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Cost estimation of a sensor technology-based traveler sprinkler under landscape irrigation conditions

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Abstract

This paper aimed to evaluate a sensor-based traveler gun sprinkler under landscape irrigation conditions. The focus was on the operating and manufacturing costs of the traveler gun sprinkler, as well as its operational performance and economic feasibility for irrigating Aswan University stadiums. The research relied on a comprehensive cost analysis methodology, classifying costs into two types: fixed including design, manufacturing, and procurement of sensor and control systems and variable, including operating, maintenance, energy, and labor costs. The results showed that the traveler gun sprinkler design, which incorporates a Wi-Fi remote control system and humidity sensors, significantly reduced operating costs compared to other systems. Economically, the analysis demonstrated that the initial manufacturing cost of the traveler gun sprinkler, amounting to 50,000 Egyptian pounds, could be offset in the long run through savings in operating costs (energy and labor). The operating cost was 63 L.E. per hour. Feasibility studies also showed an average payback period of 10 years, aligning with the average life expectancy of traveler sprinklers, making it feasible for both small farmers and large companies.

Keywords: Traveler sprinkler; Cost analysis; Smart irrigation.

1. Introduction

Traveler gun sprinklers are specialized irrigation systems widely used in agriculture. They adapt to irregularly shaped plots and quickly cover large areas of farmland. The hard hose traveler system uses a polyethylene hose, and water is evenly sprayed onto the crops through the sprinkler **[1-3].** Irrigation systems significantly increase farmers' economic returns by improving the efficiency and yield of agricultural production, allowing long-term benefits to outweigh initial investments and ensuring economic viability for farmers. Efficient irrigation technologies, such as traveler gun sprinklers, can reduce water waste and optimize water distribution, thereby improving crop yields and quality and further enhancing farmers' incomes **[1, 4, 5].** The traveler gun sprinkler is an irrigation device mounted on moving wheels and connected to flexible rubber tubes. This system is usually installed on a wheeled platform with a high-pressure nozzle of large capacity, connected to the water source via a flexible or hard hose. During operation, the sprinkler moves as the hose coils, covering different areas of the farmland **[6]**.

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A key feature of mobile irrigation systems is their flexibility to efficiently irrigate larger areas using a single device, which is more effective than fixed systems. However, these systems require high operating pressure to function properly, usually around 100 psi, which increases the operating cost **[6]**.

The traveler sprinkler system has multi-directional mobility, making it suitable for irrigating irregularly shaped fields, including hilly highlands and mountain terraces **[7, 8].** Despite their versatility, traditional Hard Hose Travelers have efficiency limitations related to the adjacent areas of irrigation strips **[8].** The adoption of traveler gun sprinkler systems is significantly constrained by their economic requirements, as they demand substantial upfront investment for establishment and installation **[9, 10].**

The traveler gun sprinkler requires a high initial investment, including equipment such as sprinklers, pipes, pumps, and controllers. In addition, as the most common type of travel irrigation system, the installation and maintenance of HVC systems also demand significant capital investment **[10, 11].** These ongoing operational costs have proven to be a significant obstacle, often causing the abandonment of these irrigation systems despite their technical advantages **[10].** Traveler gun sprinkler systems do have some significant shortcomings, mainly high initial investment, energy needs, and maintenance costs **[12].** Although sprinkler systems, including traveler guns, have some practical challenges, they generally offer significant advantages over traditional surface irrigation methods in water application efficiency **[13].**

Alternative configurations like traveling boom systems, which use multiple nozzles instead of a single gun, offer higher distribution uniformity and can reduce the high energy costs associated with traditional traveling gun systems **[14].** Operating at low flow and pressure, these systems may provide a more economical option while maintaining efficient irrigation coverage. This conclusion is supported by multiple pieces of evidence **[6].**

As the core component of the travel gun irrigation system, the gun is manufactured with a variety of nozzles (8 to 16 mm) and different operating pressures (2 to 6 bar). These parameters directly affect the system's irrigation efficiency, uniformity, and costs **[15]**. While traditional mobile cannon sprinkler irrigation systems often rely on high-pressure pumps, modern designs have introduced alternative power sources to meet diverse needs. These include electric motors, diesel and gasoline engines, gas turbines, and renewable sources **[16]**, potentially addressing energy cost concerns. Traveler gun sprinklers can be an economical option for irrigation in specific agricultural setups, especially for plantation areas with square geometric shapes **[17]**.

Farmers can expand irrigation coverage effectively without major additional investments, optimizing water distribution and enhancing crop productivity **[5]**. While the financial benefits of traveler gun sprinklers are noteworthy, it’s crucial to consider the broader economic landscape and explore alternatives. Using center pivot systems with end gun attachments not only conserve resources but also improve yields without excessive costs, making such combined approaches financially viable under certain conditions **[3].**

Therefore, this manuscript aims to analyze the cost analysis of development the traveler gun sprinkler based on sensor technology.

2. Materials and Methods

2.1. The main components

The traveler gun sprinkler has been developing and manufacturing to enhance water use efficiency in irrigation. The key design features include its simplicity, ease of use, and the fact that its components are made from locally available materials, which makes it both cost-effective and accessible. Additionally, the system is easy to manufacturing, making it ideal for irrigating farms and sports grounds. One of its major advantages is its ability for remote field operation, allowing for greater flexibility and ease in managing irrigation needs reducing the number of irrigation hours, which reduces operating costs. Traveler gun sprinkler was manufacturing at the Aswan University, Aswan, Egypt, located at a latitude of 24.08889° North and a longitude of 32.89972° East, at an elevation of approximately 85 meters above sea level. The essential components of the traveler gun sprinkler are detailed in Table 1 and Figure 1, with the specifications and features clearly outlined.

Table (1): The detailed descriptions of the traveler gun sprinkler.

The components	Descriptions
Frame	The prototype frame uses four wheels (400 × 8) to contact the ground. They are mounted on the frame, which is pulled by a four-wheeled DC motor moving the traveler gun sprinkler. The frame is covered with 1mm thick sheet metal and constructed from rectangular tubes (40 × 40 × 2 mm) and square tubes (30 × 30 × 1 mm). The rectangular frame measures 550 mm in height, 1200 mm in length, and 900 mm in width.
Power unit	The power unit used in the traveler gun sprinkler consists of four DC motors installed on the wheels. Each DC motor has a power of 350 W. The prototype sprinkler irrigation system moves at different speeds.
Power supply system	Two lithium batteries (36 V, 4400 mAh) were used as the power source for the DC motors, and a 12 V battery powered the electronic circuits.
Sprinkler irrigation system	The sprinkler irrigation system frame mainly consists of galvanized iron pipes, a sprinkler gun (D = 1.5 in) with nozzles (8, 10, 12, 14, and 16 mm), water pipes (1.5 in) at different heights (1.25 m, 1.5 m, and 2 m), hoses (1.5 in), and a gasoline engine pump.

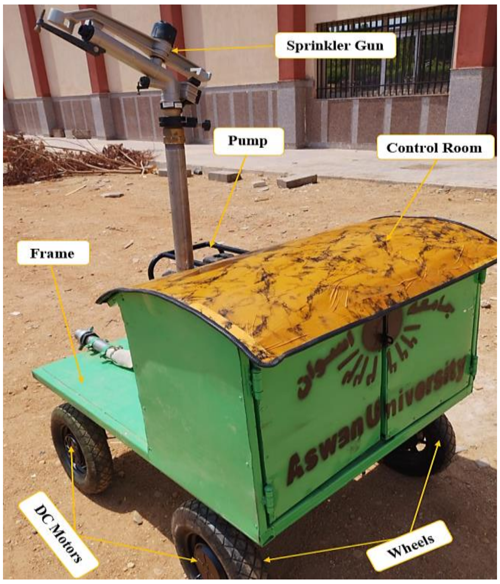

Fig.(1): The traveler gun sprinkler shows main components.

2.2. Cost analysis

The cost analysis was conducted to assess the economic developing and manufacturing of the traveler gun sprinkler using fixed standards based on the local prices set in the market. The costs were calculated based on the manufacturing of a proposed prototype of the traveler gun sprinkler, owning the machine for 10 years and using it 2000 hours per year The total operational cost for traveler gun sprinkler in the field occurred was calculated by adding annual fixed cost and variable cost in L.E./hr and L.E. /fed, Irrigation costs include both fixed costs of consumption, interest, shelter, taxation and insurance, as well as variable costs covering repair, maintenance, fuel, oil, lubricants and labor costs according to **[18].**

2.2.1. Fixed Costs

1. **Depreciation**

$$D = \frac{(Pm - S)}{Lm} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (1)$$

Where:

D is depreciation (L.E./year).
Pm is the machine purchase price (L.E).
S is salvage price (L.E).
Lm is cultivator life (year).

2. **Investment interest**

$$D = \frac{(Pm + S) \times i}{2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (2)$$

Where:

I is investment interest (L.E./year).
i is interest is compounded annually (decimal).

3. **Shelter, taxes and insurance**

Shelter, tax and insurance costs were estimated at 2% of the original value of the machine purchase, based on the methodology **[18]** in their reference study. This ratio was included within fixed costs in the overall economic analysis, which contributed to enhancing the accuracy of the results calculated for the project's financial feasibility.

2.2.2. Variable costs

1. Repair and maintenance costs: Estimated at 10% of annual consumption cost, reflecting periodic maintenance and fault repair requirements.
2. Fuel costs: Annual cost of fuel (L.E. /year) = fuel consumption rate (L/H) × 1 liter price (L.E.) × number of annual operating hours.
3. Oil and electronics costs: Estimated at 20% of total annual fuel costs, according to the technical standards of machinery maintenance.
4. Labour costs: Calculated based on operator's hourly pay (L.E./h) × total annual operating hours, where the operator is paid for the actual time of operation of the traveler gun sprinkler.

2.2.3. Total costs

The total cost (L.E./h) of the traveler gun sprinkler was calculated by combining fixed and variable costs. Fixed costs include depreciation, interest, shelter, taxes, and insurance, while variable costs cover repair, maintenance, petrol, oil, lubricants, and labor. To determine the total operating cost per hour, both fixed and variable costs were summed (L.E./h). This cost was then converted to a cost per acre by multiplying it by the actual hours required to irrigate one acre, providing an accurate measure of the total cost, including all operation and maintenance elements. This approach aims to assess the economic feasibility of the traveler gun sprinkler and support sound financial decision-making based on comprehensive and precise cost data.

2.2.4. Basic assumption

Table (2) shows the assumed performance values of the traveler gun sprinkler based on observations made during testing.

Table (2): Data assumed for the performance of the traveler gun sprinkler.

Item	Values
Initial cost.	50000 L.E.
The machine life.	10 years.
Operation days.	200 day/year
Fuel consumption.	0.850 l/h
Fuel price (Gasoline).	14 L.E./l
Interest rate (i)	0.22
The number of laborers required.	One laborer.
Labor wage.	35 L.E/h.
Operation hours.	8hours/day.

3. Results

The traveler gun sprinkler was developed and manufactured by the Department of Agricultural Engineering, Aswan University. Its performance was evaluated by irrigating the university playgrounds to estimate operational costs. The site is located at the Faculty of Agriculture and Natural Resources, University of Aswan, approximately 85 meters above sea level, at 24.088°N latitude and 32.899°E longitude. Table (3) shows the estimated irrigation costs using the traveler gun sprinkler, calculated based on performance data of the sprinkler nozzle described in the methodology. As shown, the total cost to irrigate one feddan is presented.

Table (3): Estimation of irrigation costs using the traveler gun sprinkler.

Items		Costs
Fixed cost.	Deprecation. (L.E./year)	5000
	Investment interest. (L.E./year)	2000
	Shelter, taxes and insurance	1000
Total fixed costs (L.E./year)		8000
Total fixed costs (L.E./h)		5
Variable costs.	Repair and maintenance. (L.E./h)	3
	Fuel and Electricity Charging costs (L.E./h)	15
	Oil and electronics costs (L.E./h)	5
	Labor cost (L.E./h)	35
Total Variable costs (L.E./h)		58
Total costs (L.E./h)		63

Table (3) presents a detailed analysis of the operating costs of the traveler gun sprinkler used to irrigate Aswan University stadiums, aiming to help researchers and farmers understand the cost structure of this system. The table is divided into two main parts: fixed and variable costs, offering a comprehensive view of annual expenditures and hourly operating costs. The annual depreciation cost was shown to be 5,000 Egyptian pounds, while variable costs accounted for the majority of total costs (58 L.E. out of 63 L.E.), indicating that reducing operating hours or improving system efficiency could significantly lower costs. Conversely, since fixed costs are spread over 10 years, increased system usage may reduce the fixed cost per hour.

4. Conclusion

The cost and performance analysis of the traveler gun sprinkler manufacturing shows that the total cost is mainly affected by fixed costs (primary manufacturing investments, sensor systems, control techniques) and variable costs (energy, maintenance, labour).The economic assessment found that systematic integration of these factors enables the determination of the optimal costing structure in which technical features such as remote control, moisture sensors contribute and the results cost of 63 L.E./h at a maximum of 8 working hours per day is balanced between operational costs and productive returns water resources, with long-term water and energy savings. These integrated techniques also contribute to reducing water loss and human intervention, enhancing economic viability and ensuring quality performance in different field conditions.

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