Analyzing the Impacts of AI Development and Adaptation on Human Life Using a System Dynamics Model

By
Mohammadhashem Moosavihaghighi[1]

Abstract:

Today, the development and widespread use of artificial intelligence is expanding into all aspects of human life globally. This ongoing study aims to investigate the relationship between artificial intelligence and the structural changes it will bring to human life in the future. While some impacts of artificial intelligence, especially artificial general intelligence, remain speculative and unclear both quantitatively and qualitatively, its potential to cause "structural changes" in human life is likened to historical technological revolutions such as the discovery of oil, the industrial revolution, and the invention of the Internet. This study does not seek to detail every effect of artificial intelligence on daily life but instead aims to simulate its broad dimensions and impacts using a system dynamics approach over mid and long time. By employing systematic thinking through the system dynamics model, the study intends to foster productive collaboration and enhance future result presentations. The study is ongoing, and contributions from experts, particularly in machine learning, are welcomed to enrich the research. Collaboration with other researchers and academic centers interested in this study is highly encouraged.

Keywords: Artificial Intelligence, System Dynamics, Human Life, Systematic Thinking, Structural Change

Introduction

Artificial intelligence (AI) and System Dynamics (SD) are two innovative methodologies developed in the second half of the 20th century, each bringing significant advancements in their respective fields (Sterman 2000; Boucher 2020). Throughout history, major technological breakthroughs, such as the discovery of oil, the industrial revolution, and the invention of the internet, have caused profound structural changes in human life. Similarly, the development of AI is anticipated to bring about substantial changes, both positive and negative.
System Dynamics aims to address and simulate real-world problems through a comprehensive and systematic approach. By creating simulation models that incorporate feedback loops, time delays, and nonlinearities, SD enables decision-makers to observe the potential impacts of their decisions

[1] Corresponding Author, Visiting Researcher, Department of Industrial Engineering, Antalya Bilim University, Antalya, Turkey, musavee@gmail.com , m.mousavihaghighi@areeo.ac.ir

before implementation (Sterman 2000). This approach helps reduce costly mistakes and optimize decision-making processes.

The advent of AI technologies, such as artificial neural networks (ANN), has transformed various aspects of human life by performing tasks that typically require human intelligence (Shnurenko et al. 2020; Vashishth et al. 2023). AI's rapid development and widespread application in industries like healthcare, finance, and transportation highlight its potential to accelerate economic growth and improve quality of life (Szczepański 2019).

However, the integration of AI into human life also raises concerns. While AI can complement human efforts and enhance economic development, it also poses risks such as job displacement and increased inequality (Analytical opinion of the researcher). The ethical implications of AI, including bias and misuse in military applications, further complicate its impact on society (Small 2023; Marr 2024).

Dynamic Hypothesis:

Every SD study must have a dynamic hypothesis to develop the model. The dynamic hypothesis in this study is defined as follows.

The dynamic hypothesis posits that the development and adaptation of AI will lead to significant structural changes in human life through a series of interconnected feedback loops. The primary drivers of these changes include the rapid technological advancements in AI, its integration into various sectors, and the resulting socioeconomic impacts.

A- Technological Change and Economic Growth: The development of AI technologies will drive economic growth by increasing productivity and efficiency in various sectors. This growth, however, will not be uniform, potentially exacerbating inequalities among different regions and social groups. The positive feedback loop of increased productivity leading to higher economic growth is counterbalanced by the negative feedback loop of job displacement and wage polarization.

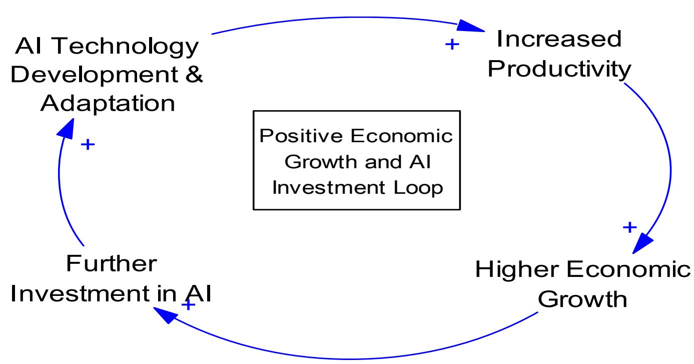

Figure 1: Economic Growth and AI investment development

In figure 1 as AI technology develops and is adapted, it leads to increased productivity in various sectors. This increase in productivity drives economic growth. Higher economic growth, in turn, provides more resources for further investment in AI, which enhances AI technology development.

B- Impact on Employment and Inequality: As AI technologies automate tasks and replace human labor in certain sectors, there will be a significant impact on employment rates. This dynamic creates a reinforcing loop where increased automation leads to higher unemployment in affected industries, potentially increasing social and economic inequalities. However, new job opportunities in AI-related fields and the complementary relationship between AI and human labor in other sectors may mitigate these effects.

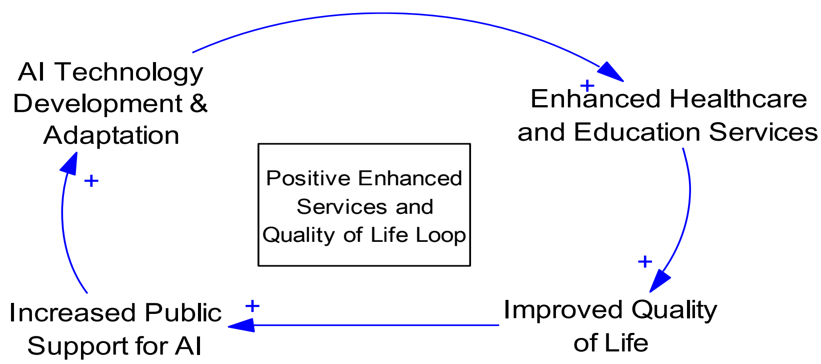

Figure 2: Impact on Employment and Inequality

In figure 2 the development and adaptation of AI lead to enhanced services in healthcare and education. Improved services contribute to a better quality of life. As people's quality of life improves, public support for AI increases, driving further development and adaptation of AI technologies.

C- Innovation and Competitive Advantage: AI technology development drives technological innovation, providing businesses with a competitive advantage. This competitive advantage results in increased profit margins, which are reinvested in AI research and development, further advancing AI technology

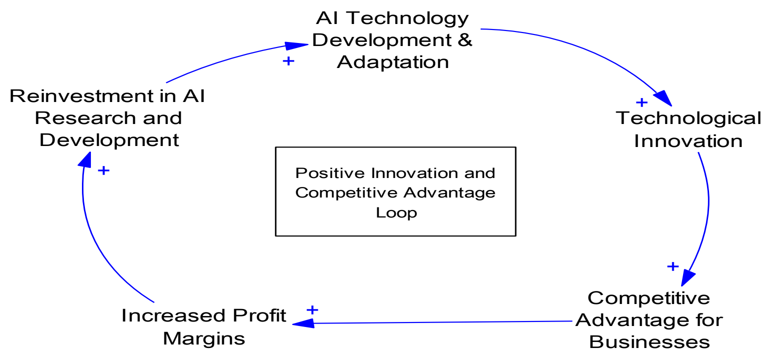

Figure 3: Innovation and Competitive Advantage

D- AI-Driven Economic Policies: The development of AI enhances economic analysis and forecasting capabilities, leading to more effective economic policies. These policies accelerate economic growth, which further increases the adoption of AI in policy-making processes.

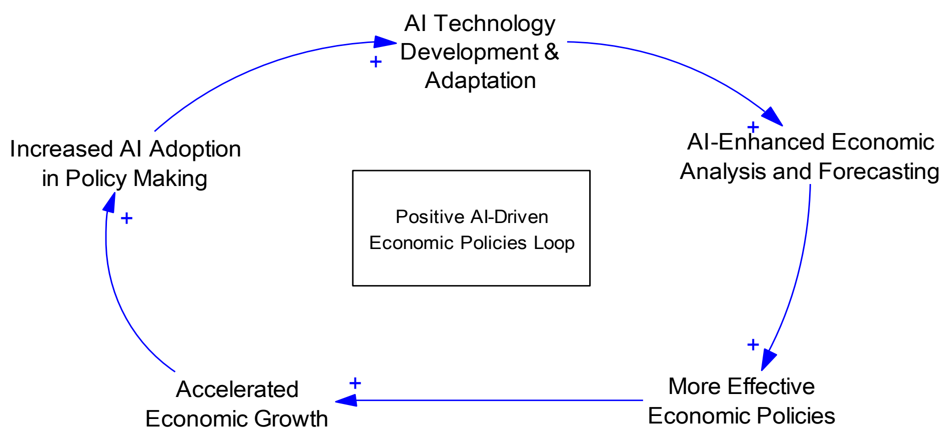

Figure 4: AI-Driven Economic Policies

E- Employment and Social Inequality Loop: As AI technology develops, it automates jobs, leading to job displacement and increased unemployment. Higher unemployment exacerbates social inequality, which can lead to public backlash and regulatory constraints on AI development. These constraints slow down further AI development.

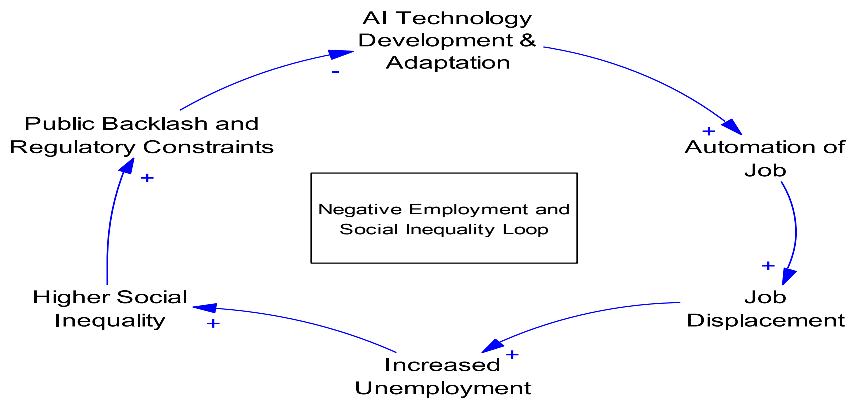

Figure 5: Employment and Social Inequality Loop

F- Privacy and Social Acceptance Loop: The development of AI increases surveillance capabilities, raising privacy concerns. As privacy concerns grow, social acceptance of AI decreases. Reduced social acceptance leads to stricter privacy regulations, which restrict the deployment of AI technologies.

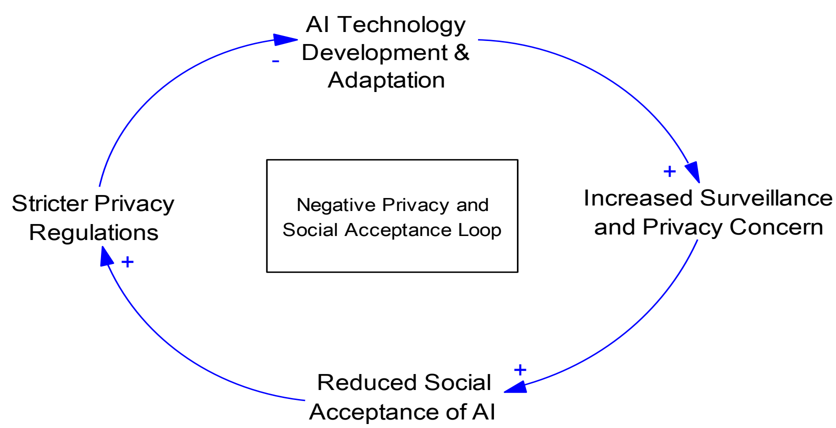

Figure 6: Privacy and Social Acceptance Loop

G- Ethical Concerns and Public Trust: As AI technology develops, ethical concerns such as bias and misuse arise. These concerns decrease public trust in AI, leading to increased demand for ethical oversight. The resulting regulatory scrutiny slows down AI development.

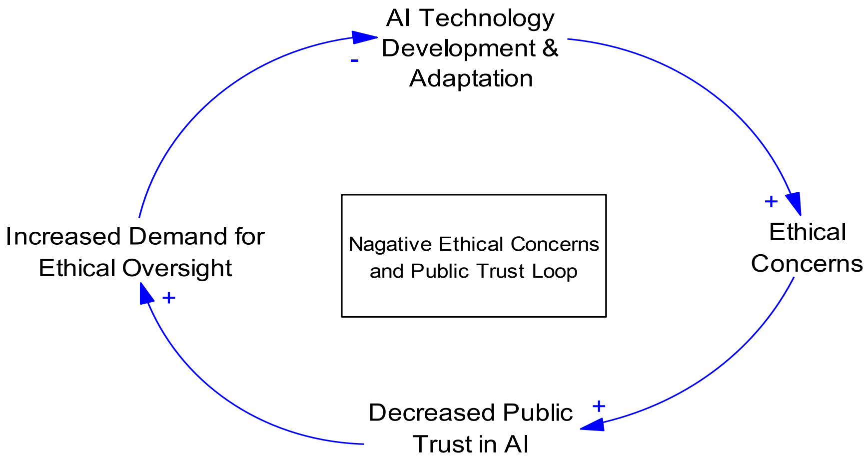

Figure 7: Ethical Concerns and Public Trust

Other positive and negative loops can be defined based on the problem statement and model boundaries. However, as mentioned earlier, this study is ongoing, and the System Dynamics (SD) modeling work is a phased process. By incorporating feedback from the modeling process in the future, additional loops may be integrated into the model as necessary such as the two loops below.

H- Quality of Life and Social Dynamics: AI's integration into daily life will have mixed effects on the quality of life. While AI can enhance healthcare, education, and other essential services, thereby improving overall well-being, it also poses risks such as loss of privacy, increased surveillance, and potential misuse in military applications. The feedback loops in this system involve both the positive impacts of technological advancements on quality of life and the negative repercussions of ethical and social challenges.

K- Policy and Governance: The role of policy and governance is critical in managing the impacts of AI on society. Effective policies can help mitigate negative effects such as job displacement and inequality while promoting the benefits of AI integration. The dynamic hypothesis includes feedback loops where policies influence AI development and adaptation, which in turn impacts policy decisions.

Description of the Subject and Review of Pervious Research:

The invention of the internet and the subsequent development of technologies like iCloud, big data, robotics, and machine learning paved the way for AI. Only a subset of AI methods, such as Artificial Neural Networks (ANN), is inspired by the human brain's functioning, aiming to perform tasks efficiently typically carried out by humans (Shnurenko I. et al., 2020; Vashishth T. K., 2023). AI has significantly impacted human life and is expected to continue accelerating these changes (Analytical opinion of the researcher).

AI tools and resources for developing AI are readily available, which has facilitated the rapid advancement of applications across various industries. General AI tools like GPT, Gemini, and

Mistral, along with services provided by Amazon, Azure, and Hugging Face, exemplify the increased accessibility of AI today compared to ten years ago. The widespread availability of information is a significant factor contributing to AI's growth, raising concerns about potential misuse by malicious entities. Unequal access to advanced AI technologies (e.g., ANN and AGI) may exacerbate existing social and economic inequalities. AI's impact on socioeconomic systems can be profound, leading to either improvements or deteriorations in the lives of different groups. For instance, the application of AI in military industries has far-reaching consequences, as evidenced by the U.S. deploying 1,000 AI systems on combat drones, known as "Wingman Robots" (The New York Times, Aug. 27, 2023; updated Aug. 28, 2023, by Eric Lipton).

The ethical implications of AI applications, particularly in military contexts, cannot be ignored. Albert Einstein once remarked, "The growth of science has nothing to do with the growth of humanity," suggesting that while technological advancements can propel humanity forward, they might also diminish our human values. Current global conflicts, such as the Russia-Ukraine war, Middle Eastern conflicts, China-Taiwan tensions, and the Armenia-Azerbaijan conflict, demonstrate the dangers of radical ideologies combined with advanced technology. The Iranian poet Forough Farrokhzad poignantly expressed this sentiment: "Friends, brothers, and consanguine, when you reach the moon, write down the date of the massacre of flowers and tell us what we have done to mankind." As long as radical ideologies persist, conflicts will continue to pose significant obstacles to peace.

The integration of AI with radical ideologies could pose a serious threat to human society. Ideological groups and governments leveraging AI could disrupt global stability, highlighting the misuse potential of AI. Therefore, the development and adaptation of AI do not necessarily bring awareness, kindness, or love to human society. AI might become a powerful tool for escalating conflicts worldwide, with policymakers possibly underestimating the risks of radical ideologies exploiting AI technology. Artificial intelligence is a double-edged sword: it can significantly benefit society but also be used for harmful purposes (Analytical opinion of the researcher).

Conversely, some believe that AI will significantly boost the world's economic growth in the coming years (Szczepański M., 2019). Like the invention of the axe or knife, which had both positive and negative impacts on human life but ultimately benefited society, AI holds similar potential. AI outperforms humans in specific tasks such as judgment, decision-making, automation, job or visa interviews, personalized medicine, psychology, and consultations (Szczepański M., 2019; Shnurenko I., 2020; Topol, E. J., 2019). AI can eliminate bias in human decision-making, such as in hiring processes, by analyzing resumes without personal biases, thus ensuring fair and accurate hiring practices. Optimists believe in the benefits of new technologies, while pessimists, or "technophobes," view them negatively (Analytical opinion of the researcher).

While pessimism is often supported by evidence of bias in decision-making, AI can make objective decisions based on processed data. However, AI models can still exhibit bias. There are methods to mitigate bias, but none guarantee a completely unbiased AI model. Recent articles have highlighted bias against Black artists in AI and how bias occurs in AI technology (Small, Z., July 4, 2023; IBM Data and AI Team, Oct. 16, 2023).

AI robots are trained based on specific tasks assigned by humans. For example, a robot designed for medical consultations will be trained to handle medical issues and may not perform well in economic queries. Thus, specialized robots have been developed for fields such as economics, consulting, and essay writing. General-purpose robots can answer various questions, but their training is also human-dependent. Proper training is crucial for developing useful AI applications, while inadequate training can lead to harmful outcomes, such as financial fraud.

The proliferation of online content has resulted in an explosion of both accurate and inaccurate information, making content verification challenging. The European Union Law Enforcement Agency predicts that by 2026, 90% of online content could be synthetically generated, leading to new challenges related to disinformation, propaganda, fraud, and deception (Marr, B., Jan. 29, 2024). Responsible AI practices, including privacy, security, and ethical guidelines, are essential to mitigate these risks. AI guardrails provide guidelines and boundaries to ensure AI applications meet ethical standards and societal expectations.

Also defining the boundaries of the model is crucial in simulating real-world systems (Sterman 2000). The primary challenge in this research is identifying the conceptual boundaries, as the study encompasses a wide range of variables, both qualitative and quantitative. The model includes time, geographical, and conceptual boundaries, with a particular focus on the latter (Analytical opinion of the researcher).

Research Objectives and Methodology:

The primary objective of this study is to simulate the potential structural changes caused by AI on human life using the SD approach. By leveraging AI's capabilities in data analysis and machine learning, we aim to enhance the accuracy and predictive power of SD models. The study will explore various scenarios and policy interventions to optimize outcomes and mitigate risks associated with AI integration.

This research is ongoing, and collaboration with experts from various fields, including machine learning and SD, is encouraged. The study aims to provide a comprehensive analysis of AI's impact on human life, offering insights into both its positive and negative effects. By understanding these dynamics, policymakers and researchers can develop strategies to maximize the benefits of AI while minimizing its potential harms.

Summary of introduction:

The combination of AI and SD offers a powerful tool for understanding and managing the complexities of modern technological advancements. As AI continues to evolve, its integration into SD models will provide valuable insights into the future of human life and economic development. This study aims to contribute to this growing field by offering a systematic and comprehensive analysis of AI's impact on society. In the following, a brief definition of SD and AI will be provided. The text then explains the differences and similarities between AI technology and SD approach. At the end, the initial schematic model will be presented for a better understanding. It should be kept in mind that the schematic model may undergo fundamental changes during the course of the study in future.

Definition of “System Dynamics” Approach

System Dynamics is an interdisciplinary approach to understanding and managing complex systems that was developed by Jay Forrester at MIT in the 1950s and 1960s. The approach involves creating simulation models of systems that incorporate feedback loops, time delays, and other nonlinearities, and then using these models to explore the behavior of the system under different scenarios and policy interventions (Forrester, 1961).

One of the key features of SD is the use of Causal Loop Diagrams (CLD) to represent the feedback loops that exist in a system. These diagrams help to illustrate the interconnections between different parts of the system and how changes in one part can affect the behavior of other parts. SD models also incorporate time delays and nonlinearities to capture the dynamic behavior of complex systems over time (Sterman, 2000).

System Dynamics has been applied to a wide range of fields, including environmental science, public policy, economical issues, socioeconomic problems, business, management and etc. For example, SD has been used to study the long-term consequences of climate change, to develop more effective public health policies, and to improve the performance of organizational systems (Analytical opinion of the researcher).

One of the key benefits of the SD approach is that it allows for the exploration of complex systems in a relatively simple and controlled environment. By simulating the behavior of a system over time, researchers can test different policy interventions and scenarios to see how they might affect the system as a whole and besides SD has been used to address a wide range of real-world problems, such as climate change, public health, energy policy, and economic development. It has also been used to improve organizational decision-making, by providing a better understanding of the dynamics of complex systems and the potential unintended consequences of policy decisions (Analytical opinion of the researcher).

Overall, the SD approach is a powerful tool for understanding and managing complex systems, and it continues to be an important area of research and application across many different fields (www.systemdynamics.org). In fact, SD is both a “methodology” and a “field” that aims to help understand and solve complex problems in the real world (Vanderminden P., 2006)

Definition of “Artificial Intelligence” Technology

The definition of AI can vary depending on the context and perspective. However, one commonly accepted definition comes from the father of AI, John McCarthy, who defined AI as "the science and engineering of making intelligent machines" (McCarthy, 2007). Another comprehensive definition of AI comes from Stuart Russell and Peter Norvig's textbook "Artificial Intelligence: A Modern Approach," which defines AI as "the study of agents that receive percepts from the environment and perform actions" (Russell & Norvig, 2020).

Artificial intelligence is a vast and rapidly developing field that encompasses various subfields, techniques, and applications. Researchers in this field are also developing and supporting this new technology using AI tools. There are several approaches to building AI systems, including (Shnurenko I., 2020):

a- Rule-based systems: These systems utilize a set of predefined rules, logic, and commands to make decisions and solve problems. They are effective in areas where rules are well-defined and easy to formulate but struggle with uncertainty and complexity.

b- Machine learning involves training algorithms on large datasets to learn patterns, predict every day, often complex problems, or classify data. Machine learning techniques include supervised learning, unsupervised learning[2], and reinforcement learning.

c- Deep learning is a subset of machine learning that utilizes artificial neural networks inspired by the structure and function of the human brain. Deep learning has achieved significant success in areas such as image and speech recognition, natural language processing, and gaming.

Deep AI is modeled after the workings of our brain. Neural networks are algorithms specifically inspired by biological neural networks in the human brain. They are reconstructed based on human behaviors, actions, and reactions in problem-solving and decision-making. Artificial intelligence has numerous applications in various industries, including healthcare, finance, transportation, complex immigration and employment processing, education, and entertainment (Boucher P., 2020).

As AI continues to advance, its impact on society and the economy is likely to grow. It has the potential to revolutionize industries and production methods, creating significant structural changes in people's lives and improving their quality of life. It also raises moral and social issues that should be considered. Artificial intelligence systems can be broadly divided into two categories: narrow AI and general AI. Narrow AI, also known as weak AI, is designed to perform specific tasks such as speech recognition or playing a game. General AI, also known as strong AI or Artificial General Intelligence (AGI), refers to the hypothetical future development of machines with human-like intelligence capable of performing a wide range of cognitive tasks (Boucher P., 2020). In a scenario where AGI dominates most aspects of human life, human society may be at significant risk of social and economic harm. The purpose of this study is to investigate and simulate the imaginary effects of developing and adapting the use of AI, both positive and negative, on human life in a systematic and interconnected manner (Analytical opinion of the researcher).

In summary, AI is a subset of computer science that focuses on developing algorithms, systems, and techniques that enable machines to perform tasks typically requiring human-like intelligence. These tasks are expected to surpass human capabilities in most cases. These tasks can include learning, reasoning, problem-solving, perception, natural language understanding, and self-development. On the other hand, AI is a broad concept that involves machines capable of performing tasks intelligently, similar to humans.

[2] It is divided to two category self-supervised learning and semi-supervised learning

Combination of AI Technology and SD Approach

This section aims to elucidate the potential benefits of combining the SD approach with AI technology. Although the advantages of this combined methodology have not been comprehensively documented in existing literature, the following analysis draws on the author's synthesis of various sources and by using the "ChatGPT 4o" for assistance.

The SD approach and AI are distinct fields with common methods and objectives. Both disciplines address complex systems but from different perspectives. SD focuses on understanding the behavior of complex systems over time using feedback loops and causal relationships to simulate scenarios and improve policies. AI, on the other hand, involves creating algorithms and systems that can learn and make decisions autonomously. Applications of AI include machine learning, natural language processing, and computer vision, used in fields such as robotics, autonomous vehicles, and speech recognition (Marjorie, 1985; Sterman, 2000; Boucher, 2020; Shnurenko et al., 2020).

While SD (SD is a field in addition to methodology, Vanderminden P., 2006) and AI are distinct fields, there are areas where they can complement each other. One such area mentioned earlier is decision support systems (DSS), where SD models can be combined with artificial algorithms to make decisions more accurate and timely. In this way, a SD model can be used to simulate the behavior of a complex system, such as a supplier, and predict its behavior in different scenarios. It can then be compared with machine learning algorithms to enhance the accuracy of predictions. By training machine learning on historical data that currently exists as a time series, the model can learn to make more accurate predictions and adjust its behavior over time accordingly. System Dynamics and AI are distinct fields with the potential to create and manage intricate details. Decision tools from both fields can be combined in interesting ways (Analytical opinion of the researcher).

Potential Benefits of Combining SD and AI:

1- Enhanced Model Accuracy and Parameter Estimation: SD models often require accurate estimation of initial inputs and parameters, which can be challenging. AI, particularly machine learning, can analyze complex data to provide more precise formulas and parameter estimates, improving the fidelity of SD models (Zolfagharian et al., 2015; Borkenhagen and Olsen, 2023). Also, based on the Figure 8, they provide better teaching conditions for the efficient transfer of concepts.

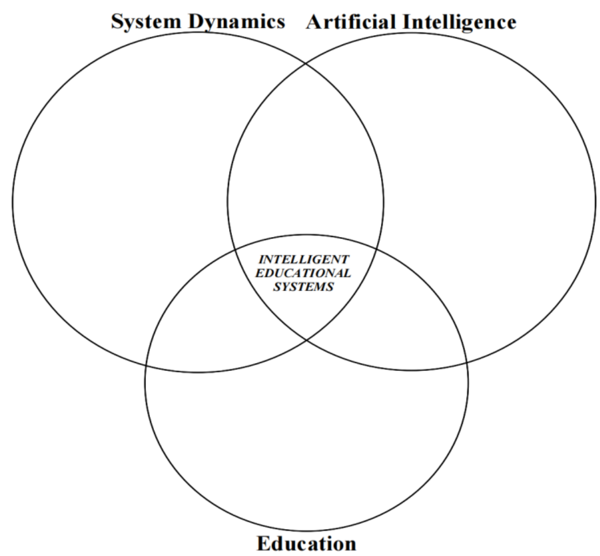

Figure 8: Intelligent Educational Systems, Marjorie Janet, 1985, Page 327

The figure above illustrates that integrating SD and AI methods into the entire education system can establish an intelligent and efficient education system that surpasses traditional education systems in effectiveness.

2- Improved Simulation and Prediction Capabilities: While SD models can simulate future behavior of systems, their predictions are often deterministic and may not account for uncertainties. AI can enhance the probabilistic predictions of SD models, thereby reducing uncertainty and providing more realistic scenarios (Analytical opinion of the researcher).

3- Identification of Non-linear Relationships: Real-world relationships are often non-linear. AI techniques, such as neural networks, can identify these non-linear relationships within data. Integrating these findings into SD models can enhance their realism and accuracy (Analytical opinion of the researcher).

4- Automated Modeling Process: The creation of SD models is typically manual and subjective, relying heavily on the modeler's expertise. AI has the potential to automate parts of this process, making it scalable and more efficient. This can be particularly useful for generating causal loop diagrams (CLDs) and stock-and-flow diagrams (Analytical opinion of the researcher).

5- Optimization of Scenarios for Structural Change: One significant challenge in SD research is recommending policies to improve systems. AI techniques, such as reinforcement learning and genetic algorithms, can facilitate scenario selection and policy-making to achieve optimal outcomes (Sterman, 2000).

6- Enhanced Explain Ability and Validation: Combining "white box" SD models with "black box" AI methods can leverage the strengths of both. SD models can clarify and validate AI-generated recommendations, increasing confidence in the proposed solutions (Analytical opinion of the researcher).

7- Estimation of Unknown Factors: AI can use historical time-series data to determine parameters and relationships within SD models, improving their accuracy. For example, machine learning can estimate delay times, response rates, and feedback loop gains, providing a data-driven basis for SD modeling (Analytical opinion of the researcher).

Similarities and Differences Between AI Technology and SD Approach:
First: Differences

1- Focus: AI focuses on developing intelligent agents capable of performing human-like tasks, learning, reasoning, and interacting with their environment. In contrast, SD focuses on understanding and modeling the behavior of complex systems over time, aiming to inform optimal decision-making in improvement scenarios (Marjorie, 1985; Sterman, 2000; Boucher, 2020; Shnurenko et al., 2020).

2- Techniques: AI employs techniques such as machine learning, natural language processing, and robotics, while SD uses mathematical modeling and computer simulation, including CLDs and stock-and-flow diagrams (Marjorie, 1985; Sterman, 2000).

3- Applications: AI is applied for example in virtual assistants, self-driving cars, medical diagnosis, financial trading and so on. SD models are used in business, economics, management, engineering, and public policy to simulate real-world scenarios and inform policy decisions (Marjorie, 1985; Sterman, 2000; Topol, 2019; Boucher, 2020).

4- Importance: AI receives significant investment and attention due to its transformative potential across various industries. In contrast, SD has received less attention, despite its utility in understanding and managing complex systems (World Bank Report, 2019; European Artificial Intelligence & Society Fund, 2023; Marr, 2024).

Second: Similarities

1- Interdisciplinary Nature: Both AI and SD are interdisciplinary fields that draw on knowledge from computer science, mathematics, engineering, and cognitive science. They address complex problems requiring a deep understanding of systems (Marjorie, 1985; Sterman, 2000; Boucher, 2020; Shnurenko et al., 2020).

2- Complex Systems: Both fields aim to comprehend and control intricate systems, fostering collaboration in science and leading to significant transformations in human life (Marjorie, 1985; Sterman, 2000; Boucher, 2020; Shnurenko et al., 2020).

3- Problem-solving: AI generates solutions for specific tasks, enhancing speed and accuracy in decision-making. SD helps decision-makers understand the implications of actions and policies by simulating complex systems, allowing for well-informed decisions without incurring real-world costs (Marjorie, 1985; Sterman, 2000; Boucher, 2020; Shnurenko et al., 2020).

In conclusion, combining AI and SD approaches can provide a comprehensive toolkit for addressing the complexities of modern technological advancements. As AI continues to evolve, its integration into SD models will offer valuable insights into the future of human life and economic development. This study aims to contribute to this growing field by systematically analyzing the impact of AI on society using the SD approach.

The Initial Model Definition

One of the main challenges in simulating the real world is defining the boundaries of the model (Sterman, 2000). Based on the current problem statement, which is considered very wide and broad, the primary challenge in this research is identifying the boundaries of the model. In the initial stage, it may seem unclear which variables should be included (endogenous variables) and which should be excluded from the simulation system (exogenous variables). The model includes three boundaries: time, geographical, and conceptual boundaries. We have no issues with time or geographical boundaries. The main issue in the current study lies in conceptual boundaries (Analytical opinion of the researcher).

Figure 9 illustrates the initial stock and flow diagram, depicting the effects of "technological change" driven by AI on the production process and its subsequent impact on world economic growth and the average quality of human life. The model emphasizes the need for accurate parameter estimation and the integration of feedback loops to capture the dynamic behavior of the system.

System dynamics generally deals with macro models. However, the model considered in this study is more comprehensive. Additionally, some of the variables in the current study are qualitative and need to be converted into quantitative form. For other intermediate variables that do not exist in the real world but are used in the model, proxy variables must be created. On the other hand, it is usually challenging to converge on modeling macro patterns to arrive at plausible answers (Moosavihaghigi, 2009, 2014; Rajabi & Moosavihaghighi, 2014).

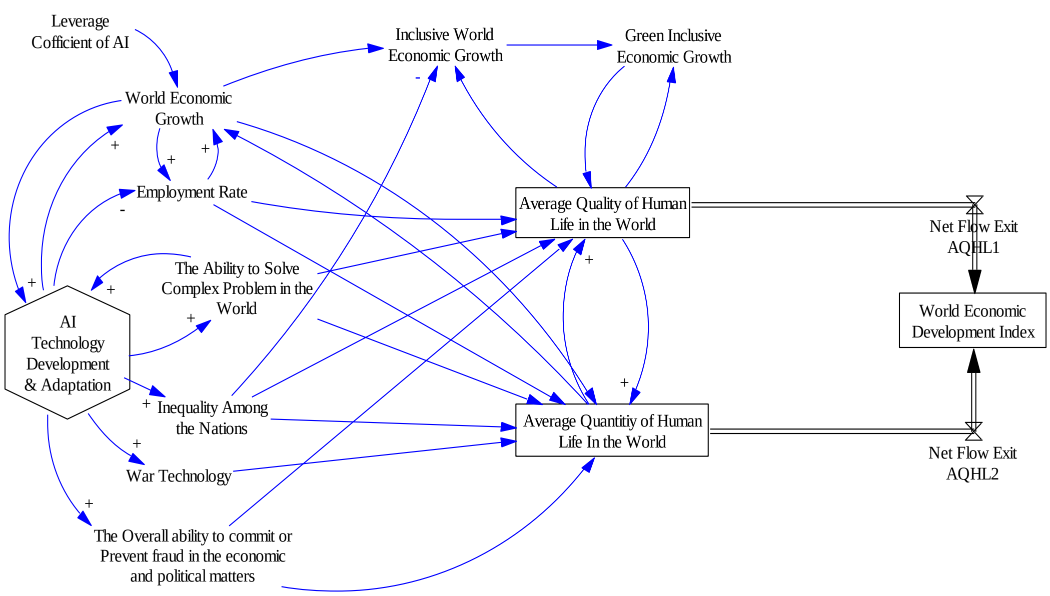

Figure 9: The Stock and Flow of Initial Model

As explained in the introduction, humans exist on a spectrum between optimism and pessimism regarding the use of AI technologies. The group that is optimistic about new technologies believes that the basic element of development is the production of wealth. By utilizing AI technologies in the production process, wealth can be created and increased, thereby accelerating the development process over time.

The stock and rate diagram shown in Figure 9 illustrates the effects of "technological change" (AI Technology Development & Adaptation) on the production process of goods and services in human society, primarily driven by the use of AI technology. This "main driver" will lead to "structural changes" in human life, impacting variables such as “world Economic Growth” and the “World Economic Development Index,” ultimately influencing the average quantity and quality of human life worldwide. Ultimately, it will also influence the “World Economic Development Index” variable. Of course, as previously mentioned, Figure 9 may undergo fundamental changes during the research process, and it is currently hypothetical (Analytical opinion of the researcher).

It is evident that the model presented in Figure 9 is based on specific assumptions that can be modified later. In all the stock and flow relationships considered in Figure 9, they must be proven based on at least one of the following four cases, in order of priority: the existence and type of cause-and-effect relationships[3] (Moosavihaghighi M. 2009, 2014).

1- The relationship between two variables should be considered an axiom, similar to physical or mathematical laws that are highly rigorous.

2- Or there is an accepted theory to prove the relationship, such as demand and supply functions, production or cost functions, or other theoretical relationships in social science.

3- Based on statistical evidence, it is possible to uncover a relationship between two variables using econometric methods (Moosavihaghighi M., 2009, 2014), as well as other parametric and non-parametric methods. Additionally, there is potential to utilize machine learning techniques or other intelligent methods to explore this relationship further. Also, based on AI technologies, relationships between variables could be extracted.

4- If the aforementioned three items are not available, expert reviews may be relied upon. This may involve techniques such as the Analytic Hierarchy Process (AHP), the Delphi method, snowball sampling, brainstorming, etc. This information is collected using documented and scientific methods to identify relationships between model variables in the simulated system.

For instance, the variable “AI Technology Development & Adaptation” in Figure 9 will not necessarily increase “Inequality Among the Nations.” AI technology is expected to be equally accessible to all nations in the future, potentially decreasing inequality over time. Therefore, this relationship should be confirmed with statistical evidence, a review of available research, or the use of expert opinion (Analytical opinion of the researcher).

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[3] The type of functional form is suitable for model building.

George Norcliffe (2009) defines four key elements for technological change. “a- Invention, b- Innovation, c- Imitation, and d- Learning” have been defined, and a distinction has been made between written and tacit knowledge. The "neighborhood effect" and "networks" influence the spread of technology. Humans now have the technology to profoundly alter nature. Technological change is a key factor in the “World Economic Development”, with innovation occurring in geographic clusters that create long waves of growth. On the other hand, technological changes brought about by AI in human society have two distinct effects on total production: "pure technological change" and "non-neutral technological change" (Moosavihaghighi M., 2008) in the production process. On the other hand, the control of intellectual property by advanced industrialized countries generates significant technological rents. The trade war between the US and China started in 2022. The U.S. decision has imposed significant restrictions on the export of advanced semiconductor and chip-making high-tech machinery to China. These machines are extensively used in the production of AI tools (Rappeport et al., 2023).

As shown in Figure 9, the state variables at the "Average Quantity and Quality of Human Life in the World" impact the "World Economic Development" index. One of the alternative variables that can replace these two important variables of quantity and quality of human life in Figure 9 is the Human Development Index (HDI), which is published annually by the United Nations Development Program (UNDP) under the supervision of the United Nations. This index is reliable and valid. The UNDP is a large organization under the supervision of the United Nations and is well-organized. It communicates extensively with countries, calculates HDI annually, and presents it separately(Human Development reports, https://hdr.undp.org/, Moosavihaghighi M., and Golam Hossein Dastbala, 2010). This index consists of the following three important parts:

1- The worldwide education index is available separately for the global level and for each country. As mentioned earlier, AI technologies can have a significant impact on this index in the near future.

2- Life expectancy index comprises various components. Indicators such as the number of physicians per capita, nurses per capita, daily calorie consumption, hospital beds per capita, mortality rate, birth rate, infant mortality rate, and various other factors are calculated annually and reported individually for a significant number of countries.

3- Income per capita index based on Purchasing Power Parity (PPP) in different countries is measured in US dollars. Because this index is adjusted based on PPP, it considers access to a specific and unique purchase basket in each country. Income per capita is calculated based on PPP within the same country and also on the US dollar exchange rate. Therefore, it is comparable because it is adjusted with PPP. According to HDI, first and second items represent the quality of human life, while the third item (income per capita) represents as proxy for the quantity of human life. These can be considered as suitable alternatives or proxies and can be incorporated with other variables into the model (Analytical opinion of the researcher).

Many factors influence the level variable “Average Quality of Human Life in the World”, as discussed in the previous section on the education and life expectancy indices, which are components of the HDI. Another factor affecting the average quality of people's lives is "Green Inclusive Economic Growth" instead of mere “World Economic Growth” (Mancur Oslen, 1986). Rapid economic growth is inevitably caused by various factors, in addition to depleting natural resources. These include unequal distribution among different segments of society, increased air and environmental pollution, higher traffic congestion, disharmony with nature, and lack of sustainability. These factors not only fail to enhance the quality of human life but in some cases may even diminish it. Therefore, inclusive green economic growth is one of the factors that affect the quality of human life, as analyzed by Mancur Olsen in his book in 1986. According to Figure 9, initially, variable "AI Technology Development and Adaptation" will boost "World Economic Growth", and subsequently, it will impact the quality of life. It is also assumed that the impact of AI on economic growth is initially positive and effective, and that economic growth does not directly affect the average quality of human life. At first, this growth must become "Inclusive World Economic Growth", and after a process, it becomes "Green Inclusive Economic Growth". To have a positive impact on the average quality of life of people worldwide (Analytical opinion of the researcher).

Besides, in order to simplify and convey the basic concepts to the readers, many of the two-way relationships between the existing variables within the model, as well as other absent influencing variables, are not shown in Figure 9. It is expected that these relationships will be demonstrated later using Vensim DSS, which has the ability to display diagrams in various views to facilitate the transfer of concepts of the final model during the ongoing study. For example, here are a few items that have been omitted for the sake of simplicity (Analytical opinion of the researcher).

1- The effects of variable "War Technology" on the variable "Inequality Among the Nations" and the "Average Quality of Human Life in the World" variable were often overlooked.

2- The role of "**delays"** in the system definitely exists, but they are not depicted in this model to avoid complexity.

3- The positive impact of AI on the speed, accuracy of phenomena, discoveries, and cost reduction is not elaborated upon in detail.

4- The impact of replacing human decision-making with AI on personal autonomy. In other words, when the majority of decisions are made by AI in the future, it will diminish individual decision-making skills over time.

5- The effect of using AI to perform operations is the reduction in the cost of producing goods and services. This is achieved by minimizing human errors and eliminating repetitive trial and error work.

6- The impact of variable "AI Technology Development & Adaptation" on the "World Economic Growth" variable, involves numerous intermediate and auxiliary variables, which are omitted here for simplicity.

7- The names of some variables may change structurally in the future in terms of both concept and type.

Speculative Conclusion

The integration of AI-SD presents a profound potential to transform our understanding and management of complex systems, offering a comprehensive approach to predict and navigate future technological impacts on human life. This study highlights the synergies between AI's data-driven precision and SD's systemic modeling, aiming to enhance the predictability and management of socioeconomic dynamics influenced by technological advancements.

The development and adaptation of AI technologies are expected to induce significant structural changes in various aspects of human life, akin to the transformative impacts of past technological revolutions such as the Industrial Revolution and the advent of the internet. These structural changes encompass both opportunities and challenges, requiring a balanced and informed approach to maximize benefits while mitigating potential harms.

By employing a robust SD framework, this research endeavors to simulate the multifaceted impacts of AI on human society. The dynamic hypothesis and causal diagrams developed herein provide a foundational understanding of the intricate feedback loops and variable interactions that characterize this complex relationship. The integration of AI enhances the accuracy and adaptability of these models, allowing for a more nuanced and comprehensive analysis.

Several key insights emerge from this study:

1- Enhanced Predictive Capabilities: AI's ability to process large datasets and uncover non-linear relationships significantly improves the predictive accuracy of SD models. This enables more reliable simulations of future scenarios, facilitating better-informed decision-making.

2- Optimization of Policy Interventions: The combined use of AI-SD allows for the exploration of various policy interventions and their potential outcomes. AI techniques, such as reinforcement learning and genetic algorithms, can optimize scenario selection, helping policymakers identify the most effective strategies for mitigating risks and enhancing benefits.

3- Identification and Management of Uncertainties: AI enhances the probabilistic predictions of SD models, reducing uncertainties and providing more realistic scenario planning. This is crucial for addressing the inherent unpredictability of complex systems influenced by technological advancements.

4- Automation and Efficiency: AI can automate parts of the SD modeling process, making it more scalable and efficient. This automation extends to the generation of causal loop diagrams (CLDs) and stock-and-flow diagrams, which are critical for understanding system dynamics.

5- Ethical and Social Implications: The study acknowledges the ethical and social challenges posed by AI, including potential job displacement, increased inequality, and bias in decision-making processes. The integration of AI with SD models helps in identifying and addressing these issues, promoting more equitable and just outcomes.

6- Interdisciplinary Collaboration: The successful integration of AI and SD requires collaboration across various fields, including computer science, economics, sociology, and public policy. This interdisciplinary approach enriches the analysis and contributes to more holistic and effective solutions.

The speculative nature of this study recognizes the dynamic and evolving landscape of AI technology. While AI holds the promise of unprecedented advancements, it also necessitates careful consideration of its broader impacts on society. Policymakers, researchers, and practitioners must work collaboratively to harness AI's potential for positive change while safeguarding against its risks.

Currently, AI is expected to be supervised by humans. But this issue can easily change in the future. Perhaps the current regulations and culture do not yet support the widespread adoption of AI, and this perspective is not widely accepted. But there is the potential power for AI to replace humans in many cases. Therefore, researchers in this field should strive to conduct more efficient work within shorter timeframes. The most crucial aspect is to investigate structural changes, specifically to analyze and forecast the escalating impact of AI on human life in the future.

In conclusion, the fusion of AI and SD methodologies offers a powerful toolkit for navigating the complexities of modern technological advancements. This research provides a foundational framework for understanding the multifaceted impacts of AI on human life, contributing to a more informed and strategic approach to managing technological change. As AI continues to evolve, its integration into SD models will be essential for anticipating and shaping the future trajectory of human society, ensuring that technological progress aligns with broader societal goals and values

In the current study, a very general concept is being considered, which can be implemented through teamwork by a research team. If I cannot succeed in finding a suitable research partner in the future, I will be forced to lower my goals (goal erosion). For example, I will focus on a specific sector, such as the impact of AI on war innovations, economic growth, reducing fraud in finance, or enhancing the healthcare system. In other words, the conceptual boundaries of the simulation system should be much more limited.

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