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Sustainable ERP Systems: A Green Perspective

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Abstract **–** Sustainability has become a top priority for industries today. Businesses require a centralized system for sustainable management. These platforms, which use systems for sustainability, are called Sustainable Enterprise Resource Planning (S-ERP) systems, aligning environmental and social impacts with corporate processes to achieve sustainable goals. Cloud-based technologies form the foundation of S-ERP systems. Cloud technology enables energy savings and facilitates information sharing, allowing for effective management of the system. Cloud computing reduces carbon footprint and lowers operational costs. Reducing electronic waste, also known as e-waste, is important for recycling and reuse. Digital platforms improve waste management and facilitate the collection and analysis of product performance data. Acting quickly is important for the sustainability of the supply chain, and green supply chain management consists of various dimensions: internal environmental management, external environmental management, investment recovery, and eco-design. Carbon footprint decreases with the implementation of Circular Economy (CE), optimizing energy consumption and improving waste management. Digital tools transform business models. Supply chain management (SCM) and green supply chain are also important. Implementing environmental policies and criteria is effective. Sustainability indicators are considered as an absolute measurement tool that can be used to assess not only environmental performance but also social and economic performance. This study examines ERP systems and software, sustainability, and supply chain relationships, and compares current ERP with sustainable ERP from a green perspective using CO2 consumption as a measure.

Keywords – ERP, Sustainable-ERP, SMAC, Carbon Footprint, *Green Supply Chain Management:*

I. INTRODUCTION

The importance of sustainability was first recognized by the Brundtland Commission, the Rio Earth Summit, and other international conferences. Businesses, on the other hand, require a management system that integrates all key functions, connects the sustainable management functions of practitioners, and enables the monitoring of business resources, operations, and status through a central database and platform. In this regard, the sustainability perspective in Enterprise Resource Planning (ERP) aims to manage, report, and align corporate processes, people, and products with environmental and social impacts to provide a holistic approach for businesses [1].

From the perspective of Information Technology (IT), a resource becomes more important than its advantages when the risks it poses outweigh its value for competitive advantage. In business organizations, the Mission, Vision, and Values (MVV) definitions determine the business strategies at the highest level of decision-making. Strategy planning, which translates these definitions into a set of performance metrics in four interconnected balanced perspectives such as finance, customer, learning and growth, and internal business processes, is carried out using the Balanced Scorecard (BSC) method, which supports actions and key issues. In order to make the business and its environment sustainable and future-oriented, the

use of the Social, Mobile, Analytic, and Cloud (SMAC) structure is generally observed [2].

This study addresses ERP systems and software, sustainability, and supply chain relationships, and finally compares the differences between current ERP and sustainable ERP with green perspective using CO_2 consumption.

II. Materials and Method

A. SMAC and ERP Systems

ERP systems have also been influenced by the evolving technological infrastructure. Particularly, it has been observed that the impact of the SMAC approach enhances productivity on business processes and goals on the path to Industry 4.0. From this perspective, the relationship between the disruptive technology of the SMAC approach and ERP, which leads to a transformation of traditional business models, is depicted as an information technology interface in Figure 1.

According to Figure 1, traditionally, ERP encompasses Customer Relationship Management (CRM) and Human Resources Management (HRM) as its core solution areas. However, thanks to the SMAC approach, it includes four main elements: smart mobile devices and applications, high-speed mass communication cycles, intelligent predictive Customer, Machine, and Process interfaces, as well as interfaces for Business Partners and Employees [2].

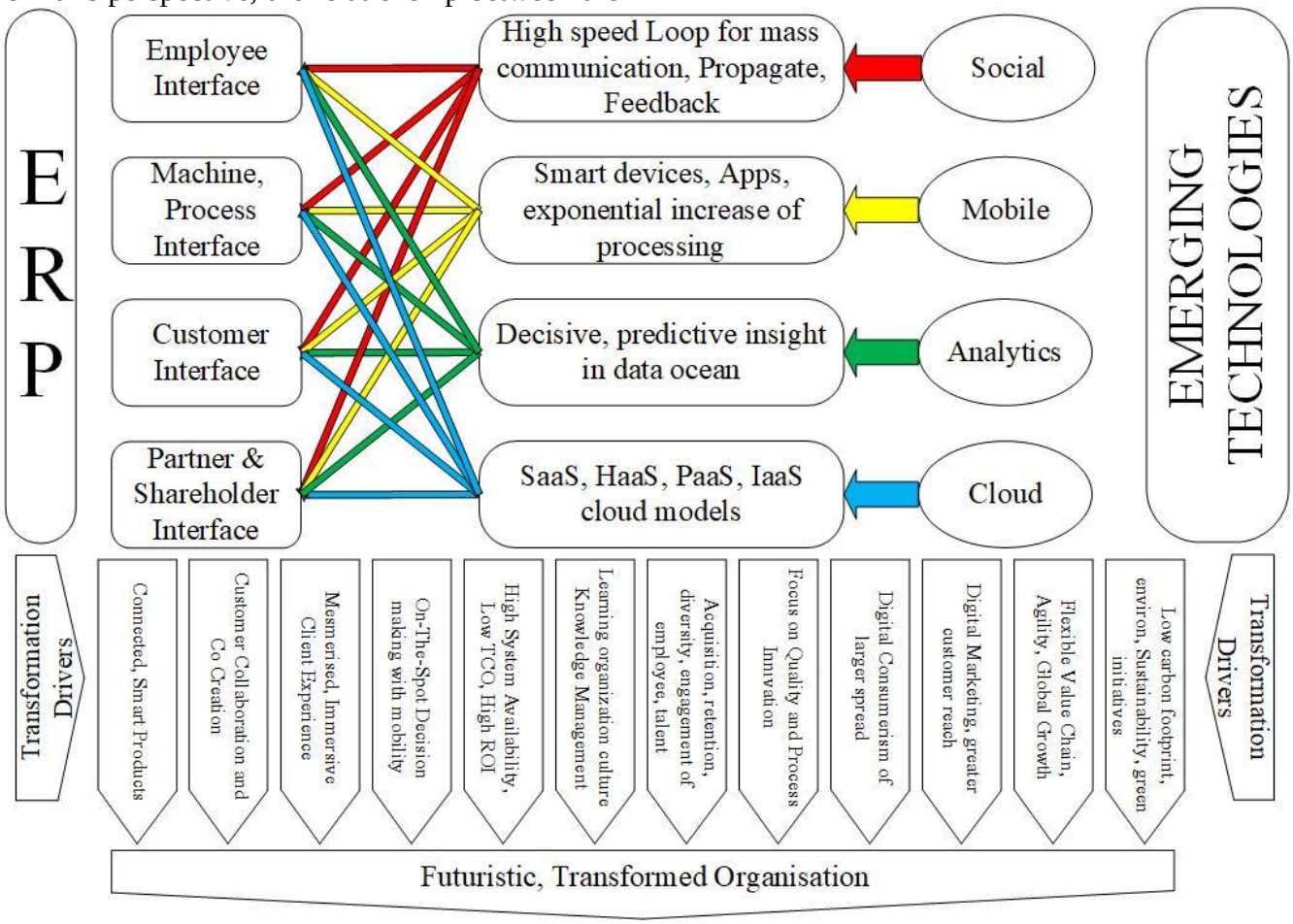

Fig. 1 SMAC-ERP Eco-System [2]

In the Sustainable ERP (S-ERP) process, corporate processes should be implemented to align employees and products with corporate sustainability goals and requirements. In this process, the impact of Cloud Computing as a component of the SMAC framework on the circular economy is illustrated in Figure 2.

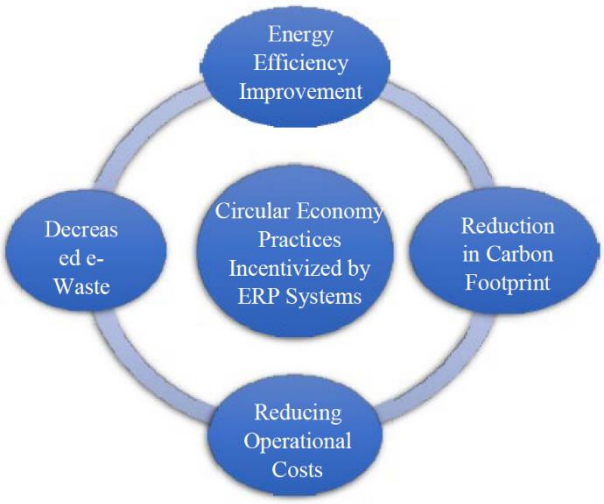

Fig. 2 Cloud Computing Effects on CE [3]

According to Figure 2, the advantages of ERP transformation in the Circular Economy (CE) can be seen in improving energy efficiency, reducing carbon footprints, facilitating e-waste management practices, and lowering operational costs. Another aspect of promoting through Cloud ERP is represented by the reductions in carbon footprints [3, 4].

The benefits brought by cloud computing employment are known to have an impact on energy efficiency and reducing carbon emissions by businesses [5]. An analysis conducted using a mathematical model developed to assess the impact of widespread adoption of cloud computing solutions in 11 countries worldwide revealed that approximately 4.5 million tons of CO_2 emissions could be reduced through the significant adoption of cloud computing solutions [6].

ERP software like as Microsoft Dynamics 365 and SAP4Hana, in line with sustainability principles, first and foremost, typically utilizes cloud-enabled technology, thereby freeing up space for server location. Secondly, it can provide energy and power savings due to the constant need for cooling. Thirdly, the implementation of S-ERP systems can help reduce the carbon footprint. Fourthly, by enabling information sharing across the organization with an accessible facility, the system can minimize waste with less pressure. Fifthly, the implementation of S-ERP system can enhance the quality of stakeholder engagement as it can provide real sustainability reporting and facilitate collaboration and communication through information sharing [1]. Then, "E-waste" refers to electronic products that have reached the end of their life cycles. Especially various electronic components, as a result of the rapid pace of technological advancement, can serve as raw materials for other industries due to their high sensitivity to becoming waste [7]. Furthermore, the use of advanced IT tools can significantly improve waste management and support recycling or reprocessing operations by providing information on shared products distributed through digital platforms [8, 9]. On the other hand, ERP, in response to the requirements related to the sustainability of the supply chain, will enable all users of the system to act swiftly [10].

B. *Sustainable ERP Systems*

By implementing the concept of sustainable supply chain management in business strategies, we can highlight two main trends that can facilitate rapid growth rates: the mutation towards CE and digitization. Wholesalers and retailers play a significant role in the proliferation of CE practices due to their continuous interactions with suppliers and end consumers. As a result, CE-related applications, such as reducing carbon footprints, optimizing energy consumption in logistics, utilizing renewable energy alternatives, and increasing the use of modern waste management methods, are becoming increasingly widespread among distribution centers and wholesalers. On the other hand, the unprecedented proliferation of digital tools encompassing the supply chain has forced wholesalers to restructure their business models to enable work to be done beyond the limitations of time, space, or functions [3]. Then, Collaboration with customers for eco-design (environmentally-friendly design), collaboration with customers for cleaner production, and collaboration with customers for green packaging. Investment recovery includes the sale of excess inventory/materials, the sale of scrap and used materials, and the sale of excess capital equipment [11].

In terms of supply chain uncertainty problems, five types of supply chain flexibility have been defined: product flexibility, volume flexibility, new product flexibility, distribution flexibility, and responsiveness flexibility [12]. Besides, GSCM (Green Supply Chain Management) suggests that green supply chain management practices consist of

four main dimensions. These are Internal Environmental Management, External Environmental Management, Investment Recovery, and Eco-design [13]. In addition, During the selection process of ERP software, several criteria are used. These include system cost, vendor support, ease of use, flexibility, functionality, reliability, and technological advantage [14].

Developing indicators for sustainability assessment can be used as an absolute measurement tool to evaluate performance from different perspectives. The process of selecting appropriate indicators is considered a challenging decision-making process. Not all existing indicators can be easily applied to every industry because some indicators may be effective while others may not. These indicators are given as Table 1[15].

Table 1. Sustainability Indicators [15]

SOCIAL PERFORMANCE INDICATORS			
Internal Human Resources			
Isı1	Job opportunities	**Isı9**	Equity
Isı2	Employment compensation	**Isı10**	Diversity
Isı3	Quality of life	**Isı11**	Labor sources
Isı4	Turnover rate	**Isı12**	Health and safety practices
Isı5	Number of employee	**Isı13**	Health and safety incidents
Isı6	Labor productivity	**Isı14**	Risk working environment
Isı7	Disciplinary & security practices	**Isı15**	Career development / education
Isı8	Employee contracts	**Isı16**	Research and development
ECONOMY PERFORMANCE INDICATORS			
Financial Health		**Performance**	
Ief1	Profit	**Iep1**	Productivity
Ief2	Liquidity	**Iep2**	Market share performance
Ief3	Margin	**Iep3**	Delivery
Ief4	Revenue / Turnover	**Quality**	
Ief5	Investment %	**Ieq1**	Quality
Ief6	R.O.I	**Ieq2**	Customer complaint
Ief7	R.O.E	**Ieq3**	Product reliability
Ief8	R.O.S	**Ieq4**	Product durability
Ief9	R.O.A	**Cost**	
Ief10	Cash Flow	**Iec1**	Operating cost
Ief11	Debt	**Flexibility**	
Ief12	Cost saving	**Ied1**	Operation Flexibility
ENVIRONMENT PERFORMANCE INDICATORS			
Air Resource		**Energy resource**	
Ina1	Air emission	**Ine1**	Primary (fuel, etc.)
Ina2	Stratospheric ozone depletion	**Ine2**	Electricity
Water resource		**Ine3**	Yenilenebilir Enerji
Inw1	Water consumption	**Ine4**	Energy saved
Inw2	Refrigerant load	**Waste & Impact**	
Inw3	Discharge water / wastewater	**Inwi1**	Solid waste
Inw4	water pollution	**Inwi2**	Hazardous waste
Inw5	% of recycle water used	**Inwi3**	Toxic waste
		Inwi4	Energy waste
Land Resource		**Inwi5**	Gürültü
Inl1	Land Usage	**Inwi6**	% of defected product
Inl2	Soil Pollution	**Environmental Commitment**	
Inl3	Product İnnovativeness	**Inc1**	Green Manufacturing
Mineral & Material Resource		**Inc2**	Karbon Ayakizi
Inm1	Material Consumption	**Inc3**	6R Concepts
Inm2	Recycle İnput Material	**Inc4**	Expenses in Environment Activity

III. RESULTS

In the scientific literature, among the sustainability indicators [15]:

• Among the social performance indicators, the most mentioned indicator is career development/education. Career development and education are considered important as they positively influence the skill and knowledge development of employees. The other most mentioned indicators are employment compensation, turnover rate, health and safety practices, and health and safety incidents.

• Among the economic performance indicators, the most mentioned indicator in the literature is Iec1 (operating cost). Operating cost includes all costs under production operations such as material cost, overhead cost, inventory cost, and others. Following that, profit, investment percentage, customer complaints, and turnover are mentioned.

• Among the environmental performance indicators, the most mentioned indicators in the literature are water consumption and electricity. Air emissions and primary energy follow.

IV. CONCLUSION

Information technology creates risks rather than providing competitive advantages. To establish a sustainable and future-oriented framework, the use of social, mobile, analytics, and cloud (SMAC) technologies is recommended. SMAC-based ERP solutions, offered as a service model such as SaaS/HaaS/PaaS/IaaS, offer opportunities for cost reduction and innovative solution development. S-ERP systems are used to manage environmental and social impacts, report and align corporate processes, people, and products with sustainability goals. The implementation of S-ERP systems requires effective planning to provide a holistic approach. The SMAC-ERP ecosystem represents a structure that combines the SMAC stack architecture with ERP interface columns, demonstrating the emergence of competitive advantages and modern organizational transformations. Implementing S-ERP systems contributes to making an organization more sustainable. Cloud-based nature of these systems frees up server space, saves energy and power, reduces carbon footprint, facilitates information sharing and collaboration, and improves the quality of stakeholder engagement. The use of cloud computing solutions enhances energy efficiency, facilitates e-waste management, and reduces operational costs. Adopting cloud computing services for small businesses reduces infrastructure investments and energy-related expenses, thus lowering operational costs. Cloud-based ERP solutions also reduce e-waste and have positive environmental impacts. These solutions improve waste management, promote recycling and reuse, embrace circular economy principles, and enable rapid response to sustainability requirements in the supply chain. Green Supply Chain Management (GSCM) practices include internal environmental management, commitment of top-level executives to GSCM, support of mid-level managers for GSCM, collaboration of multidisciplinary or interdisciplinary teams for environmental improvements, total quality environmental management, ISO 14001 certification, and environmental management systems. External environmental management includes providing design specifications to suppliers that include environmental requirements, collaborating with suppliers for environmental goals, conducting environmental audits of suppliers, and ensuring suppliers have ISO 14000 certification. Eco-design encompasses collaborating with customers for environmentally friendly design, collaborating with customers for cleaner production, and collaborating with customers for green packaging. Additionally, the investment recovery dimension includes selling excess inventory/materials, selling scrap and used materials, and selling excess capital equipment. Eco-design involves practices such as product design for reduced material/energy consumption, reuse, and recycling, and design for material and component recovery. Various potential areas exist to advance the functioning of S-ERP systems. These areas consist of efforts focused on system development, evaluation, implementation, and success, which can contribute to the development of sustainable supply chain management and clean production practices to help businesses achieve their sustainability goals. To successfully implement S-ERP systems, it is necessary to develop functional capabilities, strengthen management skills, enhance implementation capabilities, and utilize technological capabilities. Among the most mentioned economic performance indicators are operating costs, profit, return on investment, revenue, and customer complaints. These indicators can be effective in evaluating a business's financial health, investment potential, and customer satisfaction. Social performance indicators include career development/training, employee compensation, turnover rate, health and safety practices, etc. These indicators play a significant role in assessing employee skill and competency development, working conditions, and occupational safety. Environmental performance indicators include water consumption, electricity consumption, air emissions, energy use, and waste management. These indicators can serve as important criteria for evaluating a company's use of natural resources, energy efficiency, and

environmental impacts. It is important to use economic, social, and environmental indicators to assess sustainability performance. These indicators can guide businesses in achieving sustainability goals and improving their performance. However, the selection and use of indicators should be done carefully, taking into account sectoral differences. Information technology is now creating risks instead of providing competitive advantages.

Green Supply Chain Management (GSCM) encompasses internal and external environmental management, eco-design, and investment recovery. These practices aim to meet environmental requirements, collaborate with suppliers, and reduce energy and material consumption.

To successfully implement S-ERP systems, it is necessary to develop functional capabilities, strengthen management skills, and leverage technological capabilities.

The use of economic, social, and environmental indicators is important for assessing sustainability performance. These indicators can guide businesses in achieving sustainability goals and improving their performance, but sectoral differences and careful selection of indicators are important.

In conclusion, this study encourages businesses to effectively use information technologies and S-ERP systems to achieve their sustainability goals. It is also important for businesses to select appropriate indicators to evaluate their economic, social, and environmental performance. The findings of this study can provide guidance for businesses to develop sustainability strategies and monitor their sustainability performance.

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