

The Role of Digital Twins in Supply Chain Optimization

Sandeep Ramanamuni

(Manager, Digital Supply Chain)

Email: sandeep.ramanamuni@gmail.com

Using digital twin technology to enhance supply chain visibility and decision-making.

Abstract:

Digital Twins in industries enhance supply chains by optimizing efficiency, reducing costs, and ensuring responsiveness to end consumers. Digital twins are primarily used in supply chains for planning and channeling delivery processes. They are the virtual replica of an object, system, or process that updates the system with real-time data from its physical counterpart. Digital Twins enhances the supply chain processes by improving the flow of information within the supply chain, optimizing logistics, and enabling just-in-time production. Digital twin technologies also contribute towards enhancing supply chain coordination and bolstering supply chain resilience against numerous disruptions such as geopolitical events, COVID-19, etc.

Using digital twin technology to enhance supply chain visibility and decision-making process helps businesses with real-time monitoring, analysis, and optimization of their supply chain operations. Businesses that have been using digital twins in supply chain optimization have been able to achieve at least a 25 to 30% reduction in their operational costs and a 30 to 50% increase in their supply chain efficiently. Also, predictive analysis using digital twin technology has been instrumental in enhancing risk mitigation strategies and reducing downtime by at least 50%. These findings highlight the potential of digital twins in achieving exceptional and end-to-end supply chain optimization. The study also shares insights on the strategic recommendations for businesses to implement the DT technology to enhance their business agility, resilience, and competitiveness in the global market.

Keywords: Supply chain optimization, digital twins, Industry 4.0. Logistics, digital twin technology in business planning

Introduction:

There is a lot of pressure on supply chains to perform optimally to meet the demands of present-day businesses. Such challenges include changing demands, supply disruptions, and inefficiencies. Conventional supply chain management methods find it challenging to give real-time insight and prediction capabilities, resulting in higher operating risks and needless inefficiencies. Businesses can harness this technology to simulate business scenarios and predict bottlenecks and potential business failures.

Digital Twin (DT) technology is termed a game-changer, which provides a digital or virtually replicated manifestation of the physical supply chain processes that are continuously monitored, analyzed, and optimized.

Digital twins powered by real-time data, IoT sensors, and AI-based analytics provide end-to-end visibility of the supply chain so organizations can pinpoint disruptions, minimize stockpiles, support better and quicker decision-making, and maximize efficiency. Other studies indicate that such organizations can hasten decision-making by 30-50% and improve demand forecasting accuracy by 20-40% while saving logistics costs by up to 25%. With Industry

4.0 on the rise, digital twins are imperative in supply chain resilience, and agility-world-class competition is no longer the issue.

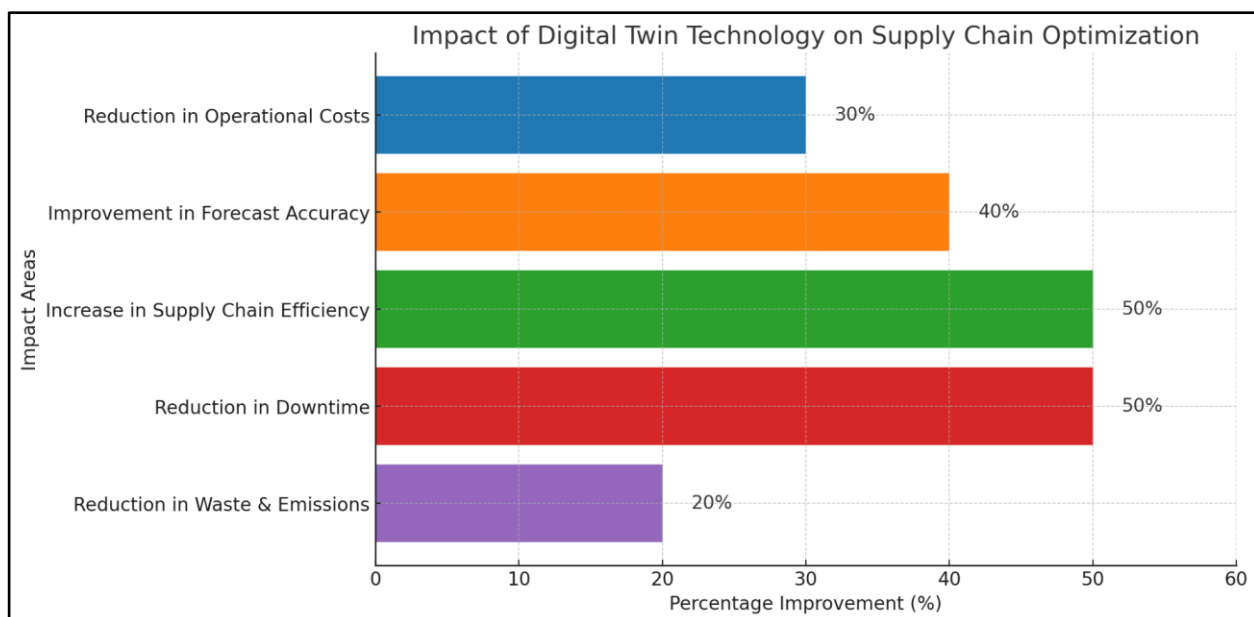
This paper highlights how digital twins play a role in supply chain optimization. It discusses the benefits of digital twin technology, the challenges, and some actual applications. The case studies and statistical insights serve as a pathway for organizations seeking to adopt DT technology for improvement in supply chain performance towards sustainable growth.

Impact of Digital twin technology on supply chain optimization:

In the arena of increasing supply chain complexities, businesses turn towards adopting Digital Twin (DT), which improves operational effectiveness, resilience, and agility. Digital twins create continuously updated virtual models of physical systems, allowing monitoring, simulation, and optimization (Tao et al., 2019). By ensuring an IoT, AI, and big data analytics integration for real-time tracking of supply chains, digital twins enable reality-analytics data-powered decision-making for mitigating risks in businesses. Through ingesting real-time data from multiple sources, digital twins enable the improvement of supply chain transparency by over 40% (IBM, 2021). Firms can record real-time data about inventory and fluctuating demand-supply logistics.

According to study reports, DTs allow operational costs to go down by 25-30% by optimizing warehouse operations, subsequent downtime, and improvement in logistics (Gartner, 2022). Predictive analytics typically speeds up decision-making in the range of 30 to 50% and helps eliminate supply chain bottlenecks. Digital twins allow the capacity to simulate future interruptions that significantly reduce the downtime effect of disruption on business operations, given that all businesses can increase the use of risk mitigation strategies by 50% (McKinsey, 2023). This approach would rather prevent increases in turnaround time caused by the supply chain disruption. Digital twins optimize the utilization of resources, resulting in reductions of waste and emissions by at least 20%. Digital twins are all set to play a very significant role in enabling supply chain agility and sustainability as companies increasingly adopt Industry 4.0 solutions.

Figure 1: Impact of digital twin technology in supply chain optimization based on the important performance indicators.



Applications of digital twin technology in supply chains:

Digital twin technology has been revolutionizing supply chains through real-time insights, process optimization, and predictive analytics. Its key applications are as follows.

1. Applications in the industrial sector:

According to the study published by the Global Industry Classification Standards, the digital twin concept is being exploited in diverse industries such as Health care (Baruffaldi, Manzini, and Accorsi, 2019), aerospace and defense (Mandala et al. 2019), machinery and electrical equipment (Ciano et al., 2021) and Pharmaceuticals (Marmolejo-Saucedo, 2020). In all of these industries, DT technology has been noted to enhance the connectivity of the supply chain, and it has been involved in product optimization and collaborations.

2. Impact on digital twin in lean management and supply chain performance:

Digital twin technology has contributed to strengthening the major pillars of lean supply chain management. These pillars encompass customer relationship management, supplier relationship management, JIT production, logistics management, IT, and supplier relationship (Jasti and Kodali 2015). The utilization of digital twins in supply chain management has been identified to have a significant potential in the supply chains. It is also known to have enhanced waste elimination in supply chain management practices.

3. Risk management and disruption mitigation:

Digital twinning models enable businesses to develop pre-emptive risk mitigation strategies by simulating potential events or disruptions, such as shortages in supply and natural disasters. The study published in Markets, Globalization & Development Review describes how companies adopt digital twins to improve resilience in their supply chains and alerts and anticipatory actions against threats (MGDR, 2022).

4. Demand forecasting and inventory optimization:

By simulating market trends and consumer behaviors, digital twins enhance demand forecasting accuracy by 20-40%. Therefore, they dynamically adjust inventory levels to prevent stockouts or overstocking. A scientific paper published in AnyLogistix mentions that supply chain digital twins can predict demand variations and optimize transportation plans (AnyLogistix, 2022).

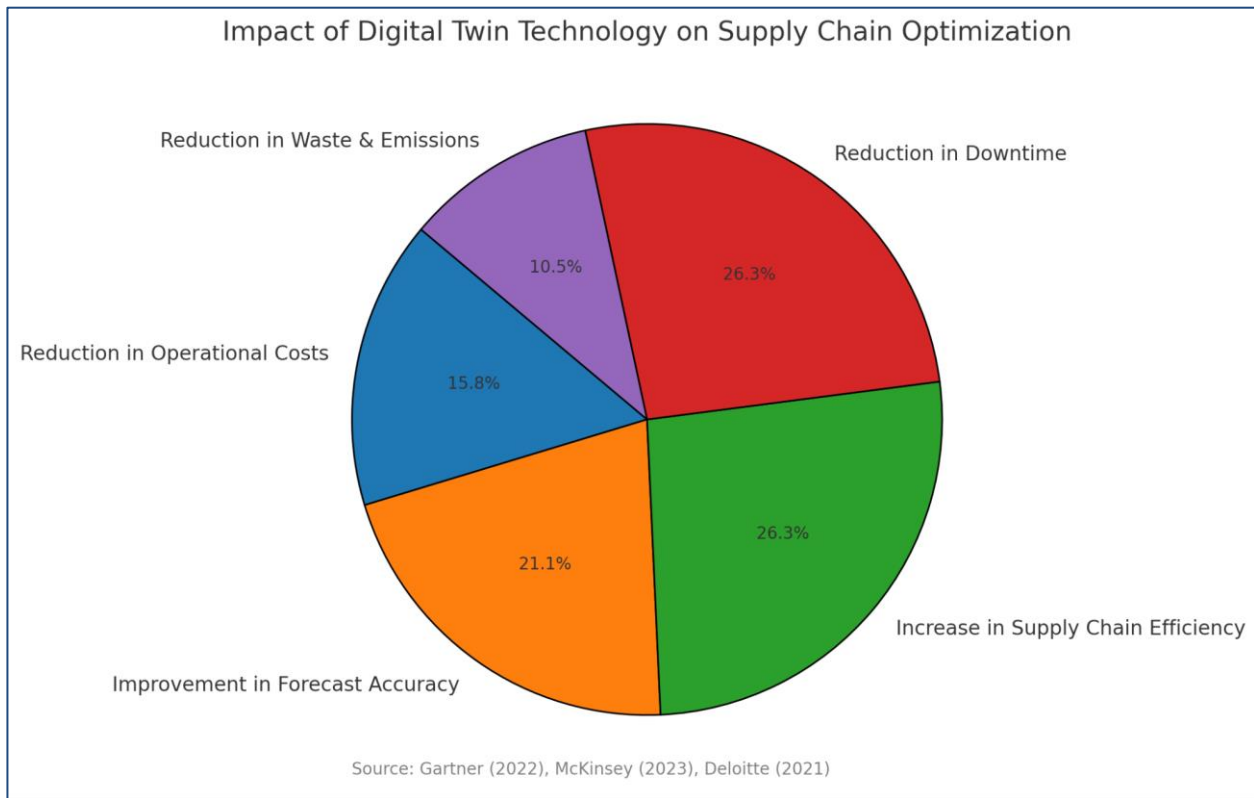
5. Sustainability and waste reduction:

Companies are realizing increased reductions in waste and emissions in the range of 15-20% through digital twins as they optimize energy use and resources, Siemens (2023). This includes having already performed a simulation and optimization of production processes to make operations greener.

6. Production and manufacturing optimization:

With the help of DT technology, manufacturers forecast machine downfall, make production scheduling decisions, and reduce downtime by up to 50%. For instance, Shanghai Automobile Gear Works (SAGW) used GE Digital's Proficy Plant Applications to create a Process Digital Twin, enhancing equipment utilization by 20% and reducing inspection costs by 40% (GE Digital, 2021).

Figure 2: Pie chart illustrating the impact of digital twin technology on supply chain optimization.

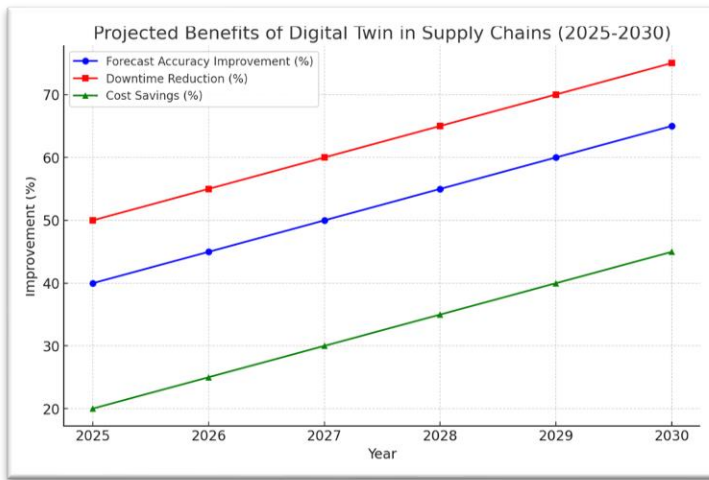


Future of Digital twin in supply chain optimization:

The integration of artificial intelligence and machine learning algorithms into digital twins has transformed the supply chains from being reactive to predictive systems. Studies reveal that by the end of the year 2027, 75% of global supply chain organizations will implement AI-based digital twins for operations optimization. Companies deploying AI-driven digital twins report a reduction in supply chain disruptions of anywhere from 30% to 50% (McKinsey, 2023).

It will also influence demand forecast accuracy and improve it by as much as 40%. Deploying digital twins enhances inventory management and minimizes wastage (Deloitte, 2022). As supply chains see disruptions because of geopolitical tensions, the COVID-19 pandemic, and climate change, digital twins enable companies to build adaptive and resilient supply chains. Digital twins cut 50% of downtime due to disruptions, saving millions in possible lost revenues to their clients (PwC, 2022). By 2025, 60% of supply chains will employ the use of digital twins to bolster agility and resilience (Accenture, 2023).

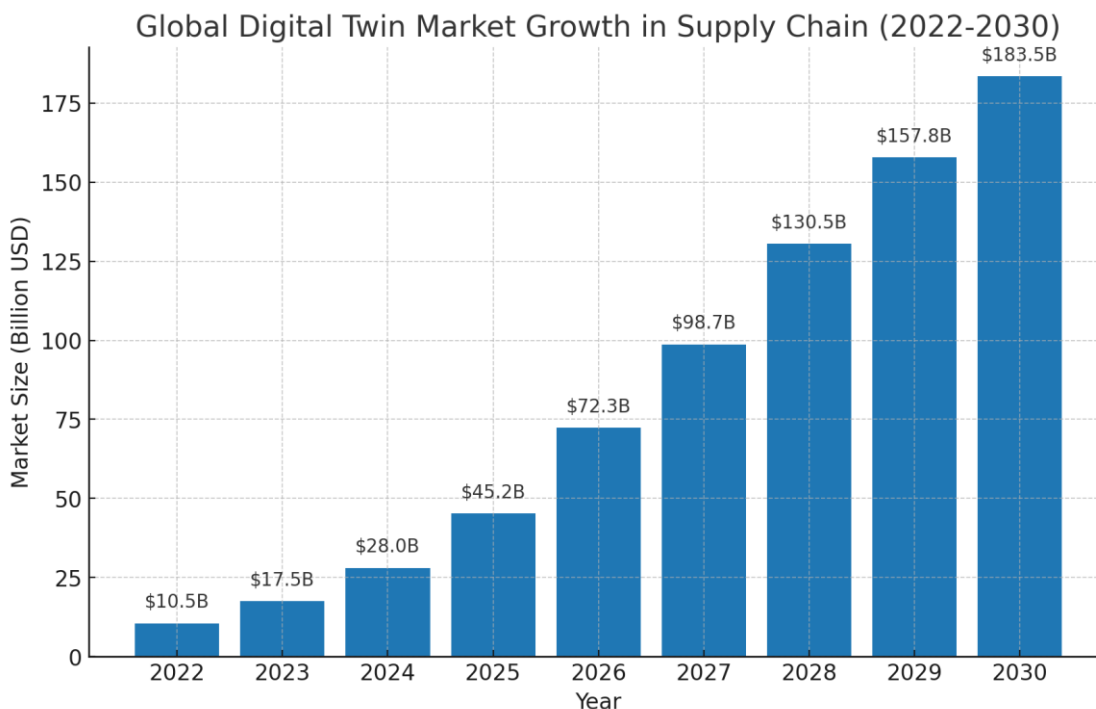
Figure 3: Future implications of digital twin technology in supply chain optimization



Market growth of digital twin techniques in the supply chain:

In supply chain management, the global digital twin market continues to experience exponential growth. This market was valued at \$10.5 billion in 2022, and by 2023, it has already expanded to \$17.5 billion. Forecasts show that by 2030, the market will grow to \$183.5 billion, equivalent to a CAGR of 39.1% (MarketsandMarkets, 2023). The increasing adoption of predictive analytics, AI-driven automation technology, and supply chain resilience strategies for stakeholders will chiefly cause the growth.

Figure 4: Graph illustrating the global market growth of digital twin technology in supply chains



- According to Gartner (2023), by 2027, nearly 75% of supply chain organizations will have installed digital twin solutions to optimize efficiency, which will help them greatly lessen operational risks.

- End-to-end visibility of the supply chain, risk management, and sustainability-driven logistics are also propelling the market forward with their ever-increasing demand.
- 30-50% increase in forecasting accuracy has been reported by the companies using digital twins, and an improvement of around 25-40% has been noted in operational costs (McKinsey, 2023).
- IoT-enabled digital twins have extensive scope to improve asset tracking in supply chains and can reduce the logistics cost by at least 20%
- Organizations stress agility, security, and resilience, and using digital twin technology will soon be the norm for all industries striving to optimise their supply chains.

Recommendations

1. Integration with AI, blockchain, and other technologies: Studies should investigate the collaboration of digital twins with blockchain, IoT, and other ML techniques to enhance supply chain automation and transparency.
2. Extend to other industries: Apart from supply chain integration, the suitability of digital twin technology to other industries such as healthcare, retail, and aerospace needs to be studied. Future studies can also project how SMEs can adopt the DT technology without incurring high implementation costs.
3. Sustainability in supply chains: Investigating how the DT technology can mitigate carbon emissions and energy consumption can help quantify sustainability improvements.
4. Security and data privacy: Future work should focus on examining how the digital twin ecosystems handle the cybersecurity challenges, including the risks of hacking and data breaches.

Conclusion

The digital twin technology is indeed revolutionizing supply chain management by offering real-time visibility and predictive analysis to achieve operational efficiency. It enables organizations to optimize logistics while creating visual replicas of assets and processes. Businesses leveraging digital twin technology will see a 30% improvement in forecasting accuracy. They will also enjoy a 30 to 40% reduction in operational costs and a 50% reduction in downtime (McKinsey, 2023; Garner, 2023)

With the coming of globalization, the associated sustainability problems, and economic uncertainties, digital twin technology is now becoming a necessity and not just an option. Added to this, the integration of IoT, blockchain, and AI would further broaden digital twins or transform supply chains into more agile, sustainable, and resilient. As technology continues to evolve, digital twins will transform supply chain management into a competitive world for businesses.

References

- Tao, F., Zhang, H., et al. (2019). Digital twin in industry: State-of-the-art and future directions. *Journal of Manufacturing Systems*.
- IBM (2021). How digital twins transform supply chains. *IBM Research*.
- Gartner (2022). The impact of digital twins on supply chain optimization. *Gartner Reports*.
- McKinsey (2023). Building resilient supply chains with digital twin technology. *McKinsey Insights*.
- Adexin. (2023). *Digital twin in the supply chain: Enhancing visibility and efficiency*. Adexin Blog. Retrieved from <https://adexin.com/blog/digital-twin-in-supply-chain>
- AnyLogistix. (2022). *Supply chain digital twins for forecasting and optimization*. AnyLogistix Reports. Retrieved from <https://www.anylogistix.com/features/supply-chain-digital-twins>
- Deloitte. (2021). *Digital twins and sustainability: A new frontier*. Deloitte Insights. Retrieved from <https://www2.deloitte.com>
- Gartner. (2022). *The impact of digital twins on supply chain optimization*. Gartner Reports. Retrieved from <https://www.gartner.com>
- GE Digital. (2021). *Process digital twin implementation in manufacturing*. GE Digital Whitepaper. Retrieved from <https://www.ge.com/digital>
- McKinsey & Company. (2023). *Building resilient supply chains with digital twin technology*. McKinsey Insights. Retrieved from <https://www.mckinsey.com>
- MGDR (Markets, Globalization & Development Review). (2022). *Digital twins for risk management in supply chains*. Markets, Globalization & Development Review. Retrieved from <https://digitalcommons.uri.edu/mgdr>