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Financial Evaluation to Select the Best Water Hyacinth Harvester to Improve Water Resources in Thailand

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ABSTRACT

Cost analysis for the eradication of water hyacinth was undertaken using a mechanical water hyacinth harvester. Two foreign harvester models (V 4702 and S 2800) were ordered and a prototype water hyacinth harvester was designed and built in Thailand. Based on reports, there are 4.52 million t of water hyacinth in Thailand. A budget of USD 0.27 million per year would eradicate 477,000 t using water hyacinth harvesters. The operating cost is not satisfactory and the permanent eradication of water hyacinths would involve an operating cost of USD 2.68/t. The results showed that the initial investment in the prototype water hyacinth harvester was lower than for the two foreign models. The engine used in the V 4702 model was the biggest and so its fuel price was the highest. Furthermore, the maintenance and labor costs of the prototype were the lowest. There was little difference in the payback period among the three units. All three water hyacinth harvesters were considered a worthwhile investment based on net present value analysis. Finally, the main capital investment was associated with the initial purchase. In future, the prototype water hyacinth harvester will reduce the initial capital investment required compared to purchasing foreign brands.

Keywords: water hyacinth, mechanical control, water hyacinth harvester, financial evaluation

INTRODUCTION

Water hyacinth (*Eichhornia crassipes*) is an aquatic plant native to the Amazon basin which can live floating freely on the surface of fresh water and is often considered a highly problematic invasive species outside its native range (Paul *et al.*, 2000). The extremely rapid rate of proliferation of the plant usually results in a reduction in height penetration and dissolved oxygen in water bodies, changes to the water chemistry, adverse effects on flora and fauna and an increased rate of water loss (Sotolu, 2013). Water hyacinths have been widely introduced in North America, Asia, Australia, Africa and New Zealand, so that in many areas, they have become an important and pernicious invasive species (Caring for our Country, 2015). Nowadays, water hyacinths are present on almost all rivers and canals in Thailand (Tran *et al.*, 2011) and they also grow in waste lagoon receiving wastewater (Pattanee, 1993). Problems associated with water hyacinth include: hindrance to water transport, clogging of irrigation intakes and hydropower and water supply systems, blockages in canals and rivers causing flooding, providing a micro-habitat for a variety of disease vectors, increased evapotranspiration, problems related to fishing and a reduction in biodiversity (Caring for our Country, 2015).

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Current control options for water hyacinth include chemical, biological and mechanical controls (Alimi and Akinyemiju, 1990). Chemical control has been discussed by Lugo *et al*. (1998) and Girisuta *et al.* (2008); herbicide spraying is effective for controlling small infestations and treatment should commence in spring before the plant flowers and normally requires several follow up treatments over the growing season. While herbicides will often provide the most cost-effective treatment, a potential drawback is the risk of the decomposing vegetation detrimentally affecting water quality and particularly dissolved oxygen levels. Furthermore, the use of herbicides in or near water bodies is strictly regulated. While biological control is most effective on larger infestations, it can take several years for it to provide successful control (Cilliers, 1991; Paul *et al.*, 2000; Groote *et al.*, 2003; Pawan and Kumar, 2014). According to Caring for our Country (2015), mechanical control should only be used where the rate of removal can exceed the rate of regrowth and should be done before flowering and seed set in spring. It is also the best method for removing infestations from rivers and canals. The harvested plants can then be removed by an excavator or similar machinery. Physical removal provides a number of advantages over other methods (Caring for our Country, 2015), including: removal of water quality issues associated with spraying and the resulting decomposition of large quantities of plant material in the water column. Thus, due to the prevalence of water hyacinths in many rivers and canals in Thailand, mechanical control is a suitable technique. After eradication of water hyacinth by mechanical control, many researchers have studied water hyacinth utilization (Gajalakshmi and Abbasi, 2002; Jianbo *et al.*, 2008; Supri and Ismail, 2011; Frank and Akhiheiero, 2013, Jayanthi and Lalitha, 2014) and some researchers have studied the effect of water hyacinth by mechanical control (Nicole *et al.*, 2006; Spencer *et al.*, 2006; Jianbo *et al.*, 2007; Supri and Lim, 2009). Due to the complexity of the design problem, few researchers have investigated the machines that can be used for mechanical control. Water hyacinth growth rates were monitored from May through October in two sewage lagoons with different nutrient loading rates (Wolverton and Rebecca, 1979). The lagoon receiving the heaviest load sustained the highest average growth rates throughout the summer. The lightly loaded lagoon averaged a 29% increase in weight per week over the six month period with the highest growth rate occurring during June with an average weekly weight gain of 71%. The heavily loaded lagoon sustained an average growth rate of 46% per week for the same six month period with the highest measured growth rate of a 73% increase in weight per week also occurring in June. In addition, the performance of three harvesters was evaluated. One harvester, consisting of a chopper and conveyor was capable of picking up and chopping approximately 2.3 t of plants per hour and delivering them to a waiting truck. The second harvester was a single 1.52 m wide conveyor, and the third was a modified clamshell bucket attached to a dragline. The average harvesting rate of each of these harvesters was approximately 9.3 t of water hyacinth per hour. A water hyacinth chopper-cum-crusher was developed at the College of Technology and Engineering, Udaipur, India (Muthur and Singh, 2004). The performance of this chopper-cum-crusher was evaluated on the basis of its ability to reduce the volume and weight of fresh water hyacinth. Two variables—feed rate and knife speed—were studied. Relationships were developed between changes in the specific volume, knife speed; percentage weight loss and feed rates.

In Thailand, a protection and eradication policy with regard to water hyacinth has been specified by the Ministry of Interior. In 1989, the Department of Public Works and Town & Country Planning was ordered by the Ministry of Interior to eradicate water hyacinth using machinery. Initially, two foreign brands of water hyacinth harvesters were ordered—the V 4702 model (Figure 1a) and the S 2800 model (Figure 1b). The engine specifications of the two units are summarized in Table 1. The water hyacinth harvesters mechanically remove and collect water hyacinth using a specially developed conveyor system and cutters and the aim is to control more extensive problems by means of water hyacinth management (The Metals Industry Research and Development Center, 2015). The water hyacinth harvesters are mounted on a steel landing craft. The draft of the harvester is 70 cm and the total weight is 5 t. A diesel engine is used to propel a steel paddle wheel. The water hyacinths are delivered from the front part of the water hyacinth harvester using a stainless steel continuous belt. In the middle part of the harvester, the water hyacinths are chopped by a steel sliding blade and they are stored at the rear of the harvester. Up until now, water hyacinth harvesters have been used on many water bodies in Thailand with considerable success (Department of Public Works and Town & Country Planning, 2015). Furthermore, the plants can balance natural lifecycles in reservoirs or in lakes that receive large amounts of nutrients (Caring for our Country, 2015). However, the large V 4702 and S 2800 harvesters cannot be used in small canals and small rivers. Normally, the water hyacinths generally grow in wet habitats and they form dense rafts in the water and mud And mechanical removal is often not practical in shallow water. In this study, a prototype water hyacinth harvester was designed and used on many water bodies

GOVERNING EQUATION

Archimedes' principle for water hyacinth harvester design

Archimedes' principle indicates that the upward buoyant force that is exerted on a body immersed in a fluid, whether fully or partially submerged, is equal to the weight of the fluid that the body displaces. Thus the new water hyacinth harvester was designed according to Archimedes' principle. From Figure 2, when a body is partially or completely immersed in a fluid, it experiences an apparent loss in weight which is equal to the weight of the fluid displaced by the immersed part of the body. The buoyancy force (F_B) is defined from White, 2011) and the forces dF_1 and dF_2 are calculated from Equations 1 and 2, respectively:

$$dF_1 = (P_0 + \gamma y_1)dA_y \quad (1)$$

$$dF_2 = (P_0 + \gamma y_2)dA_y \quad (2)$$

where y_1 and y_2 are the vertical distance from

Figure 1 Foreign water hyacinth harvesters: (a) S 2800 model; (b) V 4702 model.

Table 1 Engine properties of water hyacinth harvester models.

Model	Cylinders	Displacement (cm^3)	Bore (mm)	Stroke (mm)	Net engine horsepower
S 2800	4	2791	85	82	51
V 4702	4	4665	109	125	85
Prototype (D 142–B)	3	1395	85	82	35

free surface until dF_1 and dF_2, respectively; A_y is the shaded portion in the vertical direction; P_0 is atmospheric pressure; And the body appears between an upper surface 1 and a lower surface 2. For vertical force, the body experiences a net upward force, calculated using Equation 3:

$$dF_B = dF_2 - dF_1 \quad (3)$$

where dF_B is weight of fluid equivalent to body volume. Equations 1 and 2 can be used in Equation 3, to produce Equation 4:

$$dF_B = \gamma d\forall_S \quad (4)$$

or

$$F_B = \int dF_B \quad (5)$$

$$F_B = \iiint \forall_S \gamma \forall_S \quad (6)$$

$$W = F_B = \gamma \forall_S \quad (7)$$

where $d\forall_S$ is displaced volume; W is the weight of the water hyacinth harvester and γ is the specific weight. The landing craft component of the harvester (SB) can be expressed by Equation 8:

$$SB = w \times LOA \times h \quad (8)$$

where w, LOA and h are the width, length and depth, respectively. The bow and stern of the water hyacinth harvester are triangular in shape.

Propulsion system of water hyacinth harvester

The hydraulics of the propulsion system are taken from Peter (2008). The hydraulic pump flow rate (Q_P), the hydraulic motor oil flow rate (Q_M) and the hydraulic cylinder flow rate (Q_C) are calculated from Equations 9–11, respectively, and the total flow rate (Q_T) is calculated from Equation 12 and the remaining hydraulic oil (Q_{BYPASS}) is defined using Equation 13:

$$Q_P = V_P \times rpm \times nV_P \quad (9)$$

$$Q_M = V_M \times rpm \times nV_M \quad (10)$$

$$Q_C = A_C \times V_C \quad (11)$$

$$Q_T = \sum_{i=1}^{m} Q_M + \sum_{i=1}^{n} Q_C \quad (12)$$

$$Q_{BYPASS} = Q_P - Q_T \quad (13)$$

where nV is the percentage of volumetric efficiency; A_C is the area of a cylinder; and V_P, V_M, V_C are the capacity of the hydraulic cylinder, the hydraulic motor oil and the hydraulic pump, respectively.

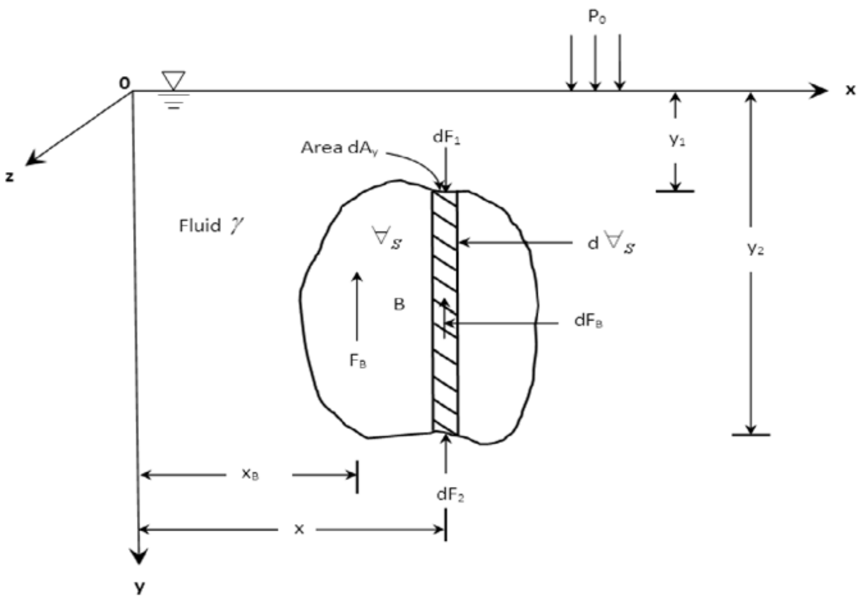

Figure 2 Forces in buoyancy of an arbitrary immersed body (dF_1 and dF_2 are forces, where y_1 and y_2 are the vertical distance from free surface until dF_1 and dF_2, respectively, dFB is the net upward force (White, 2011).

Financial evaluation

Financial evaluation is a key consideration affecting policy-making because economic development is the fundamental force that pushes the production system forward. The payback period (Equation 14), net present value (Equation 15) and internal rate of return (Equation 16) are important factors in the financial evaluation. The payback period (PP) in capital budgeting refers to the period of time required to recoup the funds expended in an investment. All else being equal, shorter payback periods are preferable to longer payback periods (Farris *et al.*, 2010). In finance, the net present value (NPV) is defined as the sum of the present values of incoming and outgoing cash flows over a period of time; incoming and outgoing cash flows can also be described as benefit and cost cash flows, respectively (Lin and Nagalingam, 2000). The internal rate of return (IRR) is the rate of return used in capital budgeting to measure and compare the profitability of investments and is also called the discounted cash flow rate of return (Hazen, 2003).

$$n = \frac{TS}{Y_i} \qquad (14)$$

where n, TS and Y_i are the payback period, initial investment and net return, respectively.

$$NPV = k_0 + \left[\frac{b_1 - c_1}{i+1}\right] + \left[\frac{b_2 - c_2}{(i+1)^2}\right] + \left[\frac{b_t - c_t}{(i+1)^n}\right] \qquad (15)$$

$$IRR = \sum_{t=1}^{n} \frac{b_t - c_t}{(i+r)^t} = 0, \; t = 1, 2, ..., n \qquad (16)$$

where NPV is the net present value; IRR is the internal rate of return; k_0 is the initial investment; b_1, b_2 and b_t are the present value of 1, 2 and t years, respectively; and c_1, c_2; and c_t are the investment of 1, 2 and t years, respectively.

The analysis of the initial investment per removal of water hyacinth (AII), the analysis of operating cost per removal of water hyacinth (AOC), the fuel price per removal of water hyacinth (SEC), the analysis of maintenance cost per removal of water hyacinth (AMC), the analysis of labor cost per removal of water hyacinth (ALC) are determined using Equations 17–22, respectively.

$$AII = \frac{T_{II}}{A_{WH}} \qquad (17)$$

$$AOC = \frac{T_{OC}}{A_{WH}} \qquad (18)$$

$$SEC = \frac{T_{FP}}{A_{WH}} \qquad (19)$$

$$AMC = \frac{T_{MC}}{A_{WH}} \qquad (20)$$

$$ALC = \frac{T_{LC}}{A_{WH}} \qquad (21)$$

$$ATC = \frac{T_{C}}{A_{WH}} \qquad (22)$$

where A_{WH} is amount of water hyacinth; and T_{II}, T_{OC}, T_{FP}, T_{MC}, T_{LC} and T_C are the total initial investment, total operating cost, total fuel price, total maintenance cost, total labor cost and total cost, respectively.

PROTOTYPE OF WATER HYACINTH HARVESTER DESIGN

Considering previous design problems, the current water hyacinth harvester was based on Archimedes' principle and in order to work in shallow water, the new harvester was smaller than the S 2800 and V 4702 units. The landing craft of the prototype harvester is shown in Figure 3. From Equation 8, the landing craft of the harvester (SB) is 2 m wide and 4.80 m in length overall (LOA) and 0.50 m in depth. When the full load is considered, the net registered displacement is 2.79 m^3 or 2.79 t. From Equation 9, the hydraulic pump flow rate (Q_P) is 58.14 L/min. From Equation 10, the hydraulic motor oil flow rate of the two turbine wheels (Q_{M1}) is 11.52 L/min, the hydraulic motor oil flow rate of the harvesting head with conveyor (Q_{M2}) is 20.16 L/min, the hydraulic motor oil flow rate of the three knife bars (Q_{M3}) is 15.48 L/min and the hydraulic motor oil flow rate of the storage conveyor (Q_{M4}) is 5.92 L/min. From Equation 11, the water hyacinth plants are scooped from the front part of the harvester with a hydraulic cylinder flow rate of two scoops (Q_{C1}) of 1.96 L/min and the water hyacinth is transported on the stainless steel continuous belt, with a hydraulic cylinder flow rate of the two conveyors (Q_{C2}) being 1.96 L/min. From Equation 12, the total flow rate (Q_T) is 57.00 L/min. From Equation 13, the flow rate for the remaining hydraulic oil (Q_{BYPASS}) is 1.14 L/min. From the above design, the hydraulic horse power is 31.63 so the net engine was selected to be 35 hp, as shown in Table 1. The design of the prototype water hyacinth harvester is shown in Figure 4. Following budget approval, the prototype harvester was built, as shown in Figure 5.

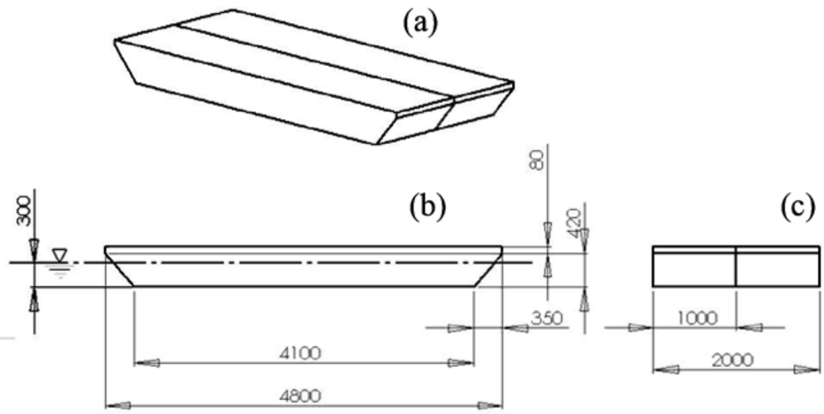

Figure 3 Landing craft of prototype water hyacinth harvester: (a) Body; (b) Side view; (c) Front view. All units in millimeters.

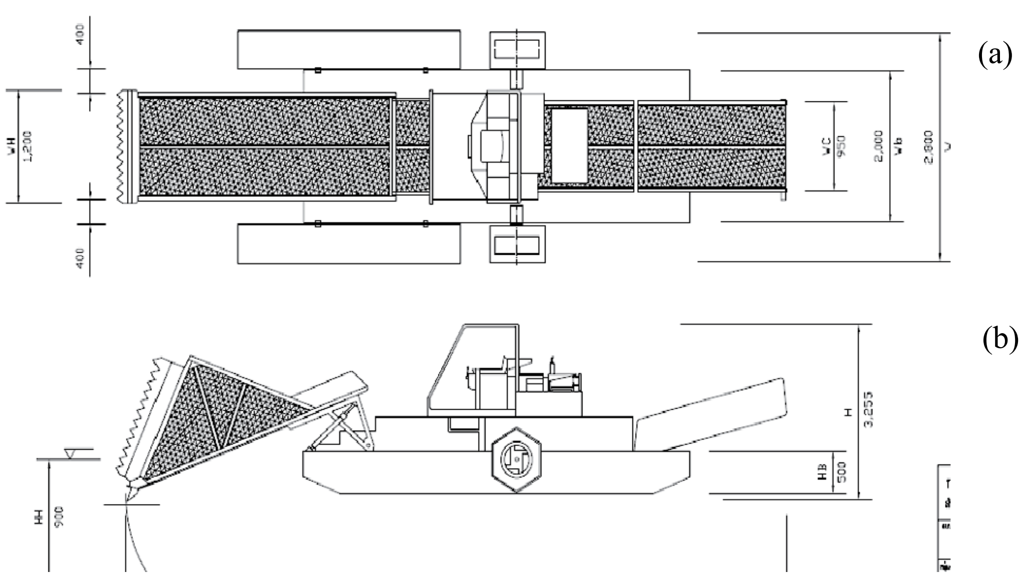

Figure 4 Design of prototype water hyacinth harvester: (a) Top view; (b) Side view. All units in millimeters.

Figure 5 Prototype water hyacinth harvester.

RESULTS AND DISCUSSION

This study compared the three water hyacinth harvesters—S 2800, V 4702 and a prototype. The financial evaluation for selecting the water hyacinth harvester considered the payback period, net present value and internal rate of return of operation. Based on the Department of Public Works and Town & Country Planning report, there are 4.52 million t of the water hyacinth on water bodies in Thailand, distributed in the Northern, Central, Eastern, Western, Southern and Northeastern regions with 2.04, 1.35, 0.023, 0.024, 0.245 and 0.842 million t, respectively. As part of the eradication plan for water hyacinth and aquatic weeds (Department of Public Works and Town & Country Planning, 2015), 16 foreign water hyacinth harvesters including one prototype water hyacinth harvester were ordered. From 2003 to 2012, these water hyacinth harvesters were used on many water bodies in Thailand such as the Nakornchaisri River, Nakhon Pathom province, Bueng Kluea in Roi Et province, Phayao Lake (Kwan Phayao) in Phayao province, Klong Chao Jed in Phra Nakhon Si Ayutthaya province, Ram Masak Canal in Ang Thong province and Bung Sri–Fai (lagoon) in Phichit province. The budget was USD 0.27 million /yr to eradicate 0.477 million t at an operating cost of USD 0.56 /t over 9.47 yr. However, the water hyacinth is continually growing and at a rate faster than eradication. If the water hyacinths are to be permanently eradicated, this operating cost is not sufficient. From previous data, 9.47 times the amount of water hyacinth in Thailand would result in an operating cost of USD 5.36 /t. After eradication, reproduction of water hyacinth increased within 6–8 mth (Jianbo *et al.*, 2008), so that the operating cost could be considered as USD 2.68 /t.

Tables 2–4 show the analysis of the operations over ten years (2003–2012) and the operating cost was calculated to be USD 2.68 /t. The total initial investment in the three types of water hyacinth harvesters is shown in Tables 2, 3 and 4, respectively. The initial investment in the water hyacinth harvesters S 2800 and V 4702 involved foreign purchases amounting to USD 164,986 and USD 144,015, respectively, taking into account differences in the exchange rate and the engine properties. The prototype harvester was designed and built in Thailand and involved an initial investment of USD 32,380 which was lower than for the two imported models, in part due to its smaller size. Where the models operated in shallow water, the height of the harvesting unit meant it could not pass under the low bridges and so operating costs included transportation and coordination costs. The operating costs are the expenses which are related to the operation of a business, or to the operation of a device, component and piece of equipment or facility. They are the cost of resources used by an organization just to maintain its existence. Due to their larger size, the S 2800 and V 4702 models were more expensive than the prototype harvester as were their engines (Table 1), so that the fuel price for operating the V 4702 model was higher than for the S 2800 model, while the prototype (being the smallest) had the lowest fuel costs. Maintenance included cleaning, regular inspection, and replacement of "production" components (filter media and lubrication). The maintenance cost for the prototype harvester was lower than for the imported models as the components could be purchased locally. The labor cost included wages paid to workers during each accounting period on a daily, weekly, monthly or job basis, plus payroll and related taxes and benefits. The smaller size of the prototype harvester meant that its associated labor costs were lower than for the S 2800 and V 4702 models. The larger S 2800 and V 4702 models removed more water hyacinth than the prototype harvester. The initial investment per removal of water hyacinth for the S 2800, V 4702 and the prototype models was 18.23, 15.51 and 9.79, respectively. It can be seen that the prototype water hyacinth harvester was the best using this analysis.

With an assumed operating cost, the payback period can be determined using Equation 14. The payback periods for the S 2800, V 4702 and prototype harvesters were 7.69, 6.44 and 7.82 years, respectively (Figure 6) and showed little variation. However, the initial investment plus operating costs for the V 4702 were lower than for the S 2800 model. Although the initial investment, operating cost, fuel price, maintenance cost and labor cost for the V 4702 model were high, the removal rate of water hyacinth was the highest and so the payback period for the V 4702 model was the lowest.

The net present value (NPV) for an operating cost of USD 2.68 /t can be calculated using Equation 15. The net present value of the S 2800, V 4702 and prototype models were USD 0.32 million, USD 0.35 million and USD 0.12 million, respectively, as shown in Figure 7. The NPV was compared with the total initial investment to determine the overall suitability of the investment. The total initial investment,

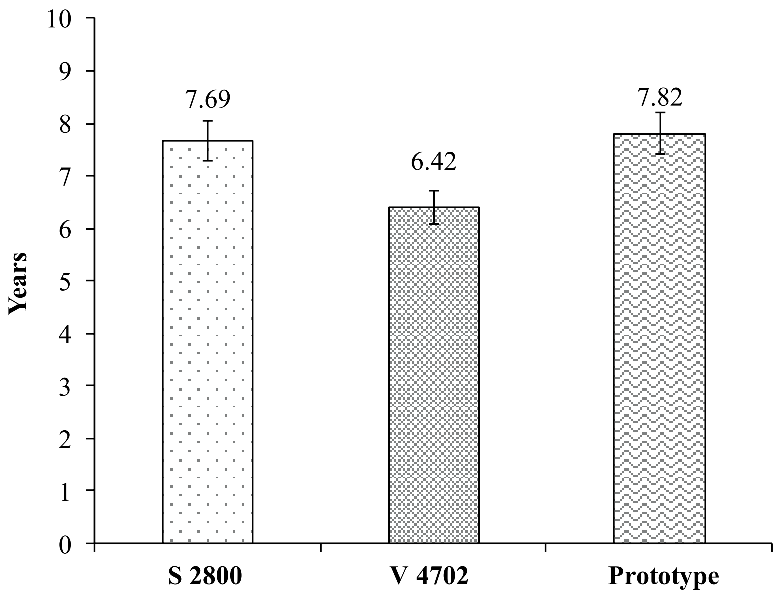

Figure 6 Payback period of operation for operating cost = USD 2.68 /t.

operating cost, fuel price, maintenance cost and labor cost make up the total initial investment. Over 10 years (2003–2012), the total initial investment for the S 2800 (Table 2), V 4702 (Table 3) and prototype (Table 4) models was USD 0.37 million, USD 0.34 million and USD 0.14 million, respectively. In all cases, the NPV was lower than the total initial investment. It can be seen that the S 2800, V 4702 and prototype models were all worthwhile investments.

The internal rate of return (IRR) for an operating cost of USD 2.68/t can be calculated using Equation 16 with values for the S 2800, V 4702 and prototype models of 101, 137 and 215%, respectively, as shown in Figure 8, indicating that the prototype harvester was the best investment. Table 5 shows the total initial investment for all 16 water hyacinth harvesters from 2003 to

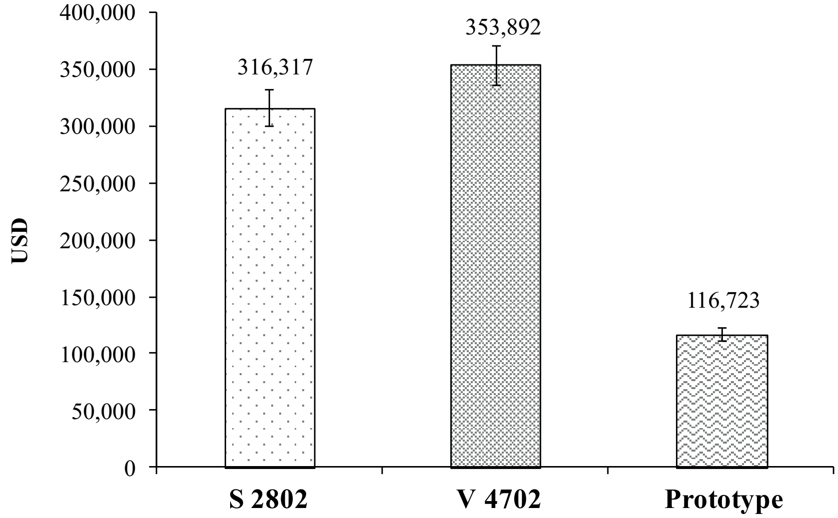

Figure 7 Net present value of operation for operating cost = USD 2.68 /t.

Table 2 Total initial investment cost of S 2800 model water hyacinth harvester using operating cost of USD 2.68/ t.

Year	Initial investment (USD)	Operating cost (USD)	Fuel price (USD)	Maintenance cost (USD)	Labor cost (USD)	Removal of water hyacinth (t)
2003	164,986	6,631	4,778	3,328	3,396	1,184
2004	0	4,178	3,989	2,429	3,574	932
2005	0	5,958	5,897	2,541	3,763	1,054
2006	0	5,603	7,813	1,582	3,960	760
2007	0	4,890	8,826	2,804	4,169	867
2008	0	7,273	11,650	1,660	4,388	896
2009	0	5,555	9,422	4,426	4,619	899
2010	0	5,609	11,498	2,206	4,863	946
2011	0	5,096	10,448	1,812	5,118	796
2012	0	5,246	9,579	1,766	5,388	715
Total	164,986	56,039	83,900	24,554	43,238	9,052

2012. Harvester numbers 1 to 15 were purchased overseas while number 16 was the prototype built in Thailand. The initial investment, operating cost, maintenance cost and labor cost for the foreign harvesters (numbers 1–15) were higher than for the domestic prototype (number 16). In all cases, fuel prices showed a similar trend. The larger imported models were more productive than the domestic prototype The parameters for investment were composed of the initial investment, operating cost, fuel price, maintenance cost and labor costs, as shown in Figure 9. The initial investment, operating cost , fuel price, maintenance cost and labor costs per removal of water hyacinth were 40.97, 15.11, 25.45, 7.21 and 11.26%, respectively. The main budget item was the initial investment in the harvesters. In future, prototype water hyacinth harvesters will replace foreign orders and so the initial investment will be reduced.

Table 3 Total initial investment of V 4702 model water hyacinth harvester using operating cost of USD 2.68/ t.

Year	Initial investment (USD)	Operating cost (USD)	Fuel price (USD)	Maintenance cost (USD)	Labor cost (USD)	Removal of water hyacinth (t)
2003	144,015	5,157	7,494	2,686	2,915	1,163
2004	0	3,398	6,185	2,626	3,068	899
2005	0	3,839	7,257	2,675	3,229	1,062
2006	0	2,822	9,172	1,497	3,399	732
2007	0	2,340	10,813	2,848	3,579	898
2008	0	3,448	11,920	1,912	3,767	688
2009	0	4,200	11,644	4,766	3,966	959
2010	0	4,243	12,128	2,207	4,174	1,032
2011	0	3,342	14,232	1,812	4,393	880
2012	0	3,002	11,176	1,766	4,625	687
Total	144,015	35,791	102,021	24,795	37,115	9,000

Table 4 Total initial investment of the prototype water hyacinth harvester using operating cost of USD 2.68/t.

Year	Initial investment (USD)	Operating cost (USD)	Fuel price (USD)	Maintenance cost (USD)	Labor cost (USD)	Removal of water hyacinth (t)
2003	32,380	0	5,588	161	1,584	316
2004	0	0	7,392	218	1,584	318
2005	0	420	8,100	173	1,757	335
2006	0	0	8,180	240	1,854	327
2007	0	420	8,444	162	1,545	326
2008	0	0	9,088	206	1,924	339
2009	0	420	9,058	300	1,918	338
2010	0	0.00	8,970	229	1,936	334
2011	0	560	9,957	276	2,016	340
2012	0	560	8,882	349	1,501	331
Total	32,380	2,380	83,659	2,313	17,619	3,304

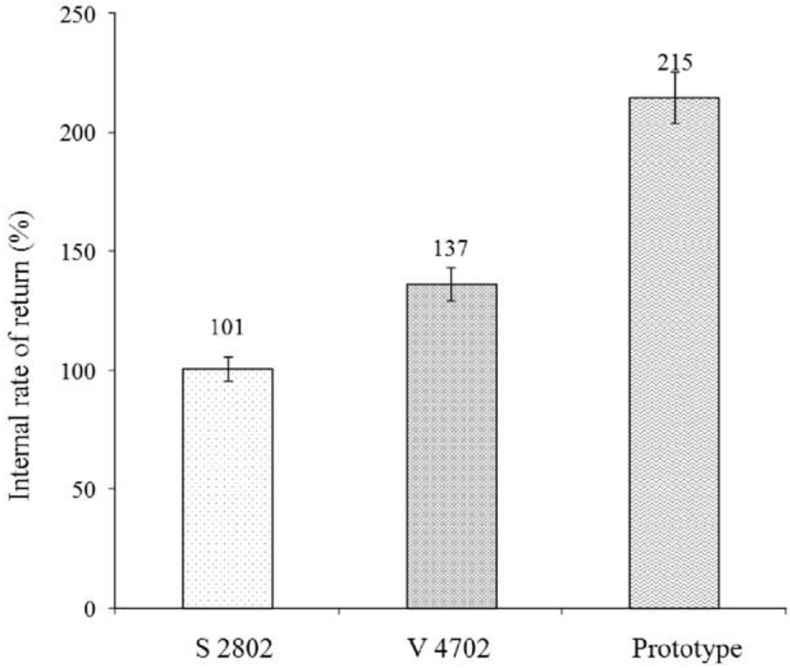

Figure 8 Internal rate of return of operation for operating cost = USD 2.68 /t.

Table 5 Total initial investment for all water hyacinth harvesters from 2003 to 2012.

Number	Initial investment (USD)	Operating cost (USD)	Fuel price (USD)	Maintenance cost (USD)	Labor cost (USD)	Removal of water hyacinth (t)	Total initial investment (USD)
1	161,624	70,323	83,288	33,395	39,303	8,281	387,936
2	167,647	78,843	97,511	29,087	46,591	9,246	413,658
3	167,647	74,380	97,292	34,364	49,068	9,624	422,753
4	167,647	69,881	86,436	26,069	49,068	8,882	399,103
5	164,986	67,429	82,738	28,363	35,904	8,578	379,422
6	164,986	56,044	83,904	24,556	43,241	9,052	375,394
7	164,986	45,905	84,320	28,067	40,841	8,986	366,781
8	164,986	66,611	89,542	26,476	40,058	9,010	390,335
9	164,845	42,356	91,796	26,177	40,841	8,358	366,017
10	152,240	57,633	96,992	26,941	40,841	9,036	374,649
11	152,240	61,256	115,121	28,911	45,750	9,402	395,056
12	152,240	35,794	102,025	24,797	37,118	9,283	343,750
13	152,240	47,429	95,004	30,723	42,405	8,434	359,578
14	152,240	54,356	110,433	25,617	39,303	8,852	373,730
15	142,840	50,050	83,812	24,177	49,068	8,849	349,949
16	32,380	2,380	83,659	2,313	17,619	3,304	138,351
Total	2,425,774	880,679	1,483,873	420,033	657,019	137,177	5,836,462

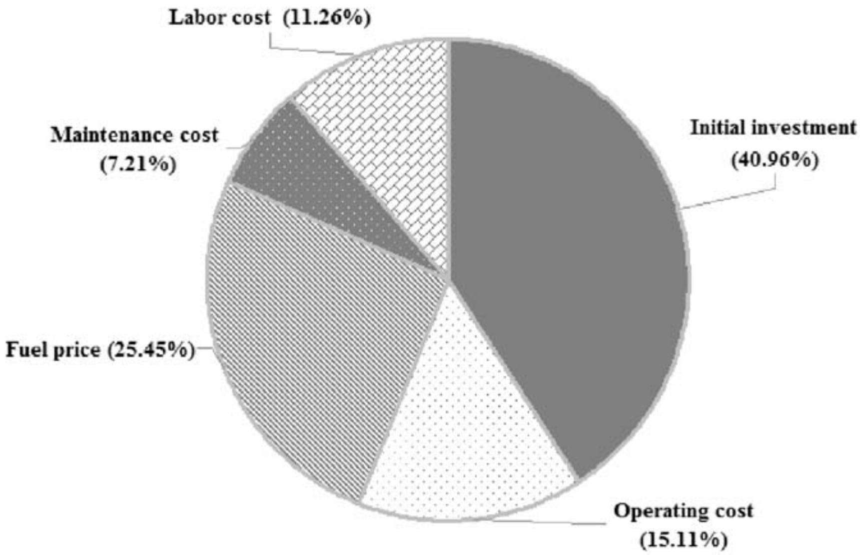

Figure 9 Percentage of investment per removal of water hyacinth.

CONCLUSION

Financial evaluation to selecting the best water hyacinth harvester was undertaken to investigate the payback period, net present value and internal rate of return for two foreign models and a prototype designed and built in Thailand based on Archimedes' principle. The permanent eradication of water hyacinth from water bodies in Thailand, would require an operating cost of USD 2.68/t. The following conclusions were made:

1. The initial investment in a domestic prototype water hyacinth harvester was lower than that for a foreign-ordered unit, as were the operating cost, maintenance cost and labor cost.

2. There was little difference among the payback periods for all three models and they all represented a worthwhile investment based on the net present value The internal rate of return analysis indicated that the prototype was the best water hyacinth harvester.

3. Of the main parameters of investment (initial investment, operating cost, fuel price, maintenance cost and labor cost), the main budget item was the initial investment.

The financial evaluation underpinning this work can be used as guidance for selecting water hyacinth harvesters to improve water resources in Thailand.

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