**ORGANIZATIONAL BIOMIMICRY: HOW ORGANIZATIONS CAN BENEFIT FRIM ANT COLONIES?**

Dr. Ayşe Meriç Yazıcı, Lund University, [ayse.meric@bmsis.org](mailto:ayse.meric@bmsis.org), <https://orcid.org/0000-0001-6769-2599>

**ABSTRACT**

Business management is an interdisciplinary field under the influence of many areas, including both natural sciences and social sciences. Biomimicry is a scientific field focusing on nature, models, systems, and processes to find inspiration for human problems. Ant colonies are intelligent organizations acting on collective behavior. They cooperate to function as an intelligent system. Some models, such as multiple ant colonies, show the cooperation of several systems to achieve a global goal. Collaboration in such a system optimizes overall goals in human organizations as in a corporate network. The laws that creatures living in colonies in nature abide by are also applicable to social and organizational systems. The organizational functioning of ant colonies focuses on individuality and group identity. This study analyzes biomimicry, the art, and science of imitating nature and life, from the aspect of modern organizational theory. The study also reviews the basic biological principles seen in the organization of ant colonies and the fundamentals of the decentralized nature of such systems. It also defines the mechanisms under the complex collective behavior of ant colonies, from the concept of stigmergy to the theory of self-organization in biological systems.

**Key words:** Biomimicry, ant colonies, organizational systems, stigma, biological systems.

**ÖRGÜTSEL BİYOMİMİKRİ: KARINCA KOLONİLERİNİNİN İŞBİRLİĞİNDEN ORGANİZASYONLAR NASIL FAYDALANABİLİR?**

**ÖZET**

Disiplinlerarası bir alan olan işletme yönetimi, hem doğa bilimlerinden hem de sosyal bilimlerin birçok alanından etkilenmektedir. Biyomimikri, insanların problemlerini çözmek için doğayı, modellerini, sistemlerini ve süreçlerini taklit edip, ilham alınacak unsurlarını inceleyen uygulamalı bir bilimdir. Karınca kolonileri, kolektif davranışa dayanan, doğadan ilham alan zekalardır. Karınca kolonileri, sistem içinde işbirliğini gösteren akıllı sistemlerdir ve çoklu karınca kolonileri gibi bazı modeller, küresel bir hedefe ulaşmak için birkaç sistemin işbirliğini göstermektedir. Bu tür bir sistemdeki işbirliği, insan organizasyonlarında bir kurumsal ağda olduğu gibi genel hedeflere ulaşılmasını optimize etmektedir. Doğada sürüler halinde yaşayan canlıların, sosyal ve benzer şekilde örgütsel sistemlere uygulanabilir ortak yasaları mevcuttur. Karınca kolonilerinin örgütsel işleyişinde bireysellik ve grup kimliği dikkate alınır. Bu çalışmada, teknolojik çözümler için doğayı ve yaşamı taklit etme sanatı ve bilimi olan biyomimikri, modern organizasyon teorisi perspektifinden incelenmiştir. Çalışmada ayrıca, karınca kolonilerinin organizasyonunun altında yatan temel biyolojik ilkelerin gözden geçirilip, bu tür sistemlerin merkezi olmayan doğası hakkında bazı temel bilgiler, stigma kavramından biyolojik sistemlerde kendi kendini örgütleme teorisine kadar, karınca kolonilerinin karmaşık kolektif davranışlarının altında yatan mekanizmaları tanımlanmıştır.

**Anahtar kelimeler:** Biyomimikri, karınca sürüleri, örgütsel sistemler, stigma, biyolojik sistemler.

**INTRODUCTION**

In terms of sustainability, the only accurate model is the natural world. For 3.8 billion years, nature has been offering favorable conditions for life, taking into account all the deep patterns present on Earth, offering excellent solutions for resilience and survival (Benyus, 1997). Biomimicry is an innovative approach that seeks sustainable solutions to human problems by imitating the time-tested strategies of nature (Akkaya & Yazıcı, 2020). Specifically, we can see biomimicry as a science studying the survival of living organisms in an ever-changing environment to learn the strategy patterns adaptable to human problems in the most sustainable way. Companies have been applying biomimicry principles to manage the organizational tension between product performance and environmental impact.

The question of how large groups can organize themselves effectively is not unique to human societies. Innovation at the social scale also represents a biomimicry frontier as it accelerates toward the unique challenges of modern technologically-driven societies. This new social world requires effective ways to communicate across large networks and innovative organizational approaches to produce compelling social outcomes in the community at global levels.

The organization concept is studied extensively in economics, sociology, and psychology. Creatures living in colonies act on the collective behavior of self-organizing and decentralized systems. Ants cooperate to solve a problem as a population. Every living being can perform a certain amount of tasks, as natural observation suggests. However, they have limited capacity when acting independently. Acting as a colony can help them solve complex problems more efficiently. Modern organizations can adapt how they cooperate and organize themselves as an intelligent system.

Considering that it provides the group member with a distinctive qualification, the concept of specialization is highly related to the concept of organization as it will offer greater efficiency to the organization in the pursuit of organizational goals. Such collaboration enables organizations to achieve better results by providing group members with information on the organization's environment (Román & Pérez-Delgado, 2020).

In this study, biomimicry, which is the art and science of imitating nature and life for technological solutions, is examined from the perspective of modern organizational theory. This study analyzes biomimicry, the art, and science of imitating nature and life, from the aspect of modern organizational theory. It also defines the mechanisms under the complex collective behavior of ant colonies, from the concept of stigma to the theory of self-organization in biological systems. The study also reviews the basic biological principles seen in the organization of ant colonies and the fundamentals of the decentralized nature of such systems.

1. **Living Systems Theory and Organizational Biomimicry**

Biology is the domain of ecology and all other disciplines that incorporate systems thinking into their research and practice (Iouguina, Dawson, Hallgrimsson & Smart, 2014). A system is a group of regularly interacting or interconnected elements that make up a unified whole (Arnold & Wade, 2015: 670). The systematic nature of organizations since the mid-20th century has been characterized by a combination of interrelated parts or interdependent elements (Robbins & Coulter, 2012). In short, organizations are designed both as a system and as open systems (Weber & Waeger, 2017). Systemic thinking is based on examining the whole and its parts. The systemic thinking approach enables us to understand better the movements and interrelationships that occur within the organization and between the organization and its environment as in nature (O'Connor & McDermott, 1997).

Humans, the main component of organizations, are social by nature (Aristotle, 1981), and there are life cycles in organizations. Like any living being, they are born; they grow, age, and die (Adizes, 2004). There are different views of human nature, and these beliefs about the nature and purpose of human life often lie in different lifestyles, political systems, and economic models (Stevenson, 1974). To understand organizations as a living system, we need to analyze them well, break them down into simple parts, and understand the relationships between the various parts to interpret the outcomes.

Mature ecosystems consist of different entities pursuing common goals (Benyus, 2002). Organizational biomimicry proposes a systemic approach, a worldview that sees the organization and its people as an integral part of nature, and an R&D system based on continuous learning from nature (Olaizola, Morales-Sánchez & Huerta, 2021). Mature systems have nine key points, and organizational biomimicry adapts these critical points to organizations: (1) Nature works with sunlight. (2) Nature uses only the energy it needs. (3) Nature adapts form to function. (4) Nature recycles everything. (5) Nature rewards cooperation. (6) Nature relies on diversity. (7) Nature demands local expertise. (8) Nature does not produce waste. (9) Nature benefits from the power of borders (Benyus, 1997: 8). These principles are design lessons from nature. Based on the interconnectedness and interdependence of life on Earth, nature has functioned as an organization for 3.8 billion years. Benyus refers to these vital elements since they have been critical for the survival of species so far.

Nature uses and optimizes these strategies together to create conditions for living beings. With biomimicry, it is possible to produce innovative strategies from these design courses, evaluate these strategies according to sustainability criteria in nature, and use nature as a mentor.

The concept of organizational biomimicry refers to a group, institution, or organization interacting with one other to achieve positive outcomes for the individual and the whole organization.

Organizational Biomimicry refers to a business network, an association of organizations collaborating to solve problems that they cannot solve in a way that complements each other. This concept allows us to classify and measure specialization and cooperation within and between different organizational systems.

Organizational biomimicry is a powerful tool for sustainable innovation. For organizations, biomimetic solutions are often disruptive innovations considered a threat to established competitors. Therefore, market entrants need to identify mutually beneficial ways of working with industry players while entering a market ecosystem.

1. **Ant Colonies and Organizational Flow**

The primary objective of ants is to find an optimal path between the food source and the nest. Each path ants create represents a potential solution to the problem, which reflects the collective intelligence of the ants (Dorigo, Maniezzo & Colorni, 1996). Most ants have underdeveloped visual sensitivity, and some ants are entirely blind. The communication between ants is through the use of chemicals they produce. As these chemicals, called pheromones, walk from the food source to the nest or vice versa, the ants leave the pheromones on the ground, forming a pheromone trail. Ants can smell the pheromone and tend to take paths marked by potentially strong pheromone concentrations. The more ants follow a trail, the more attractive that trail becomes to other ants (Manju & Kant, 2013). There is an interesting analogy for these characteristics of ants, especially for teamwork in organizations. It is possible to analyze the interactions between people who organize themselves to achieve a common goal in terms of colony intelligence. Perhaps the most substantial insight from colony intelligence is that complex collective behaviors can emerge from individuals following simple rules (Bonabeau & Meyer, 2001). Harmony is the essence of how nature works. An organism must somehow fit into its ecosystem by exchanging values with other organisms or with its environment, which is also the case in the business environment. The early stages of business planning and innovation require harmony between the value and the customer.

Social insects can also teach a lot about innovation and leadership. Their foraging strategies suggest a balance between using existing resources and seeking out new ones. These strategies suggest an emerging and democratic decision-making process and collective support for chosen options (Bonabeau & Meyer, 2001). The ant workforce is self-managed by adapting to local conditions without the oversight of supervisors or any hierarchy of control (Davidow & Malone, 1992). Southwest Airlines had some problems in cargo operations for a while. The average aircraft used only 7% of the cargo space. Some airports did not have sufficient capacity to accommodate scheduled loads, causing Southwest Airlines' cargo routing and transport systems problems. Southwest Airlines used an ant-based simulation model to track aircraft to increase the efficiency of aircraft routes, informing each agent about its path and the paths of other agents, such as the pheromone trails left by ants. Southwest Airlines have found that if they wanted to send a package from Chicago to Boston in the first place, it might be more efficient to leave it on a flight to Atlanta and then back to Boston, and then put it on the next flight to Boston. This prediction has reduced the freight transfer rate by up to 80% at the busiest cargo stations. It reduced the workload of cargo carriers by up to 20% and significantly reduced the number of overnight transfers. Southwest Airlines also generated more than $10 million in annual revenue while allowing it to cut cargo storage facilities and minimize fare costs. Similar research into the behavior of ants has helped many companies, including Unilever, McGraw-Hill, and Capital One, develop more efficient ways to plan factory equipment, divide tasks among workers, organize people, and even plan strategies. (Bonabeau & Meyer, 2001).

Social insects live in self-organizing groups without central control. Ants tend to contribute to the current task, and many individual decisions of ants affect the division of labor of the colony. An ant's location also determines with whom it will interact. Ants represent a significant mode as they rely heavily on interactions in their subsequent decisions towards collective colony targets. The Spatio-temporal distribution of ants is an essential component of the collective behavior in the colony (Heyman, Shental, Brandis, Hefetz & Feinerman, 2017).

Ant colonies encode simple learning, unlike humans' complex learning processes and problem-solving approaches. Ants learn primarily by trial and error. However, they lack more complex processes such as systematic parallel experimentation, rapid-batch experimentation, and passive learning that require timing and coordination to reduce targeted uncertainties and accelerate knowledge acquisition (McDonald & Eisenhardt, 2020). Ant colonies also engage in modular problem solving, but not hybrid problem-solving approaches to new complex problems (Baumann & Siggelkow, 19).

* 1. **Stigmergy**

In 1959, Grassé first introduced the concept of stigmergy to explain the coordination paradox in termite mounds. How can colonies of individuals, acting with no apparent concern for the actions of others, achieve such a level of coordination and complexity in mound architecture? He sought an answer to the question. Grassé's answer to this question was that construction itself is a stimulus that triggers specific responses from workers, as it provides all the information needed to coordinate activities. Termites' stigmergy and coordination are critically dependent on the importance of the work performed as an incentive for further activity and critical mass effects that trigger behavioral steps that enable these super-intelligent creatures to still complete constructions even in the absence of stable teams (Heylighen, 2007). If social insects such as ants, bees, and termites have stigmergy at the core of their building behavior, this is a vital principle because the structures of social insects are notable for their complexity, size, and adaptive value. However, it is easily possible to extend the idea to other areas since it can be an even more compelling and general explanation of how simple systems can produce a wide range of seemingly highly organized and coordinated behaviors and behavioral outcomes simply by taking advantage of the influence of the environment (Holland & Melhuish, 1999).

Stigmergy is the revealing of certain environment-altering behaviors through the sensory effects of local environmental changes produced by the previous and past behaviors of the entire community. Stigmergy is a class of mechanisms that mediate animal-animal interactions through artifacts or indirect communication, providing a kind of environmental synergy, information gathered from ongoing work, a distributed incremental learning and memory across society. The work surface is not just where constituent units meet and interact. It is precisely where a dynamic cognitive map can allow the formation of adaptive memory, collaborative learning, and perception (Theraulaz & Bonabeau, 1999 ).

Stigmergy has been a third alternative to the traditional dichotomy of explicit and implicit coordination (Rezgui & Crowston 2018: 1). Self-organization in social insects is generally the direct or indirect interaction between insects. Direct interactions are apparent interactions, such as chin contact, visual contact, chemical contact in food, or liquid exchanges of insects. Indirect interaction is implicit since two organisms interact indirectly, changing the environment and the other responding later to the new environment (Ajith & Crina, 2006: 3).

The fundamental mechanism for social group organization is the stigmergy (Heyman et al., 2017). Stigmergy is achieved through indirect agent interaction, whereby agents change the environment, acting as an external memory. Thus, work can be continued by any person, depending on the actual state of the environment. On the other hand, the same simple code of conduct can create different designs (Bonabeau, Dorigo & Theraulaz, 1999: 14). Stigmergic processes can be an ideal model for information management systems. It is possible to analyze the new Enterprise 2.0 technology from such a perspective. Insights from stigma research can help adequate systems enforce knowledge sharing and acquisition (Schatten, Bača & Ivanković, 2009).

* 1. **Self-Sufficient Organization**

Biomimicry is the search for design inspiration from the natural world (Yazıcı, 2020; Yazıcı & Kınay, 2021). Innovation also represents a frontier of biomimicry, especially as it rapidly moves towards the unique challenges of modern technologically driven and interconnected societies. In this new social world, effective ways of communicating across vast networks and innovative organizational approaches produce effective social outcomes in the community at global levels. The question of how large groups can organize themselves effectively is, of course, not unique to human societies. Social insects, especially ants, termites, and honey bees, have lived in large complex societies for about 200 million years (Hölldobler & Wilson, 2009). Social insect colonies vary considerably in size and degree of social complexity. Ant colonies range from a few dozen individuals to millions (Bourke & Franks, 1995). The tremendous ecological success of social insects such as ants manifested in their diversity and biomass is due to the complex organization of their society based on a clear division of labor (Novgorodova, 2015).

Decentralization and centralization are opposite strategies for the spatial organization of workers and resources. In central systems, resources are on a single site. In decentralized systems, resources are distributed across multiple sites. Decentralization and centralization have many interactive costs and benefits that make it difficult to determine which should be adapted in a given context. Ant colonies are a potential source of insight for trade-offs between centralization and decentralization. The workforce and resources of most ant colonies are concentrated in a single nest, known as a monodome. However, some ant species decentralize their colonies by dividing into several semi-autonomous subgroups that live in multiple nests, known as polydome. Decentralization through polydome provides several benefits to colonies. These benefits include: 1) reducing the risk of colony extinction through the risk of spread; 2) ensuring that colonies exceed population limits imposed by structural or organizational limitations on nest size; 3) improving colony foraging and defense by well-dispersed anthills throughout the collection area; 4) buffering the effects of local environmental variability; and 5) enabling colonies to benefit from a large colony size without associated reductions in productivity (Burns, Pitchford, Parr, Franks & Robinson, 2019).

The phenomenon of self-organization is not a natural feature of purpose-built and spontaneously formed systems. Instead, specific requirements must be met, such as reduced formalization, decision delegation, and self-coordination (Brueckner & Czap, 2006). Self-organization is a process in which patterns at the global level of a system emerge only from the myriad interactions between lower-level components of the system. In addition, the rules determining the interactions between system components are executed via only local information without reference to the global pattern (Camazine, Deneubourg, Franks, Sneyd, Theraulaz & Bonaneau, 2001: 8).

Many structures built by social insects result from a process of self-organization where the repeated actions of insects in the colony interact with the time-varying physical environment to create a characteristic end state (Holland & Melhuish, 1999). Ant colonies have developed the ability to self-organize without leadership and decision hierarchy (Camazine et al., 2001: 8). Evaluations by ants regarding the labor demands of the colony vary, but they follow a collective sense while making a choice.

This method of job seeking enables a colony to redistribute labor effectively in response to ever-changing conditions without the need for supervision. A result of more significant information flow in large colonies is that they are more stable (homeostatic) in the long run than small colonies, allowing them to bounce back from environmental or economic disturbances. In self-organization, components interact locally without an overview of the pattern or process. Also, there are no managers who organize the system by monitoring and communicating information about the status of the global model (Franks & Deneubourg, 1997).

**CONCLUSION**

Nature has inspired man since the beginning of history. This study summarizes several nature-inspired concepts that have led to significant advances in the theory and practice of modern organizational structures. It is seen that biomimicry, which is the art and science of imitating nature to reach solutions, has an important application area in contemporary social sciences, especially in modern organizational theory. In technology and information systems, a biomimetic application is achieved by mimicking biological systems' (primarily physical) properties. Most biomimetic practices in modern organizations deal with metaphors. However, in the cases shown, there are implications that nature's structures are self-replicating in social and organizational systems. The use of metaphors is probably the first step in creating a more concrete application of biomimetics in organizational theory. The development of such applications can provide us with a suitable basis for understanding, analyzing, and optimizing modern organizations.

**KAYNAKÇA**

Adizes, I. (2004). *Managing Corporate Lifecycles.* Adizes Institute Pub: Santa Bárbara, CA, USA.

Ajith, A., & Crina, G. (2006). *Stigmergic Optimization: Inspiring Technologies and Perspectives Stigmergic Optimization.* Springer Berlin Heidelberg.

Akkaya, B., & Yazıcı, A. M. (2020). Comparing Agile Leadership With Biomimicry-Based Gray Wolf: Proposing A New Model. *Business Management Studies: An International Journal*, 8(2):1455-1478. https://doi.org/10.15295/bmij.v8i2.1480

Aristotle. (1981). *The Politics*, Penguin Books: London, UK.

Arnold, R. D., & Wade, J. P. (2015). A definition of systems thinking: A systems approach. *Procedia Comput. Sci.,* 44, 669–678. <https://doi.org/10.1016/j.procs.2015.03.050>

Baumann, O., & Siggelkow, N. (2013). Dealing with complexity: integrated vs. chunky search processes. *Organ Sci.,* 24(1):116–132.

Benyus, J. (1997). *Biomimicry: Innovation Inspired by Nature*. HarperCollins: New York, NY, USA.

Benyus, J. (2002). *Biomimicry: innovation ınspired by nature*. New York: Perennial.

Bonabeau, E., Dorigo, M., & Theraulaz, G. (1999). *Swarm Intelligence – From Natural to Artificial Systems*. Oxford University Press.

Bonabeau, E., & Meyer, C. (2001). Swarm Intelligence – A Whole New Way to Think About Business. Harvard Business Review, [Erişim Tarihi: 01.05.2022], <https://hbr.org/2001/05/swarm-intelligence-a-whole-new-way-to-think-about-business>

Bourke, A. F., & Franks, N. R. (1995). *Social evolution in ants*. Princeton: Princeton University Press.

Brueckner, S., & Czap, H. (2006). Organization, Self-Organization, Autonomy and Emergence: Status and Challenges. *Int. Trans. Syst.Sci.Appl.,* 2, 1-10.

Burns, D. D. R., Pitchford, J. W., Parr, C. L., Franks, D. W., & Robinson, E. J. H. (2019). The costs and benefits of decentralization and centralization of ant colonies, *Behavioral Ecology,* 30(6), 1700-1706. Doi:10.1093/beheco/arz138

Camazine, S., Deneubourg, J., Franks, N. R., Sneyd, J., Theraulaz, G., & Bonabeau, E. (2001). *SelfOrganization in Biological Systems*. Princeton, NJ: Princeton University Press.

Davidow, W. S., & Malone, M. S. (1992). *The Virtual Corporation: Customization and instantaneous response in manufacturing and service*. New York: Harper-Collins Publishers.

Dorigo, M., Maniezzo, V., & Colorni, A. (1996). Ant System: Optimization by a Colony of Cooperating Agents. *IEEE Transactions on Systems, Man, and Cybernetics-Part B*, Vol. 2, No. 1, pp. 29-41. DOI:10.1109/3477.484436

Franks, N. R., & Deneubourg, J. L. (1997). Self-organizing nest construction in ants: individual worker behaviour and the nest’s dynamics. *Anim. Behav*., 54, 779-796. DOI:10.1006/anbe.1996.0496

Grassé, P. P. (1959). La reconstruction du nid et les coordinations interindividuelles chezBellicositermes natalensis etCubitermes sp. la théorie de la stigmergie: Essai d'interprétation du comportement des termites constructeurs. *Insectes sociaux*, 6(1), 41-80.

Heylighen, F. (2007). Warum ist Open-Access Entwicklung so Erfolgreich?. B. Lutterbeck, M. Baerwolff & R. A. Gehring (Eds.), *Why is Open Source Development so Successful? Stigmergic organization and the economics of information* (ss. 165-180). Open Source Jahrbuch Lehmanns Media. <https://doi.org/10.48550/arXiv.cs/0612071>

Heyman, Y., Shental, N., Brandis, A., Hefetz, A., & Feinerman, O. (2017). Ants regulate colony spatial organization using multiple chemical road-signs. *Nature Communications*, 8, 15414. DOI:10.1038/ncomms15414

Holland, O., & Melhuish, C. (1999). Stimergy, Self-Organization, and Sorting in Collective Robotics. *Artificial Life,* 5(2): 173-202. DOI:10.1162/106454699568737

Hölldobler, B., & Wilson, E. O. (2009). *The superorganism: The beauty, elegance, and strangeness of insect societies*. New York: WW Norton & Company.

Iouguina, A., Dawson, J. W., Hallgrimsson, B., & Smart, G. (2014). Biologically Informed Disciplines: A Comparative Analysis of Bionics, Biomimetics, Biomimicry, and Bio-Inspiration Among Others. *Int. J. of Design&Nature and Ecodynamics*, Vol. 9, No. 3, 197-205. DOI:10.2495/DNE-V9-N3-197-205

Manju., & Kant, C. (2013). Ant Colony Optimization: A Swarm Intelligence based Technique. *International Journal of Computer Applications*, Volume 73, No, 10. DOI:10.5120/12779-9387

McDonald, R. M., & Eisenhardt, K. M. (2020). Parallel play: Startups, nascent markets, and efective business-model design. *Administrative Science Quarterly*, 65, no. 2, 483–523.

Nicolis, G., & Prigogine, I. (1977) *Self Organization in Nonequilibrium Systems— From Dissipative Structures to Order through Fluctuations*. Wiley, New York.

Novgorodova, T. A. (2015). Organization of honeydew collection by foragers of different opecies of ants (Hymenoptera: Formicidael): Effect of colony size and species specificity. *Eur. J. Entomol.,* 112(4): 688-697. Doi:10.14411/eje.2015.077

O’Connor, J., & McDermott, I. (1997). *The Art of Systems Thinking: Essential Skills for Creativity and Problem Solving*. Thorsons: San Francisco, CA, USA.

Olaizola, E., Morales-Sánchez, R., & Huerta, M. E. (2021). Biomimetic Leadership for 21st Century Companies. *Biomimetics,* 6, 47. https://doi.org/10.3390/biomimetics6030047

Rezgui, A., & Crowston, K. (2018). Stigmergic coordination in Wikipedia. *OpenSym*, 18, August 22-24, Paris, France. DOI:https://doi.org/10.1145/3233391.3233543

Robbins, S.P., & Coulter, M. A. (2012). *Management*. 11th ed., Pearson/Prentice Hall: Upper Saddle River, NJ, USA.

Román, J. A., & Pérez-Delgado, M. L. (2020). A Proposal for the Organisational Measure in Intelligent Systems, *Appl. Sci.,* 10, 1806. DOI:10.3390/app10051806

Schatten, M., Bača, M., & Ivanković, M. (2009). Public Interfaces as the Result of Social Systems Structural Coupling. *1st International Conference on Information Society and Information Technologies ISIT*, Dolenjske Toplice.

Stevenson, L. (1974). *Seven Theories of Human Nature*. Oxford University Press: Oxford, UK.

Theraulaz, G., & Bonabeau, E. (1999). A Brief History of Stigmergy. *Artificial Life*, 5(2): 97-116. DOI:10.1162/106454699568700

Weber, K., & Waeger, D. (2017). Organizations As Polities: An Open Systems Perspective. *Academy of Management Annals*, Vol. 11, No. 2, 886-918. https.//doi.org/10.5465/annals.2015.0152

Yazıcı, A. M. (2020). Biomimicry and Agile Leadership in Industry 4.0. A. Bülent (Eds.), *Agile Business Leadership Methods for Industry 4.0* (s.155-170). Emerald Publishing. doi:10.1108/978-1-80043-380-920201010.

Yazıcı, A. M., & Kınay, M. (2021). How Biomimicry Inspires Robotics For Space Research. *Havacılık ve Uzay Çalışmaları Dergisi*, 1(2), 64-77.