# **LiFi and WiFi in Education: An Economic Comparative Analysis**

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## ABSTRACT

In a digital age, education is undergoing a technological transformation, with reliable internet connectivity becoming more and more pivotal. This case study delves into the economic implications of adopting Wi-Fi and Li-Fi technologies in schools, examining direct costs, benefits, and long-term impact. While Wi-Fi is established as the mainstream wireless communication solution, emerging Li-Fi technology, which employs light waves for data transfer, offers higher speeds and heightened security. Analyzing various financial metrics, such as Benefit-Cost Ratio (B/C), Net Present Value (NPV), Return on Investment (ROI), and Internal Rate of Return (IRR), the study finds Li-Fi to be economically more viable, showcasing better B/C ratios, NPV, ROI, and IRR. The results detail Li-Fi's potential for significant returns, though initial costs and device compatibility must be addressed. As education evolves, this study recommends considering Li-Fi for faster, secure, and stable connectivity, aligning with long-term goals in an ever-evolving technological landscape.

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## INTRODUCTION

In the age where computers and the internet seem to be prominent in almost every aspect of our society, education too has become greatly affected by this shift in digitization. Namely, the modern classroom has evolved drastically, with technological integration becoming an essential facet of the educational experience. For instance, students nowadays need access to online resources like textbooks, connect to cloud-based platforms, or even communicate through course management websites like Canvas. A key factor in this transformation is the need for reliable and efficient internet connectivity.

WiFi, the more traditional and widely-used technology, employs radio waves to transmit information between devices and internet routers, and it has been at the forefront of providing wireless communication to the public (Escobar, 2015). In contrast, LiFi is a relatively new communication system that uses light waves from LED light bulbs to send and receive data. Utilizing visible light from LED fixtures, LiFi promises higher speeds and enhanced security (Raj, 2022). This presents a compelling alternative to the traditional WiFi system; however, as with every emerging technology, its feasibility, especially in terms of its economic implications, is still not well discussed.

The purpose of this case study report is to investigate the economic aspects of adopting WiFi and LiFi technologies in schools. By analyzing the direct and indirect costs, benefits, and potential long-term economic implications, the information compiled will provide educational institutions with a comprehensive understanding of which technology would be the most cost-effective and beneficial for their specific needs.

**LITERATURE REVIEW**

**Theoretical Underpinning:**

WiFi is rooted in radio frequency (RF) technology. WiFi leverages electromagnetic waves to transmit data between devices. Its theoretical framework is built upon the principles of RF communication, where “data is modulated onto carrier waves for transmission” (Escobar, 2015). Given its wide range and ability to penetrate walls, WiFi has been a crucial part of modern-day communication, being used in homes, offices, public places, and even in remote areas with internet access. Furthermore, setting up Wi-Fi connections is straightforward and can be done using a Wi-Fi router, making it user-friendly.

LiFi operates on the principle of optical communication. Unlike WiFi, which uses RF waves, LiFi modulates visible light from LED light fixtures to transmit data. The rapid on-off switching of LED lights, not visible to the human eye, is then employed to carry data (Raj, 2022). This results in faster potential data transmission rates, given the higher frequencies at which visible light operates. It must be noted that its line-of-sight requirement means physical barriers can disrupt the connection, but this also means it can be more secure than Wi-Fi as the signal does not pass through walls, thus reducing the risk of unauthorized access. As highlighted by *Lifi.co* (2022), Li-Fi is less susceptible to radio frequency interference, leading to more stable and reliable connections since it’s operated by light. As a bonus, *Lifi.co* (2022) also emphasizes that the LED lights used in Li-Fi are energy-efficient, contributing to reduced energy consumption compared to Wi-Fi.

**Existing Studies and Findings:**

As we have stated before, wireless communication in educational institutions

is widely utilized due to WiFi’s easy accessibility to the public. Despite its widespread adaptation, there are concerns about its bandwidth limitations, especially in densely populated areas like schools. According to Burns (2014), American schools lack enough bandwidth to carry out critical technical operations with efficiency with surprising estimates of “only 39% of US school districts having adequate access to functioning technology and/or adequate broadband access.” With insufficient bandwidth, this congestion can lead to slower internet speeds during peak times, thus affecting online learning sessions. To add on, Wi-Fi networks can be vulnerable to hacking if not properly secured, potentially compromising sensitive information.

A publication by Apoorv, Bhowmick, and Annadevi (2019) on the very topic revealed the potential of LiFi in offering faster data transmission rates, claiming it can achieve speeds up to 10 Gigabits per second as its bandwidth can reach a max 750 terahertz. To put it in perspective, radio frequency can only provide a bandwidth frequency of 300 gigahertz, and comparing it with the recommended speed of 100 Mbps for a wireless communication system in schools provided by Education Super-Highway (Abenschien and Hill, 2014), LiFi is essentially 100x faster than WiFi (Alqrwqaz, 2016). Similarly, a study published by the *International Journal of Engineering Research and Technology* highlighted LiFi's potential for data density, indicating its capability to serve multiple users within a confined space, like a classroom, without significant interference (Raghuvanshi and Singh, 2020).

School-specific studies, such as the one by Kyle Academy Secondary School in Ayr, Scotland (Robinson, 2018), implemented LiFi technology in one of their classrooms as a pilot run. With just the installation of eight LiFi-enabled LED lightbulbs, Kyle Academy reported not only faster internet speeds but also a reduction in connectivity-related interruptions as the additional bandwidth reduced network congestion. Despite its advantages, schools adopting LiFi face challenges. Khan (2016) pointed out that LiFi's dependency on light poses a limitation, as connectivity can be disrupted when lights are turned off or obstructed.

**Gaps:**

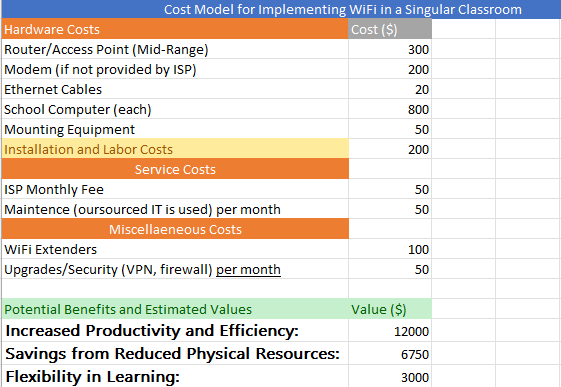
Despite the wealth of comparative technical data, there is a noticeable gap in comprehensive economic analyses specific to school settings. Few studies provide a thorough understanding of the long-term economic implications, ROI, and non-tangible benefits of these technologies in an educational environment. This means that the information available on the adoption of LiFi in schools is limited. This is mostly likely attributed to a lack of infrastructure and the initial setup cost.

**ANALYSIS**

To properly and fairly analyze the two technologies, data collection will comprise mostly of the existing real-life examples. Using the information gathered from Kyle Academy Secondary School (Robinson, 2018) and approximation quotes of the implementation of LiFi by *Lifi.co* (2022)*,* I will compare it with the provided technology and cost models by Christine Diggs in the *Office of Educational Technology* (Diggs, 2021) on implementing WiFi in a single classroom. A data processing tool like Microsoft Excel will be used for most of the economic analysis.

**Assumptions:**

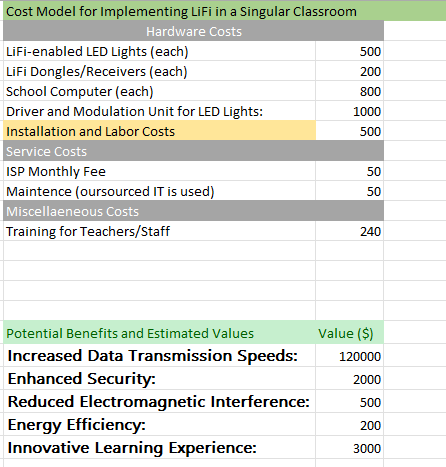
* **Classroom Size:** The estimates assume a singular classroom of approximately 30 students, which is a common size for many schools but can vary widely.
* **Tech Utilization:** It's assumed that the technology (whether WiFi or LiFi) is utilized to its full potential and integrated into the curriculum. If it's only used sporadically, the benefits would likely be lower.
* **Constant Technology Performance:** It's assumed the technology performs consistently well throughout the year, with minimal downtime or technical issues.



Real costs can vary depending on location, specific hardware choices, labor costs, and more, but this is a general breakdown of a cost model for implementing WiFi in a Singular Classroom.

**Benefit Values Explanation (WiFi):**

* **Increased Productivity and Efficiency:** With fast and reliable WiFi, students can quickly access online resources, submit assignments, or participate in online discussions. If a student saves 1 hour per week due to the speed and efficiency of WiFi, with 30 students in a class, that's 30 hours saved. Over a 40-week school year, that's 1,200 hours saved. Valuing each hour at a conservative $10 (a measure of time's potential value), the savings would be $12,000.
* **Savings from Reduced Physical Resources:** Fewer physical textbooks and paper handouts are needed. A single textbook can cost $50-$100, but we will use the average value of $75. If WiFi and online resources eliminate the need for 3 textbooks per student, for a classroom of 30 students, that’s a savings of $6750.
* **Flexibility in Learning:** Enables self-paced learning and resource access outside school hours. This is more intangible. But valuing the flexibility and the potential for improved learning outcomes, we might estimate a value of $3,000 for the entire class per year.



The cost can also vary depending on the specific solutions or vendors chosen, region, and other factors, but this is the general breakdown of a cost model for implementing LiFi in a singular classroom.

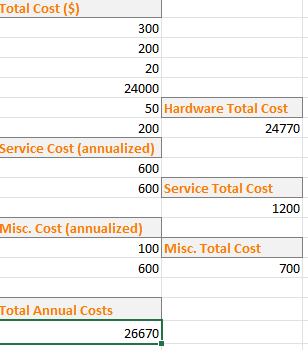
**Benefit Values Explanation (LiFi):**

* **Increased Data Transmission Speeds:** LiFi can, in some scenarios, offer faster data transfer rates than traditional WiFi. Like the WiFi model, if a student saves time due to faster access, over a year this can accumulate into considerable time savings. Estimating a value is tricky, but let's say it saves a student 10 hours a week due to the speed of LiFi (10x more than the WiFi) and there are 30 students in a class. That’s 300 hours saved, and over a 40-week school year, that’s 12,000 hours saved. Valuing each hour at a conservative $10 (a measure of time's potential value), the savings would be $120,000
* **Enhanced Security:** LiFi signals can't penetrate walls, providing a physical layer of data security. In settings where data security is a priority, this can result in savings from potential data breaches. However, in a typical classroom, the value might be more intangible. Assigning a rough value might place it at $2,000 for peace of mind and added security for the entire class.
* **Reduced Electromagnetic Interference:** In settings where electronic interference is an issue, LiFi can be advantageous. For most classrooms, this might not be a direct benefit. But in specialized settings (e.g., labs with sensitive equipment), this can be significant. For an average classroom, we might value this at a minimum of $500.
* **Energy Efficiency:** If the lighting system is optimized for LiFi, it might result in some energy savings, especially if LEDs are used both for lighting and data transmission. Over a year, this could result in, say, a $200 savings in electricity bills for that classroom.
* **Innovative Learning Experience:** Being one of the early adopters of new technology can expose students to innovation, potentially sparking interest in tech or STEM fields. This is quite intangible. However, let's estimate it conservatively at $3,000 for the entire class, representing potential future pursuits or projects inspired by this experience.

Let's first consider the costs and benefits over a one-year period for both options.

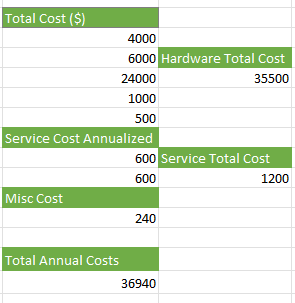
**WiFi**

* **Total Hardware Costs =** $300 (router/access point) + $200 (modem) + $20 (ethernet cables) + $24,000 ($800 computer x 30 students) + $50 (mounting/equipment) + $200 (installation/labor) = $24,770
* **Total Annual Service Costs =** $600 ($50 ISP monthly fee x 12 months) + $600 ($50 maintenance monthly fee x 12 months) = $1,200
* **Total Annual Miscellaneous Costs =** $100 (wifi extenders) + $600 ($50 security upgrade \* 12 months) = $700

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* **Total Costs =** $24,770 (Total Hardware Costs) + $1,200 (Total Service Costs) + $700 (Total Miscellaneous Costs) = $26,670
* **Total Annual Benefits =** $12,000 (increased productivity) + $6,750 (savings from physical resources) + $3000 (flexibility in learning) = $21,750

**LiFi**



* **Total Hardware Costs =** $4,000 ($500 LiFi lightbulbs x 8 needed) + $6,000 ($200 dongle x 30 computers) + $24,000 ($800 computer x 30 students) + $1,000 (Driver and Modulation Unit) + $500 (labor cost) = $35,500

(\*Note - 8 LiFi enabled lightbulbs were used since Kyle Academy utilized that amount in their singular classroom)

* **Total Annual Service Costs =** $600 ($50 ISP monthly fee x 12 months) + $600 ($50 maintenance monthly fee x 12 months) = $1,200
* **Total Miscellaneous Costs =** $240 (training for teachers/staff)
* **Total Costs =**  $35,500 (total hardware cost) + $1200 (total annual service cost) + $240 (misc cost) = $36,940
* **Total Annual Benefits** = $120,000 (increased data transmission speeds) + $2,000 (enhanced security) + $500 (reduced electromagnetic interference) + $200 (energy efficiency) + $3000 (innovative learning experience) = $123,000

**Summary of Economic Analysis Methods:**

**B/C Ratio** = Total Benefits/Total Costs

* **WiFi** = $21,750/$26,670 = 0.815523
* **LiFi** = $123,000/$36,940 = 3.32972
  + We can see that the B/C ratio of LiFi is comparatively much higher than WiFi’s

**NPV (Net Present Value) =** Sum of (CashFlow)/(1+r)^t - Initial Investment

NPV will be calculated over a 5-year period with at a 10% discount rate. It is assumed that the cash flow is uniform.

* **WiFi** = (Total Benefit - Total Annual Cost) (P/A, 10%, 5 years) - Initial Cost

(21,750 - 1,900)(3.791) - 24,770 = 50481.35

* **LiFi** = (Total Benefit - Total Annual Cost) (P/A, 10%, 5 years) - Initial Cost

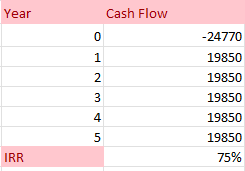
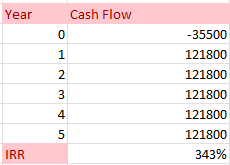
(123,000 - 1200)(3.791) - 35,500 = 426243.8

* We can see that the B/C ratio of LiFi is comparatively much higher than WiFi’s

**Return on Investment (ROI) =** (Benefits - Costs) / Costs \* 100

* **WiFi** = (($21,750 - $26,670)/ $26,670) \* 100 = -18.4477 %
* **LiFi** = ($123,000 - $36,940)/ $36,940 = 232.9824 %
  + We can see that the ROI percentage of LiFi is comparatively much higher

**Internal Rate of Return (IRR)** 0 = NPV = Sum of CFn/(1+IRR)^n

**WiFi :**  **LiFi:**

* + We can see that the IRR percentage of LiFi is comparatively much higher

**RESULTS**

Interestingly enough, our economic analysis of the implementation of Wi-Fi and Li-Fi technologies in school settings yielded very distinct outcomes. Perhaps it was the overestimation of the benefits of LiFi, but LiFi provided the best results from of an economic analysis standpoint. The Benefit Cost ratio of LiFi yields a return of approximately $3.33 for every dollar spent while WiFi yields a return of approximately $0.82. The NPV for LiFi is expected to generate a net value of $426,243.80 more than its cost when accounting for the time value of money, but WiFi is expected to generate a net value of $50,481.35. The ROI percentage value, which indicates the profitability of an investment, is a staggering 232.9824 % for LiFi, yet WiFi’s ROI is shockingly -18.4477 %. To further analyze our data, I also calculated the IRR for WiFi and LiFi. Considering that WiFi’s ROI was negative, I also assumed that its IRR would be too but it’s surprisingly 75%, but LiFi’s IRR was a dramatic 343%. It seems like despite the hefty initial cost, LiFi really showcased its benefits (such as enhanced data transmission speeds and superior security features) which resulted in such astonishing results.

My rough estimates for LiFi’s cost models definitely swayed the results, but with all things considered, I think it was a good first step in the economic analysis of LiFi as there are not a lot of detailed cost breakdowns for this technology in general. I’m confident my WiFi cost model analysis is pretty accurate, but perhaps when more accurate information can be provided, I would really like how different the results would be.

**CONCLUSION**

In conclusion, the choice between Wi-Fi and Li-Fi isn't merely economical but also strategic. While Wi-Fi offers familiarity and widespread compatibility, Li-Fi promises a leap into next-generation technology. Through my exploration of the economic viability of each tech, it appears that LiFi would be my recommendation as the next step in wireless communication in school settings.

Li-Fi shows promise for applications as high-speed, secure, and interference-resistant data transmission is essential, but its limited range and higher costs are currently hurdles to overcome for broader adoption. A suggestion for this challenge would be to strategically place multiple Li-Fi emitters to ensure comprehensive coverage. Alternatively, a hybrid system of both WiFi and LiFi could be implemented, getting the best of both worlds. Another challenge I could potentially see with LiFi is that only a limited range of devices currently support Li-Fi. This could require additional expenditure on compatible devices, but to tackle this issue, I would recommend adopting a phased approach. Schools can begin by implementing Li-Fi in crucial areas, like computer labs, before expanding it school-wide. This would greatly lower the initial cost, and it would be a safe way in navigating an uncertain future.

As with any new technology, it rapidly evolves so there’s always a risk involved with the unpredictability of how it behaves and how it will perform in the future. Nonetheless, schools must consider not just the immediate financial implications but also the long-term vision of where they want to position themselves in the evolving educational landscape.

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