test the significance of individual independent variables). Accordingly, Model (1) was fitted 54 times, as shown in Table (7), and Model (2) 31 times, as shown in Table (9), using regression methods. The fitting of Models (1) and (2) using a genetic algorithm was performed with R-4.0.5 software and the ga function in the GA package (Scrucca, 2013). The initial population size was set to 250 chromosomes, and a maximum of 250 generations were executed to obtain results. In each generation, 80% of the chromosomes were selected for crossover, with a 5% survival rate for the best chromosome in each generation.

The mutation probability was set at 0.1. In chromosome selection, some current chromosomes are chosen to produce new ones based on the evaluation function, with chromosomes closer to the optimal solution being more likely to be selected. Ultimately, variables with a value of one have the ability to impact working capital, and their coefficients are determined. In both the regression and genetic algorithm model fittings, the correlation between the absolute value of regression errors and the working capital efficiency level of companies, as well as the Model's accuracy in estimating companies with excess and shortage of working capital, is calculated. The results are presented in Tables (7) to (11).

Table 7 - Validation Test of Models Based on the Dependent Variable WC and Multiple Regression

Model	Correlation	Significance Level	Rank Based on Correlation	Accuracy of Identifying WC Surplus (%)	Accuracy of Identifying WC Deficit (%)	Average	Rank Based on Prediction Accuracy	Average Rank	Final Rank
1	-0.0044	0.8442	41	67.37	72.72	70.05	54	47.5	52
2	-0.019	0.409	10	74.86	71.65	73.26	50	30	33
3	-0.0186	0.4206	12	75.93	71.65	73.79	40	26	24
4	-0.0188	0.4138	11	75.4	71.65	73.53	45	28	26
5	-0.0193	0.4035	9	76.47	70.05	73.26	49	29	28
6	-0.0111	0.63	31	74.86	72.19	73.53	44	37.5	42
7	-0.0098	0.6697	33	75.4	72.72	74.06	34	33.5	37
8	-0.0097	0.6737	35	74.86	73.73	74.3	28	31.5	35
9	0.0083	0.7166	43	77	73.79	75.4	18	30.5	34
10	-0.0084	0.7155	38	75.41	73.79	74.6	22	30	32
11	-0.0156	0.4986	15	75.41	71.65	73.53	43	29	27
12	0.0084	0.7146	44	76.47	66.31	71.39	53	48.5	54
13	0.0099	0.6661	45	77	66.84	71.92	52	48.5	53
14	0.0132	0.5679	47	80.21	68.98	74.6	21	34	39
15	0.0137	0.5018	49	79.14	68.98	74.06	33	41	46
16	0.0135	0.5593	48	79.14	68.98	74.06	32	40	44
17	-0.0535	0.0205	2	77.54	77	77.27	2	2	1
18	-0.0526	0.0227	3	78.6	74.86	76.73	5	4	2
19	-0.0518	0.0249	4	76.47	76.47	76.47	11	7.5	5
20	-0.0127	0.5828	21	75.93	73.79	74.86	20	20.5	16
21	0.0155	0.5002	53	78.6	68.98	73.79	39	46	51
22	0.0143	0.5363	50	79.67	68.98	74.33	27	38.5	43
23	0.0151	0.5132	52	79.14	68.44	73.79	38	45	50
24	0.0148	0.5203	51	79.14	68.44	73.79	37	44	49
25	-0.0142	0.5386	19	75.4	71.12	73.26	48	33.5	36
26	-0.0145	0.5293	18	75.4	71.65	73.53	42	30	31
27	-0.0085	0.719	37	73.26	74.33	73.8	35	36	41
28	-0.0083	0.7186	39	73.26	73.26	73.26	47	43	48

29	-0.0108	0.6387	32	73.79	73.79	73.79	36	34	38
30	-0.0098	0.6753	34	74.86	73.79	74.33	26	30	30
31	-0.0126	0.5841	22	80.74	72.19	76.47	10	16	10
32	-0.0125	0.5887	24	80.21	72.72	76.47	9	16.5	11
33	-0.0129	0.5744	20	77.54	70.58	74.06	31	25.5	23
34	0.0112	0.6265	46	79.67	68.98	74.33	25	35.5	40
35	0.0166	0.6151	54	79.14	68.98	74.06	30	42	47
36	-0.016	0.4865	14	75.93	71.12	73.53	41	27.5	25
37	-0.0163	0.4801	13	75.93	72.72	74.33	24	18.5	13
38	-0.0087	0.7057	26	73.79	72.72	73.26	46	41	45
39	-0.0125	0.5861	25	79.67	72.72	76.2	13	19	14
40	-0.0126	0.5857	23	79.14	72.72	75.93	16	19.5	15
41	-0.0118	0.6069	30	80.74	73.26	77	4	17	12
42	-0.024	0.2979	8	72.19	72.72	72.46	51	29.5	29
43	-0.0156	0.4991	16	79.67	72.72	76.2	12	14	8
44	-0.0156	0.4995	17	77.54	70.58	74.06	29	23	22
45	-0.0053	0.8171	40	80.74	73.26	77	3	21.5	20
46	-0.0601	0.0092	1	74.86	74.33	74.595	23	12	7
47	-0.0463	0.045	6	80.21	72.72	76.47	8	7	4
48	-0.0467	0.0432	5	78.6	72.19	75.4	17	11	6
49	-0.0449	0.0516	7	80.21	72.72	76.47	7	7	3
50	-0.0119	0.6045	28	79.14	72.72	75.93	15	21.5	19
51	-0.0122	0.5955	26	80.21	72.72	76.47	6	16	9
52	0.0048	0.8347	42	75.93	79.14	77.54	1	21.5	18
53	-0.0119	0.6053	29	80.21	71.65	75.93	14	21.5	17
54	-0.0121	0.6001	27	78.6	71.65	75.13	19	23	21

Results of Table 7 indicate that the accuracy of model predictions ranges approximately from 70 to 79.68. The best-performing Model in terms of prediction accuracy and correlation coefficient is Model 17. Initially, the Model was estimated using all dependent variables. Subsequently, insignificant variables were removed, and the Model was re-estimated. To achieve the best Model, different combinations of independent variables were selected, and regression models were re-estimated accordingly. Ultimately, for selecting the best Model, models were initially ranked based on the strength of the correlation coefficient and the Model with the highest correlation coefficient between its error and the operational efficiency of companies was chosen as the best Model. Models were then ranked again based on their accuracy in predicting companies with surplus or deficit working capital. Consequently, a model was selected as the best Model when it simultaneously exhibited a strong correlation coefficient with company efficiency and high prediction accuracy. Based on this approach, Model 17 achieved rank 2 in terms of correlation and 2 in terms of prediction accuracy. Model 46 ranked 1 in correlation coefficient but 23 in prediction accuracy. Additionally, Model 52 ranked 1 in prediction accuracy; however, it ranked 42 in terms of correlation coefficient. Therefore, Model 17 emerged as the best Model using the WC

dependent variable and multiple regression. As mentioned, various models were obtained by individually adding and removing independent variables. The estimation results of this Model are presented in Table 8. The results of the F-Limer test indicate the use of the panel method, and the results of the Hausman test show that fixed effects are appropriate for estimating Model 17. In the above Table, the significance level of the Fisher F statistic indicates the overall significance of the Model. The Durbin-Watson statistic is 1.56, and since it is between 1.5 and 2.5, the independence of regression errors is confirmed. The significance level obtained from the Jarque-Bera test for the regression error variable is 0.72, which is greater than the error level of 0.05, indicating that the distribution of regression errors is normal. The significance level obtained from the Breusch-Pagan-Godfrey test for the regression error variable is 0.0000, which is less than the error level of 0.05, indicating heteroscedasticity of regression errors. The generalized least squares method is used to address heteroscedasticity. The VIF statistic for all research variables is between one and ten. The coefficient of determination for Model 17 is 0.8890, indicating that 88.90% of the changes in the dependent variable in Model 17 are explained by the independent variables.

According to Table 8, the correlation coefficient between the absolute value of regression errors and the efficiency level of companies is -0.0535, which is statistically significant (the significance level for the correlation coefficient is 0.0205, which is less than the error level of 0.05). The negative correlation coefficient indicates that as the absolute value of regression errors increases (decreases), the efficiency level of companies decreases (increases). Regarding the predictive power of Model 17, it can be said that Model 17 has a prediction accuracy of 77.54% for companies with excess working capital and 77.00% for companies with a working capital deficit.

Table 8. Estimation of Model 17 with Significant Independent Variables

Variable	Significance Level	Std. Error	t-Statistic	Coefficient	VIF
WC1	0.4455	0.0369	12.0803	0.0000	1.405333
RISK	0.0386	0.0148	2.6108	0.0091	1.034134
SIZE	-0.0205	0.0033	-6.2384	0.0000	1.104347
OCF	-0.1103	0.0263	-4.1870	0.0000	1.823410
LEV	-0.3140	0.0249	-12.6027	0.0000	1.733899
ATO	0.0338	0.0086	3.9247	0.0001	1.204807
GPM	0.0850	0.0099	8.6260	0.0000	2.072595
DIV	-0.0806	0.0290	-2.7852	0.0054	1.912758
PC	0.3664	0.0263	13.9350	0.0000	2.654574
C	0.4684	0.0509	9.2003	0.0000	
Coefficient of determination		0.8890	Durbin-Watson statistic		1.56

Fisher's F-statistic	83.3757	Significance Level of F-statistic	0.0000
Limer F-statistic	Significance Level	Hausman statistic	Significance Level
2.1162	0.00000	265.1762	0.0000
Breusch-Pagan-Godfrey Test	Significance Level	Jarque-Bera Test	Significance Level
55.9840	0.0000	0.7246	0.6960
Correlation between Absolute Regression Errors and Efficiency Level			
Correlation Coefficient		Significance Level	
- 0.0535		0.0205	
Accuracy for Companies with Excess Working Capital		Accuracy for Companies with Shortage of Working Capital	
77.54		77.00	

Based on the significance of all coefficients in this section, the working capital management model is derived using the multiple regression method with the dependent variable WC as follows:

$$\mathrm{WC} = 0.4684 + 0.4455\ \mathrm{WC1} + 0.0386\ \mathrm{RISK} - 0.0205\ \mathrm{SIZE} - 0.1103\ \mathrm{OCF} - 0.3140\ \mathrm{LEV} + 0.0338\ \mathrm{ATO} + 0.0850\ \mathrm{GPM} - 0.0806\ \mathrm{DIV} + 0.3664\ \mathrm{PC} \quad (3)$$

In the above Model, WC1 is the working capital of the previous year, RISK is the firm-specific risk, SIZE is the firm size, OCF is the liquidity level, LEV is the financial leverage, ATO is the asset turnover, GPM is the gross profit margin, DIV is the dividend distribution, and PC is the operational productivity. Model (2) with the dependent variable CCC was estimated 31 times with all independent variables, significant independent variables, and combinations of significant independent variables. The summary of the diagnostic accuracy of the models based on the dependent variable CCC and multiple regression, as well as the correlation between the absolute value of model errors and the efficiency level of companies, is presented in Table (10). The results indicate that among the 31 estimated models with the addition and removal of variables based on explanatory power and increased accuracy, the best Model is model 85, with an accuracy of 80.74% for detecting excess working capital and 77.54% for detecting working capital deficiency. The average diagnostic accuracy for this Model is 79.14%. The correlation between the absolute value of regression errors and the efficiency level in this Model is -0.0849, which is significant at the 95% confidence level. To present the working capital management model, after eliminating insignificant variables impacting working capital management, model 62 with the independent variables CCC1, RISK, GPM, TC, Q, and OC was estimated. The average

diagnostic power of this Model was 63.365. Subsequently, by adding variables like Age, SIZE, OCF, CFOV, LEV, ATO, COD, Z, ROA, CP, SSALE, CAPEX, HHI, DDP, EPU, IR, and BC one by one, it was observed that the highest increase in accuracy was related to model 77, with an average diagnostic accuracy of 78.07%. Therefore, in this section, model 77 with the independent variables CCC1, RISK, GPM, TC, Q, OC, and EPUEPUEPU was selected as the base model, and independent variables were added again, provided they increased diagnostic accuracy. By adding various variables like Age, SIZE, OCF, COD, and ROA one by one (models 80 to 84), it was observed that the diagnostic power of the Model remained constant in some cases and decreased in others. Finally, it was observed that by adding the variable CP, model 85 with the independent variables RISK, GPM, TC, Q, OC, EPU, and CP had the highest diagnostic power. Ultimately, the most appropriate Model, considering both diagnostic accuracy and the correlation between the absolute value of regression errors and the efficiency of working capital management of companies, is model 85, which is presented in Table (10).

Table 9. Model Validation Test Based on the Dependent Variable CCC and Multiple Regression

Model	Correlation	Significance Level	Rank Based on Correlation	Accuracy of Identifying WC Surplus (%)	Accuracy of Identifying WC Deficit (%)	Average	Rank Based on Prediction Accuracy	Average Rank	Final Rank
55	-0.0807	0.0001	12	78.07	74.86	76.465	7	9.5	11
56	-0.0852	0.0002	10	78.07	72.72	75.395	11	10.5	12
57	-0.0862	0.0001	8	78.07	74.33	76.2	9	8.5	9
58	-0.087	0.0001	5	78.07	74.86	76.465	8	6.5	5
59	-0.0709	0.0021	15	64.17	61.49	62.83	31	23	26
60	-0.0716	0.0019	13	63.63	63.63	63.63	29	21	20
61	-0.0709	0.0021	16	63.1	64.17	63.635	28	22	22
62	-0.0713	0.0011	14	63.1	63.63	63.365	30	22	23
63	-0.0605	0.0034	31	67.91	77	72.455	22	26.5	29
64	-0.0674	0.0035	18	67.91	76.47	72.19	24	21	21
65	-0.0678	0.0033	17	68.44	77.54	72.99	17	17	14
66	-0.067	0.0036	25	68.44	77.54	72.99	16	20.5	17
67	-0.0674	0.0035	19	68.98	78.07	73.525	13	16	13
68	-0.0672	0.0035	23	66.84	75.93	71.385	26	24.5	27
69	-0.0672	0.0035	24	69.51	75.93	72.72	20	22	24
70	-0.0642	0.0054	29	68.98	75.4	72.19	23	26	28
71	-0.0626	0.0067	30	67.91	74.33	71.12	27	28.5	31
72	-0.0657	0.0044	28	71.65	72.19	71.92	25	26.5	30
73	-0.0669	0.0037	27	68.94	77	72.97	18	22.5	25
74	-0.0673	0.0035	20	68.44	77	72.72	21	20.5	18
75	-0.0673	0.0035	21	68.98	77.54	73.26	15	18	15

76	-0.0673	0.0035	22	67.91	77.54	72.725	19	20.5	19
77	-0.0871	0.0001	4	79.14	77	78.07	4	4	2
78	-0.0864	0.0001	7	79.14	72.19	75.665	10	8.5	10
79	-0.067	0.0037	26	68.98	77.54	73.26	14	20	16
80	-0.0882	0.0001	3	78.6	77.54	78.07	5	4	3
81	-0.087	0.0001	6	79.14	77	78.07	3	4.5	4
82	-0.0854	0.0002	9	76.47	77	76.735	6	7.5	8
83	-0.0895	0.0001	1	76.47	72.72	74.595	12	6.5	6
84	-0.0852	0.0002	11	79.14	77	78.07	2	6.5	7
85	-0.0888	0.0001	2	80.74	77.54	79.14	1	1.5	1

The estimation results of model 85 are presented in Table 10

Table 10. Estimation of Model 85 with a Combination of Independent Variables

Variable	Significance Level	Std. Error	t-Statistic	Coefficient	VIF
CCC1	0.4668	0.0525	8.8836	0.0000	1.564778
RISK	-0.0971	0.0610	-1.5912	0.1117	1.091675
GPM	0.1843	0.0558	3.3022	0.0010	1.103253
TC	-0.2873	0.0260	-11.0413	0.0000	1.479332
Q	-0.0132	0.0038	-3.4799	0.0005	1.205948
OC	0.4587	0.0546	8.3986	0.0000	2.058010
EPU	0.4014	0.2154	1.8634	0.0626	1.195346
CP	-0.0371	0.0505	-0.7348	0.4626	1.900063
C	0.0086	0.0256	0.3367	0.7364	

Coefficient of determination	0.7665	Durbin-Watson statistic	2.06
Fisher's F-statistic	764.8693	Significance Level of F-statistic	0.0000

Limer F-statistic	Significance Level	Hausman statistic	Significance Level
1.3320	0.0054	0.0000	1

Breusch-Pagan-Godfrey Test	Significance Level	Jarque-Bera Test	Significance Level
42.5470	0.0000	1.4931	0.4739

Correlation between Absolute Regression Errors and Efficiency Level	
Correlation Coefficient	Significance Level
- 0.0888	0.0001
Accuracy for Companies with Excess Working Capital	Accuracy for Companies with Shortage of Working Capital
80.74	77.54

As can be seen, the correlation coefficient between the absolute values of regression errors and the efficiency level of companies is -0.0888, which is statistically significant. The negative correlation indicates that as the absolute values of regression errors increase (or decrease), the efficiency level of companies decreases (or increases). To assess the predictive power of Model

85, it can be said that Model 85 has an 80.74% prediction accuracy for companies with a surplus of working capital and a 77.54% accuracy for companies with a deficit of working capital. Based on the significance of all coefficients in this section, using the multiple regression method with the dependent variable CCC, the working capital management model is as follows:

$$\mathrm{CCC} = 0.0086 + 0.4661\ \mathrm{CCC1} - 0.0971\ \mathrm{RISK} + 0.1843\ \mathrm{GPM} - 0.2873\ \mathrm{TC} - 0.0132\ \mathrm{Q} + 0.4587\ \mathrm{OC} + 0.4014\ \mathrm{EPU} - 0.0371\ \mathrm{CP} + \varepsilon \quad (4)$$

In the above Model, CCC1 represents the Cash Conversion Cycle (working capital management), RISK denotes specific risk, GPM stands for Gross Profit Margin, TC indicates Total Cost, Q represents Tobin's Q ratio, OC denotes Operating Cash Flow, EPU stands for Economic Policy Uncertainty, and CP represents Credit Policy. In fitting Model (1) using a genetic algorithm, 21 models were estimated with all independent variables, significant independent variables, and combinations of significant independent variables. A summary of the Model's predictive accuracy based on the dependent variable WC and the genetic algorithm, as well as the correlation between the absolute residuals of the models and the companies' efficiency levels, is presented in Table (11). The results showed that Model 88, with independent variables WC1, LEV, ATO, GPM, DIV, PC, TC, CapEx, and OC, has an average predictive accuracy of 77.005%. Subsequently, by adding variables RISK, SIZE, OCF, CoD, Z, TC, CP, HHI, and BC one by one to Model 88, the highest increase in predictive accuracy was achieved with the variable BC in Model 97. The average predictive accuracy of Model 97 is 79.39%. It is worth noting that the correlation between the absolute residuals and efficiency is not significant in any of the above models. Therefore, it can be said that despite their high predictive power, Models 88 to 97 are not suitable models for working capital management.

Further analysis revealed that Model 98, with independent variables RISK, SIZE, OCF, CoD, Z, CP, HHI, and BC, has the highest predictive accuracy with an average of 89.03%. The correlation between the absolute residuals and efficiency in this Model is negative and statistically significant at the 95% confidence level. However, the genetic algorithm results showed that the variables HHI and BC do not have a significant impact on WC. Therefore, by excluding these variables from Model 88, Model 99 is estimated using the genetic algorithm with independent variables RISK, SIZE, OCF, CoD, Z, and CP. The average predictive accuracy of this Model is 87.425%. The correlation between the absolute residuals and efficiency in this Model is negative and

statistically significant at the 95% confidence level. Adding various variables to this Model and estimating it using the genetic algorithm showed that only adding the variable LEV in Model 100 increases the Model's predictive power. In other words, Model 100, with independent variables RISK, SIZE, OCF, CoD, Z, CP, and LEV, has an average predictive accuracy of 88.495% (predictive accuracy of 82.88% for detecting excess working capital and 94.11% for detecting working capital shortages). The correlation between the absolute residuals and efficiency in this Model is negative and statistically significant at the 90% confidence level. Ultimately, the most appropriate Model, considering both predictive accuracy and the correlation between the absolute residuals and the efficiency level of companies' working capital, is Model 98. Therefore, Model 98 is the best Model with the dependent variable WC and the genetic algorithm.

Table 11. Model Validation Test Based on the Dependent Variable WC and Genetic Algorithm

Model	Correlation	Significance Level	Rank Based on Correlation	Accuracy of Identifying WC Surplus (%)	Accuracy of Identifying WC Deficit (%)	Average	Rank Based on Prediction Accuracy	Average Rank	Final Rank
86	-0.0075	0.7426	6	72.72	75.4	74.06	20	13	12
87	-0.0075	0.7435	7	74.33	79.67	77	15	11	7
88	-0.0007	0.9736	11	76.47	77.54	77.005	14	12.5	10
89	0.0018	0.937	16	77.54	75.4	76.47	16	16	20
90	-0.0046	0.8412	8	77.54	78.6	78.07	12	10	6
91	0.0015	0.9476	14	77.54	78.6	78.07	11	12.5	11
92	0.0012	0.9564	13	76.47	78.6	77.535	13	13	13
93	-0.0123	0.5941	5	70.05	77.54	73.795	21	13	14
94	-0.0011	0.9588	9	77	74.33	75.665	18	13.5	15
95	0.0009	0.967	12	76.47	74.86	75.665	17	14.5	19
96	0.0077	0.7383	21	73.79	76.47	75.13	19	20	21
97	0.0017	0.9398	15	80.74	78.04	79.39	9	12	9
98	-0.0475	0.0397	3	83.95	94.11	89.03	1	2	1
99	-0.0484	0.036	2	82.88	91.97	87.425	3	2.5	2
100	-0.044	0.0567	4	82.88	94.11	88.495	2	3	4
101	-0.0535	0.0205	1	81.28	93.04	87.16	4	2.5	3
102	0.003	0.8957	17	77.54	79.14	78.34	10	13.5	16
103	-0.001	0.9629	10	85.02	78.04	81.53	6	8	5
104	0.0045	0.8425	19	78.6	81.81	80.205	8	13.5	17
105	0.0033	0.8834	18	81.81	81.81	81.81	5	11.5	8
106	0.0059	0.797	20	79.14	81.28	80.21	7	13.5	18

The estimation results for Model 98 using the genetic algorithm are shown in Table (12). According to this Table, the second column, which indicates the presence in the Model, shows the variables that have a value of one and have the ability to impact working capital. The coefficient value for each variable is also shown in the second column.

Table 12. Genetic Algorithm Results for Model 98 with a Combination of Independent Variables

Initial Population Size		250 chromosomes
Crossover Rate		0.8
Mutation Probability		0.1
Stopping Criterion		The algorithm is repeated 250 times
Survival Rate of the Best Chromosome in Each Generation		0.05
Variable	Presence in Model	Coefficient
C	1	0.2584
Risk	1	0.0866
Size	1	-0.0146
OCF	1	-0.1602
CoD	1	-0.3678
Z	1	0.2595
Cp	1	0.0328
HHI	0	0.0371
BC	0	0.0112
Correlation between Absolute Regression Errors and Efficiency Level		
Correlation Coefficient		Significance Level
-0.0475		0.0397
Accuracy for Companies with Excess Working Capital		Accuracy for Companies with Shortage of Working Capital
83.95		94.11

Based on the significance of all coefficients in this section using the genetic algorithm method with the dependent variable WC, the working capital management model is as follows:

$$WC = 0.2584 + 0.0866\,Risk - 0.0146\,Size - 0.1602\,OCF - 0.3678\,CoD + 0.2595\,Z + 0.0328\,CP \quad (5)$$

In the above Model, RISK is a firm-specific risk, SIZE is the size of the firm, OCF is the level of liquidity, COD is the cost of debt rate, Z is financial health, and CP is the credit policy. In fitting Model (2) with the dependent variable CCC using the genetic algorithm, 13 models were estimated with all

independent variables, significant independent variables, and combinations of significant independent variables. The summary of the accuracy of these models based on the dependent variable CCC and the genetic algorithm, as well as the correlation coefficient between the absolute values of model errors and the efficiency level of companies, is presented in Table (13). The results showed that model 109, with the independent variables CCC1, RISK, GPM, TC, Q, OC, and EPU, has an average accuracy of 79.41%. Subsequently, by adding the variables AGE, OCF, CoD, DIV, pc, Z, roa, cp, exr, and rgdp one by one to model 109, the highest increase in accuracy was related to the variable exr in model 118. The average accuracy of model 118 is 82.08%. The correlation coefficient between the absolute values of residuals and efficiency in this Model is negative and statistically significant at the 99% confidence level. Therefore, model 118 is considered the best Model with the dependent variable CCC and the genetic algorithm. For selecting the best Model, similar to the previous section, after ranking based on correlation and accuracy, model 118 was ultimately chosen as the best Model in this section.

Table 13. Model Validation Test Based on the Dependent Variable CCC and Genetic Algorithm

Model	Correlation	Significance Level	Rank Based on Correlation	Accuracy of Identifying WC Surplus (%)	Accuracy of Identifying WC Deficit (%)	Average	Rank Based on Prediction Accuracy	Average Rank	Final Rank
107	-0.0549	0.0173	13	77.54	73.26	75.4	13	13	13
108	-0.0876	0.0001	9	77.54	78.6	78.07	8	8.5	10
109	-0.0927	0.0000	3	81.28	77.54	79.41	4	3.5	2
110	-0.0926	0.0000	4	79.67	72.19	75.93	12	8	9
111	-0.0869	0.0001	11	77.54	77.54	77.54	9	10	11
112	-0.094	0.0000	1	80.21	74.86	77.535	10	5.5	5
113	-0.0923	0.0000	5	80.21	78.6	79.405	5	5	4
114	-0.0917	0.0000	6	81.81	78.6	80.205	3	4.5	3
115	-0.0871	0.0001	10	81.81	78.6	80.205	2	6	6
116	-0.0794	0.0005	12	79.67	73.79	76.73	11	11.5	12
117	-0.0885	0.0001	8	80.21	78.07	79.14	6	7	7
118	-0.0931	0.0000	2	80.74	83.42	82.08	1	1.5	1
119	-0.0889	0.0001	7	81.28	75.4	78.34	7	7	8

The estimation results for model 118 using the genetic algorithm are shown in Table (14). According to this Table, in the second column, which indicates the presence in the Model, the variables with a value of one are capable of influencing the cash conversion cycle (working capital management), and the coefficient value for each variable is also shown in the second column.

Table 14. Results of the Genetic Algorithm for Model 118 with a Combination of Independent Variables

Initial Population Size		250 chromosomes
Crossover Rate		0.8
Mutation Probability		0.1
Stopping Criterion		The algorithm is repeated 250 times
Survival Rate of the Best Chromosome in Each Generation		0.05
Variable	**Presence in Model**	**Coefficient**
C	1	0.0708
CCC1	1	0.4662
RISK	1	-0.0816
GPM	1	0.1768
TC	1	-0.2482
Q	1	-0.0126
OC	1	0.4152
EPU	1	-0.0778
EXR	1	-0.0244
Correlation between Absolute Regression Errors and Efficiency Level		
Correlation Coefficient		Significance Level
- 0.0931		0.000
Accuracy for Companies with Excess Working Capital		Accuracy for Companies with Shortage of Working Capital
80.74		83.42

Based on the significance of all coefficients in this section, using the genetic algorithm method with the dependent variable CCC, the working capital management model is as follows:

$$CCC = 0.0708 + 0.4662\ CCC1 - 0.0816\ RISK + 0.1768\ GPM - 0.2482\ TC - 0.0126\ Q + 0.4152\ OC - 0.0778\ EPU - 0.0244\ EXR \quad (6)$$

In the Model above, CCC1 is the cash conversion cycle of the previous year (working capital management), RISK is specific risk, GPM is gross profit margin, TC is trade credit, Q is growth opportunities, OC is the operating cycle, EPU is economic policy uncertainty, and EXR is exchange rate changes.

Final Working Capital Management Models

The aim of this research is to present a model with high predictive power, meaning it can closely approximate actual observations. To provide the final working capital management model, considering the aforementioned points and using rankings based on correlation coefficient and prediction accuracy from the selected models (i.e., models 17, 85, 98, and 118) from previous

sections, it is observed that model 118 is the best Model (results in Table 15). The average prediction accuracy of model 118 is 82.08%. Model 118 has a prediction accuracy of 80.74% for identifying surplus working capital and 83.42% for identifying a deficit in working capital. The correlation coefficient between the absolute residuals and efficiency in this Model is -0.0931, which is statistically significant at the 95% confidence level. It is noteworthy that this Model is estimated using the genetic algorithm method. Additionally, various models (61 different models) with combinations of independent variables were estimated, along with the 119 calculated models, but due to their low prediction accuracy, their results still need to be presented.

Table 15. Summary of Selected Model Results

Model	Correlation	Significance Level	Rank Based on Correlation	Accuracy of Identifying WC Surplus (%)	Accuracy of Identifying WC Deficit (%)	Average	Rank Based on Prediction Accuracy	Average Rank	Final Rank
118	-0.0931	0.0000	1	80.74	83.42	82.08	2	1.5	1
98	-0.0475	0.0397	3	83.95	94.11	89.03	1	2.5	2
85	-0.0888	0.0001	2	80.74	77.54	79.14	3	2.5	2
17	-0.0535	0.0205	3	77.54	77	77.27	4	3.5	3

Based on the aforementioned points, the working capital management model, using the estimation of model 118, is presented as follows.

$$CCC = 0.0708 + 0.4662\ CCC1 - 0.0816\ RISK + 0.1768\ GPM - 0.2482\ TC - 0.0126\ Q + 0.4152\ OC - 0.0778\ EPU - 0.0244\ EXR \quad (7)$$

In the above Model, CCC1 is the cash conversion cycle of the previous year (working capital management), RISK is the specific risk, GPM is the gross profit margin, TC is the trade credit, Q is the growth opportunities, OC is the operating cycle, EPU is the economic policy uncertainty, and EXR is the exchange rate changes.

Conclusion

Recent changes in the global economy, the introduction of new technologies into production, competitive strategies in free markets, and the expansion of international markets have altered the perspective on working capital management. Managers have shifted their focus from long-term investments and vision to the current section of the balance sheet. When financial needs arise, companies prefer to change their operational cash flow management

policies rather than seek long-term financing. Unfortunately, for many years, working capital management has been overlooked due to excessive efforts to change short-term policies compared to increasing profits. Given the recent developments mentioned and the efforts of companies to explore different methods of financing their activities, along with the resultant profitability and risk, the importance of effective working capital management has become more evident. In developed economies, not only large corporations but especially medium and small-sized enterprises have recognized the role that working capital can play in creating integrated management. The contribution of this research is to provide a working capital management model for companies listed on the Tehran Stock Exchange. The proposed Model determines the expected level of working capital for a company in such a way that it can create the highest value with that level of working capital. Additionally, this Model can be used to measure the efficiency of working capital management by considering the difference between the actual level of working capital and the expected level as an indicator of inefficiency in working capital management.

In this context, by reviewing related studies and aligning them with theoretical foundations, 28 factors affecting working capital management were identified. After fitting a total of 119 models using regression and genetic algorithms and determining the diagnostic accuracy of the extracted models for companies with surplus and shortage of working capital, the most appropriate models were extracted. In analyzing the above findings, it should be noted that larger company size, a larger economic scale, and greater supply chain coordination impact working capital. This indicates that smaller companies must maintain relatively high levels of inventory to benefit from volume discounts and expect relatively unstable sales. The lack of managerial skills and sufficient human resources in small companies can reinforce these limitations and, as Diaz and Sensini (2020) state, lead to a strategic approach that is different from competitive dynamics. Another reason could be that small companies offer more trade credit to ensure product quality. The above findings are consistent with the results of Banos-Caballero et al. (2010), Peel and Wilson (1996), Howorth and Reber (2023), and Mohammadi and Yousefvand (Regarding the levels of operating cash flow, the findings indicate that companies with lower operating cash flow invest more in working capital, and vice versa. This can be interpreted as companies with less capacity for internal financing holding lower levels of current assets. These results contrast with the findings of Chiou et al. (2006), Hill et al. (2010), and Afrifa (2016). According to the findings, financial leverage, the cost of debt rate, and credit policy are also influential variables on the appropriate level of working capital.

In fact, since credit and access to capital markets are important determinants in trade credit extended by vendors, the use of trade credit, which leads to a longer accounts receivable conversion period, can provide companies with good access to financial credits a competitive advantage over those with more limited access.

Additionally, companies usually offer their products and services on credit to remain competitive in the market. However, credit sales create receivables, and a company must have a suitable credit policy that ensures timely collection and a realistic credit policy for its customers. Generally, a credit policy is implemented through the average collection period, which is influenced by multiple factors. With this interpretation, it is evident that if a company follows a liberal credit policy, it requires more working capital, while if it follows a strict or short-term credit policy, it must manage with lower levels of working capital. These findings align with the results of Niskanen et al. (2022) and Mohammadi and Yusefvand (2020). Another influential variable is the company's specific risk. It is evident that a company's specific risk compels managers to think more deeply about working capital policies and maintain suitable flexibility during crises to ensure the continuity of their company's operations. In today's complex and challenging business environment, where companies face risks, managers have a crucial responsibility in deciding on their company's working capital policies. It is clear that specific risks can be controlled and managed by implementing effective policies, including appropriate working capital policies. Therefore, companies with excess working capital may have to pay higher interest costs and bear greater specific risks. In other words, the appropriate level of working capital for companies varies across different markets and is significantly influenced by prevailing economic conditions and the company's specific risks. Consequently, managers adopt strategies that enable them to manage these risks effectively. Furthermore, financial health plays an important role in determining the optimal level of working capital for a company. A company that continuously meets its short-term obligations, including timely payment of salaries, procurement of essential raw materials, and coverage of other operational costs, can strengthen the confidence of investors and lenders. This, in turn, facilitates easier access to financial resources and reduces borrowing costs.

It is evident that proper working capital management optimizes operational cash flow, debt repayment, and profitability, shaping the future of a company during shocks like COVID-19 and ongoing economic recessions. Efforts to align the level of working capital (proper working capital management) require a systematic approach to address all elements of working capital, a dedicated

task force to unlock short-term potentials rapidly, and a carefully considered transformation to integrate net working capital management as an integral part of the company's operations. In today's economy, which constantly presents a changing landscape, a strategic approach to working capital management is more crucial than ever. Generally, excess working capital can indicate inefficient asset management, while a shortage can lead to operational cash flow problems and potential business disruptions. In this context and based on the findings of this study, the following suggestions are proposed: The proposed Model, having undergone a thorough screening of all influential factors, is a suitable and localized model for companies listed on the Tehran Stock Exchange. It can serve as a solid foundation for determining the appropriate level of working capital by the company's management, aiding in short-term planning, gaining competitive advantage, and creating value. Additionally, from the shareholder's perspective, the Model can be used to review and evaluate the critical position of working capital in achieving investment goals and controlling operational cash flow. Efficient working capital management can contribute to higher profitability by optimizing inventory holding costs and managing receivables to ensure timely cash flows. Effective management of receivables is often positively perceived by investors, indicating a company's ability to convert sales into cash and efficiently manage its financial resources.

Additionally, given that access to financial markets is essential for working capital management and that developing economies (such as Iran) often have relatively inefficient markets, less developed infrastructure, and fewer requirements for precise disclosures, legislators and policymakers, especially in Iran's financial markets, can use these findings to assess the impact of key variables on companies' working capital management and consider appropriate supportive measures or policy adjustments. Policies such as improving credit availability and developing diverse financing tools can help companies access funding at reasonable costs, positively impacting working capital management. Moreover, lenders can use the above Model to reassess their credit risk models and lending criteria by considering the appropriate levels of working capital observed in companies. Our findings also convey to active companies that they can adopt conservative working capital strategies to maintain a stronger financial position and improve operational cash flow during economic uncertainty. However, the specific strategies adopted by companies may vary depending on the economic conditions and policies of each country.

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