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Empirical Approaches Regarding Interdependency between Technology and Sustainable Tourism

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Abstract:

The use of technology has transformed the tourism industry, enabling travelers to search for and book travel online, as well as access information about destinations and activities through websites, social media, and mobile apps. Technology has the potential to promote sustainable tourism practices, while sustainable tourism can, in turn, drive the development and adoption of new technologies. This paper intends to be an overview about empirical approaches regarding the interdependency between technology and sustainable tourism involve studying real-world data and conducting empirical research to understand how technology influences and contributes to sustainable tourism practices. These approaches aim to analyze the impact of technological advancements on various dimensions of sustainability in the tourism industry. Then, it discusses the role of tech and tourism in achieving the goals of sustainable development, identifies different technologies, including data-driven, artificial intelligent, agent-based modeling, that are being used to promote sustainable tourism practices.

Keywords: sustainable development goals (SDGs); tourism, sustainability; travel experience; technology.

JEL Classification: O14; Q01; Z32.

Introduction

Technology and sustainable tourism are closely interdependent. Technology can provide valuable data on tourist behavior and preferences, helping tourism organizations and local governments make informed decisions about infrastructure, policies, and regulations that promote sustainable tourism practices. This can help reduce the impact of tourism on natural and cultural resources, promote the well-being of local communities, and foster a more sustainable tourism industry. By working together, these two fields can help create a more sustainable and responsible tourism industry.

The interdependency between these 2 keys factors is significant and growing. Virtual and augmented reality technologies can reduce the environmental impact of tourism by allowing visitors to experience destinations virtually. This reduces the need for physical travel, which can help preserve natural and cultural resources. Virtual and augmented reality technologies can also enhance the tourism experience, making it more engaging and immersive. These technologies are also enabling the collection and analysis of data on tourist behavior and preferences, which can inform the development of sustainable tourism policies and practices.

Tourists can use mobile apps to locate and rent sustainable transportation options (electric cars, buses, and bikes), and smart city technologies can help reduce congestion and improve traffic flow. Smart thermostats, lighting systems, and energy-efficient appliances can help reduce energy waste and costs. Moreover, renewable energy sources such as solar panels and wind turbines can help power hotels and resorts, reducing reliance on fossil fuels. Digitalization and automation can help reduce paper waste, streamline processes, and reduce the need for human labor. For example, digital check-in and payment systems can eliminate paper waste, while automation can reduce the need for human labor and the associated carbon emissions.

1. Background of Research

The relationship between technology and sustainable tourism has been widely explored in academic literature. Sustainable tourism refers to the type of tourism that is conducted in a way that does not harm the environment or the local culture and benefits the local communities economically, socially, and environmentally (Fennell and Cooper 2020) and moreover, this is becoming increasingly popular. According to the World Tourism Organization (2022), sustainable tourism is growing at a rate of 10-15% per year, and is expected to represent 20% of all tourism by 2025. This growth is driven by increasing awareness of environmental issues and the desire to minimize the negative impact of tourism on local communities and ecosystems.

Technology has become an essential tool in the sustainable tourism industry, helping to reduce the impact of tourism on the environment and improve the quality of the tourist experience providing tools for personalized recommendations, real-time information, and seamless transactions (*e.g.,* mobile apps can provide information about local attractions, restaurants, and events, while digital payment systems can make it easier to pay for goods and services (Loureiro and Nascimento 2021).

Buhalis and Law (2008) conducted a review of the literature on the impact of technology on tourism, highlighting the importance of technology in facilitating the entire tourism experience, from pre-trip planning to post-trip reflection. They argue that the use of technology can improve the efficiency of tourism services, reduce costs, and enhance the visitor experience.

Gretzel, Sigala, Xiang and Koo (2015) conducted a review of the literature on smart tourism destinations, which refers to destinations that use technology to improve the tourism experience while also contributing to sustainable development. They identified four key components of smart tourism destinations: (1) smart mobility, (2) smart environment, (3) smart economy, and (4) smart governance. Further, they drew attention to the great need for research to inform regarding the smart tourism development and management, facilitating dialogue and collaboration among stakeholders and enhancing the overall tourism experience.

Xiang, Du, Ma, and Fan (2017) examined the impact of mobile technology on tourist behavior and found that it has transformed the way tourists plan and experience their trips using a comparative analysis of major online review platforms. They also found that mobile technology has facilitated real-time communication between tourists and tourism service providers, leading to more personalized experiences and improved satisfaction.

The role of technology in enhancing the visitor experience was explored by Buhalis and Sinarta (2019), were found that real-time service offers dynamic engagement with connected consumers. However, they also noted that the use of technology can detract from the authentic experience and recommended a balanced approach between interconnected characteristics that revolutionize the tourism and hospitality, namely: in real-time, co-created, data-driven, consumer-centric and experience. Later, Buhalis (2020) explain how technology has become an essential tool in the tourism industry, transforming the way tourists plan, book, and experience their trips. This includes the use of online travel agencies, booking platforms, mobile applications, and virtual reality experiences.

However, the adoption of technology in sustainable tourism requires collaboration and coordination among stakeholders, as well as appropriate regulation and oversight to ensure that it supports sustainable tourism goals and aligns with broader sustainability objectives. In this regard, Ali (2021) identifies various technologies, including AI, IoT, drones, and virtual reality, that are being used to promote sustainable tourism practices, also discuss the potential benefits and challenges of using technology in sustainable tourism, including issues related to energy consumption, data privacy and security, and the digital divide.

Also, a lot of research papers provide up-to-date insights into the application of agent-based modeling for tourism sustainability or smart cities They cover topics such as tourist behavior, destination management, sustainable tourism planning, and the integration of agent-based modeling with information and communication technologies (Khan *et al.* 2022, Guzman, Dijkstra and de Kort 2021, Myeong *et al.* 2022).

2. Technology and Tourism as Part of Sustainable Development Goals (SDGs)

Technology and tourism both play an essential role in achieving the United Nations Sustainable Development Goals (Tourism for SDGS 2021), particularly in the areas of economic growth, environmental sustainability, and social development. The SDGs are a set of 17 global goals designed to end poverty, protect the planet, and ensure prosperity for all. Here are some of the ways in which technology and tourism contribute to the SDGs:

- SDG 8: *Decent Work and Economic Growth:* Tourism is a significant contributor to economic growth, providing employment opportunities and driving economic development in many regions. Technology can facilitate this growth by providing tools and resources for tourism businesses to operate more efficiently and sustainably, while also creating new opportunities for innovation and entrepreneurship.

- SDG 9: *Industry, Innovation, and Infrastructure:* Technology is critical to achieving this goal, as it underpins innovation and the development of sustainable infrastructure. For tourism, this means investing in sustainable transport systems, smart energy management, and digitalization of tourism services and experiences.
- SDG 11: *Sustainable Cities and Communities*: Sustainable tourism practices can help promote the development of sustainable cities and communities, by driving sustainable urban development, protecting cultural and natural heritage, and promoting community participation in tourism planning.
- SDG 12: *Responsible Consumption and Production*: Technology can play a critical role in promoting responsible consumption and production in tourism, by facilitating sustainable supply chains, reducing waste and carbon emissions, and promoting sustainable tourism practices.
- SDG 13*: Climate Action*: Tourism is a significant contributor to greenhouse gas emissions, and the industry must take action to reduce its carbon footprint. Technology can facilitate this by promoting sustainable transport systems, smart energy management, and innovative approaches to reducing carbon emissions.

Sustainable tourism practices are essential for protecting the environment and preserving natural and cultural resources. Technology can facilitate sustainable tourism by promoting energy efficiency, reducing waste, and encouraging the use of renewable resources. For instance, smart energy management systems and renewable energy sources, such as solar and wind power, can reduce the carbon footprint of tourism.

Technology can help drive tourism as significant contributor to economic growth by enabling the development of new tourism products and services and providing new channels for marketing and distribution. Online booking platforms have made it easier for small businesses to reach global markets and grow their customer base.

2.1. Stages of ICT Development Differentiated for Tourism Industry

Information and Communication Technology (ICT) has had a transformative impact on various sectors, including tourism. Over the years, the development of ICT within the tourism industry can be categorized into four distinct stages. These stages represent the evolution of technology and its integration into tourism practices, shaping the way businesses operate and travelers engage with the sector. Let's explore these stages:

1. *Computerization*: The initial stage of ICT development in tourism was marked by computerization. This stage emerged with the introduction of computers and their utilization in tourism-related tasks. Businesses started using computers for basic functions like reservations, accounting, and inventory management. This shift from manual to computer-based systems streamlined operations, improved efficiency, and reduced human errors. Computerization laid the foundation for further advancements in ICT within the tourism industry.
2. *Connectivity and Online Presence:* The second stage of ICT development in tourism witnessed the proliferation of the internet and the establishment of online connectivity. This stage revolutionized the way tourism businesses interacted with customers. Travel agencies, hotels, and airlines started creating websites to showcase their offerings, allowing travelers to access information and make bookings online. This shift empowered consumers to research and plan their trips independently, reducing their reliance on traditional intermediaries. The emergence of online travel agencies further facilitated the booking process and expanded the reach of tourism services.
3. *E-commerce and Online Transactions:* The third stage of ICT development in tourism was characterized by the widespread adoption of e-commerce and online transactions. This stage saw the integration of secure online payment systems, enabling travelers to book and pay for their travel arrangements online. E-commerce platforms and secure payment gateways enhanced the convenience, efficiency, and security of transactions, further empowering travelers to make instant bookings and secure deals. This stage also witnessed the rise of review platforms and social media, allowing tourists to share their experiences, influencing others' travel decisions, and shaping the reputation of tourism providers.
4. *Mobile Technology and Personalization:* The current stage of ICT development in tourism is marked by the proliferation of mobile technology and the emphasis on personalized experiences. Mobile devices, such as smartphones and tablets, have become ubiquitous, enabling travelers to access information, make bookings, and engage with tourism services on the go. Mobile applications and location-based services provide customized recommendations, real-time updates, and interactive experiences to enhance the overall travel experience. Additionally, emerging technologies like

augmented reality (AR) and virtual reality (VR) are being integrated into tourism to offer immersive and interactive experiences, further enhancing personalization and engagement.

It is important to note that these stages are not mutually exclusive, and advancements in technology continue to shape the tourism industry. The ongoing development of ICT in tourism includes innovations like artificial intelligence (Duvnjak, Gregorić and Gorše 2020), big data analytics (see Bibri 2018) and the Internet of Things (IoT), which have the potential to further revolutionize the sector by offering predictive insights, personalized recommendations, and seamless connectivity. The four stages of ICT development in tourism, highlight the evolution and impact of technology within the industry. As technology continues to advance, it is crucial for tourism businesses to embrace these developments, adapt to changing consumer demands, and leverage ICT to enhance the overall travel experience.

2.2. ICT and Data-Driven Leverages in Enhancing a Sustainable Travel Experience

For enhancing a sustainable travel experience, ICT plays a crucial role in enabling personalized experiences through data analysis, artificial intelligence, and machine learning algorithms that can understand and anticipate traveler preferences. By harnessing the power of data analytics, stakeholders can make informed decisions, develop targeted strategies, and drive positive change.

Sustainable travel experiences involve practices and activities that prioritize environmental, social, and economic responsibility while providing enriching and authentic travel experiences. Moreover, can have a transformative effect on travelers themselves. Embracing data-driven approaches is vital for achieving a more sustainable future for travel and tourism, where environmental impact is minimized, and responsible practices are prioritized. Leveraging data is the most effective and efficient way to achieve sustainability goals. This includes gathering data on carbon emissions, energy consumption, water usage, waste generation, and other relevant factors. Traveling in itself is responsible for roughly 8% of the world's carbon emissions, according to Sustainable Travel International by analyzing this information, businesses and policymakers can identify areas of high impact and develop targeted initiatives to reduce their carbon footprint (Lenzen *et al. 2018).*

Some statistics and facts highlight the increasing demand for sustainable travel experiences and the efforts being made in the industry to promote eco-friendly accommodations and responsible tourism. These highlight the importance of sustainable travel and the increasing awareness and actions taken by travelers, accommodations, and the tourism industry to promote sustainability, as follows:

- Increasing Demand for Sustainable Travel:
  - According to Booking Holdings (2022), 81% of global travelers expresses a desire to travel sustainably in 2022, with 50% saying that recent news about climate change has influenced them to make more sustainable travel choices;
  - The Global Sustainable Tourism Council (GSTC 2019) estimated that sustainable tourism grew at an annual rate of 6-7% between 2014 and 2019 with a forecast grew of 9-10% nor next period up to 2023.
- Eco-Friendly Accommodation:
  - The number of eco-certified hotels worldwide increased by 20% from 2017 to 2019 with a forecast by 32% for next 5 years period (GSTC 2019).
  - A Booking.com survey found that 70% of global travelers would be more likely to book an accommodation if it were eco-friendly.
- Rise of Responsible Tour Operators:
  - The Adventure Travel Trade Association (ATTA 2023) notes in its annually report that when presented with five sustainable options in 2033, only 19% of travelers were very likely to choose an option that required them to make a notable sacrifice, such as supporting a limit on international travel or occasionally opting for virtual travel.
- Impact of Carbon Emissions:
  - Sustainable Travel International estimates that the travel and tourism industry contribute to around 8% of global carbon emissions (Lenzen *et al. 2018).*
  - Air travel is a significant contributor to carbon emissions, with one long-haul flight generating more carbon emissions per passenger than the average person produces in a year (International Civil Aviation Organization).
  - Amadeus' Traveler Tribes 2033 found that while 35% of travelers express excitement about the prospect of more environmentally friendly travel options, 63% are unwilling to pay extra for biofuel-powered flights.

- Conservation Efforts:
  - The World Tourism Organization (UNWTO) estimates that 10% of global GDP is generated by the tourism sector, contributing to conservation and preservation efforts worldwide.
  - The United Nations Environment Programme (UNEP) states that sustainable tourism can help protect natural and cultural heritage and support biodiversity conservation.

Addressing this challenging problem is at the top of the tourism industry's list of priorities. For a comprehensive understanding, Table 1 provides a general overview about the ways in which data-driven can contribute to promoting sustainability in the travel industry, enabling stakeholders to make informed decisions, implement targeted strategies, and drive positive change.

Table 1. Data driven addressing tourism sustainability

Data-driven Approaches	Benefits and Applications
▪ Environmental Impact Assessment	▪ Assessing carbon emissions, energy consumption, water usage, waste generation, etc. to identify areas for reduction;
▪ Sustainable Destination Management	▪ Managing visitor flows, optimizing resource allocation, protecting ecosystems based on data on visitor patterns and ecological indicators;
▪ Smart Transportation and Infrastructure	▪ Analyzing transportation data for optimizing routes, reducing congestion, promoting sustainable modes of transport;
▪ Consumer Awareness and Education	▪ Providing transparent information to travelers about environmental impact and promoting responsible choices;
▪ Collaboration and Innovation	▪ Sharing data, best practices, and innovative solutions among industry stakeholders to drive sustainability efforts.

Based on historical data, several ongoing agent-based modelling approaches are avoiding the power of AI to analyze and identify the behavior of agents *(i.e.,* travelers) in context of sustainability. The data-driven tourism for sustainability project funded by the Austrian Research Promotion Agency, seeks to answer the question of how the combination of fair AI and agent-based modelling/simulation can contribute to resilient and sustainable regional tourism in Austria (Wallinger *et al.* 2023). Popîrlan and Ștefănescu (2009, 2011) use a mobile agent's architecture for an intelligent data analysis (knowledge bases management). allowing the mobile agents to make intelligent data analysis and to answer for diverse queries.

One of the main advantages of agent-based modelling (ABM) is its ability to capture the heterogeneity and diversity of actors within the tourism system. Agents in an ABM model can represent various stakeholders, such as tourists, local communities, businesses, and policymakers, each with their own characteristics, preferences, and decision-making processes. This enables users to explore the effects of different policies, interventions, and behaviors on sustainability outcomes.

Agent-based modelling can be used to simulate and analyze various aspects of sustainable tourism. For example, it can model the behavior of tourists in terms of their destination choices, travel patterns, and preferences for sustainable practices (Luo *et al.* 2021, Student 2022) or in innovative use for visitor management in the context of visitor experience, visitor satisfaction and psychological carrying capacity (Štekerová, Zelenka and Kořínek 2022). By incorporating factors such as environmental awareness, cost considerations, and cultural interests, the model can predict the potential impacts of different tourist behaviors on sustainability indicators, such as carbon emissions, resource consumption, and cultural heritage preservation.

Furthermore, agent-based modelling can simulate the interactions between tourists and local communities, exploring the economic, social, and cultural implications of tourism activities. It can model how the presence of tourists affects the livelihoods of local residents, the dynamics of community development, and the preservation of cultural heritage. This can inform the design of strategies and policies that promote sustainable tourism development while benefiting local communities. Agent-based modelling can also assess the effectiveness of sustainability initiatives and policies. By introducing different scenarios into the model, users can analyze the potential outcomes of various interventions, such as the implementation of eco-certifications, community-based tourism initiatives, or changes in transportation systems. This allows policymakers and destination managers to test different strategies in a virtual environment before implementing them in the real world, reducing risks and optimizing decision-making.

In addition to its predictive capabilities, agent-based modelling can also provide valuable insights into emergent behaviors and system dynamics (Hell and Petric 2021). It can help identify potential bottlenecks,

feedback loops, and unintended consequences that may arise from different interactions within the tourism system. This understanding of system dynamics can guide the development of more effective and robust sustainability strategies.

Implementing an agent-based modelling for tourism sustainability requires a multidisciplinary approach, combining expertise from fields such as tourism, sustainability, computer science, and data analysis (Dam, Nikolic and Lukszo 2021). Collaboration with stakeholders and engagement with the local community are also essential to ensure that the model captures the complexity and nuances of the specific tourism system under study. An ABM for tourism sustainability as an iterative process requires collaboration, data integration, and ongoing refinement, as follows:

- Define the Research Question: Clearly identify the research question or problem that the ABM will address. This could be related to understanding the impacts of tourism on sustainability, evaluating the effectiveness of certain policies or interventions, or exploring the dynamics of sustainable tourism development.
- Identify Agents and their Characteristics: Determine the different types of agents that will be included in the model, such as tourists, local residents, businesses, and policymakers. Define their characteristics, behaviors, decision-making processes, and interactions within the tourism system. Consider factors relevant to sustainability, such as resource consumption, environmental awareness, economic motivations, and cultural preservation.
- Gather Data and Validate the Model: Collect relevant data to inform the model's parameters and initial conditions. This includes information about the agents, their interactions, and the contextual factors influencing tourism sustainability. Validate the model by comparing its outputs with real-world data or existing studies to ensure its accuracy and reliability.
- Develop Agent Rules and Behaviors: Specify the rules and behaviors of the agents based on available data and research. Define how agents make decisions, interact with each other, and respond to changes in their environment. This can include decision rules related to destination choices, accommodation preferences, transportation modes, waste management practices, or engagement in sustainable activities.
- Define the Environment and Spatial Context: Determine the spatial boundaries and characteristics of the environment in which the agents operate. This includes specifying the geography, attractions, infrastructure, and natural resources relevant to the tourism system. Consider spatial factors such as accessibility, congestion, carrying capacities, and the distribution of resources.
- Model Interactions and Feedback Loops: Capture the interactions between agents and their environment. Define how agents influence each other's behaviors and how their actions feedback to affect the overall system dynamics. This could include social influence, information dissemination, economic dependencies, or environmental impacts.
- Implement Simulation and Analysis: Program the ABM using appropriate software or simulation platforms. Implement the agent behaviors, environment, and interactions defined earlier. Run simulations to observe the emergent behavior of the system and analyze the outcomes in relation to the research question or problem. Use statistical analysis, visualization techniques, and sensitivity tests to interpret the results and gain insights into the sustainability dynamics of the tourism system.
- Scenario Testing and Policy Analysis: Utilize the ABM to test different scenarios and policy interventions. Simulate the effects of various strategies and interventions on sustainability indicators such as carbon emissions, resource consumption, or community well-being. Assess the impacts of policy changes, new regulations, or alternative development scenarios on the sustainability outcomes of the tourism system.
- Iterate and Refine: Continuously refine and improve the ABM based on feedback, additional data, and insights gained from the simulation results. Validate the model against new data or real-world observations to ensure its accuracy and reliability.
- Communicate and Disseminate Findings: Present the findings of the ABM in a clear and accessible manner to stakeholders, policymakers, and researchers. Share the insights gained from the model to inform sustainable tourism planning, policy development, and decision-making processes. Encourage dialogue and collaboration among relevant stakeholders to foster a shared understanding of the sustainability challenges and opportunities in the tourism industry.

However, it's important to note that agent-based modelling is a modeling tool and its outputs depend on the assumptions and data used. Therefore, careful calibration and validation of the model with real-world data are essential to ensure its reliability and accuracy.

Conclusions

Technology and tourism can drive innovation and infrastructure development, which are critical components of sustainable development. New technologies, such as artificial intelligence, virtual reality, and blockchain, are transforming the tourism industry, creating new opportunities for innovation and growth. At the same time, tourism infrastructure, such as transportation networks, accommodations, and attractions, is essential for supporting sustainable tourism practices and promoting sustainable development. And although many international companies and tourism destinations claim to be "data-driven," most of them have yet to grasp the tangible benefits that data can offer, particularly regarding sustainability and inclusivity.

Further research is needed to understand how technology can be harnessed to support sustainable tourism practices while mitigating its negative impacts; also suggests that the future of technology and sustainable tourism is likely to involve the use of artificial intelligence, big data, and blockchain technologies to improve sustainability and promote responsible tourism.

In the same time, in strength connection with data-driven, agent-based modeling offers a valuable approach for understanding and managing sustainable tourism. By capturing the heterogeneity and interactions of different actors within the system, ABM provides insights into the complexities of achieving sustainability goals. It can inform policy decisions, predict the impacts of different behaviors and interventions, and help optimize strategies for sustainable tourism development. As sustainability becomes increasingly important in the tourism industry, ABM can serve as a powerful tool for shaping a more sustainable and resilient future for tourism destinations.

By promoting sustainable tourism practices and leveraging technology for innovation and growth, we can create a more sustainable and responsible tourism industry that benefits both local communities and the environment. In conclusion, we can say that as the tourism industry continues to grow, the importance of this interdependency will only increase.

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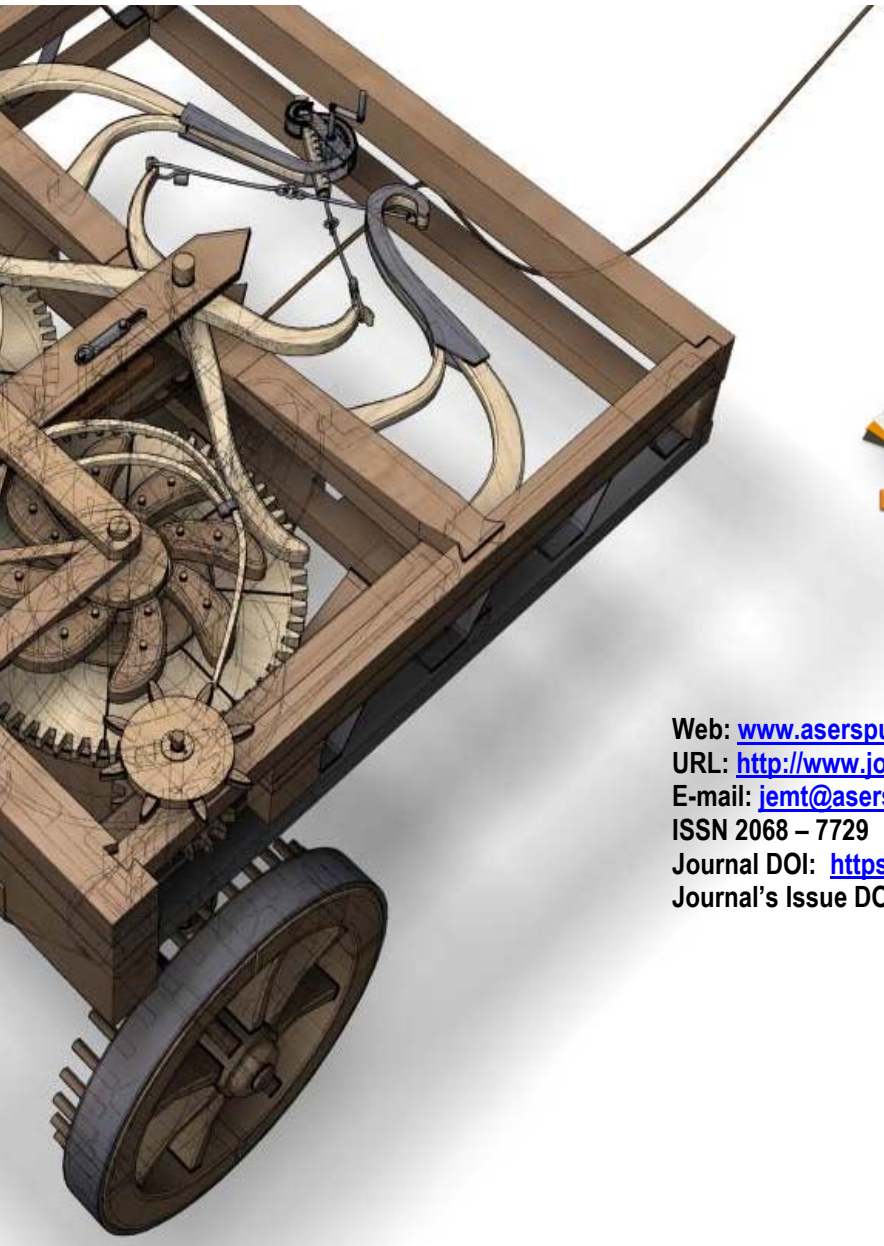

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