Mechanical Ventilator Acquisition Strategy in a Large Private Tertiary Medical Center Using Monte Carlo Simulation

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ABSTRACT

Background and Objective. Mechanical ventilators are essential albeit expensive equipment to support critically ill patients who have gone into respiratory failure. Adequate numbers should always be available to ensure that a hospital provides the optimal care to patients but the number of patients requiring them at any one time is unpredictable. Finding therefore the best balance in providing adequate ventilator numbers while ensuring the financial sustainability of a hospital is important.

Methods. A quantitative method using Monte Carlo Simulation was used to identify the optimal strategy for acquiring ventilators in a large private tertiary medical center in Metro Manila. The number of ventilators needed to provide ventilator needs 90% of the days per month (27/30) was determined using historical data on ventilator use over a period of four years. Four acquisition strategies were investigated: three ownership strategies (outright purchase, installment, and staggered purchase) and a rental strategy. Return on Investment (ROI), Internal Rate of Return (IRR), Modified Internal Rate of Return (MIRR), Net Present Value (NPV), and Payback period (or Breakeven Point) for each strategy were determined to help recommend the best strategy.

A qualitative survey was also conducted among doctors, nurses, and respiratory therapists who were taking care of patients hooked to ventilators to find out their experiences comparing hospital-owned and rental ventilators.

Results. It was found that a total of 11 respirators were needed by the hospital to ensure that enough respirators were available for its patients at least 90% of the days in any month based on the previous four-year period. This meant acquiring three more ventilators as the hospital already owned eight. Among the strategies studied, projected over a 10-year period, the installment strategy (50% down payment with 0% interest over a 5-year period) proved to be the most financially advantageous with ROI = 9.36 times, IRR = 97% per year, MIRR = 26% per year, NPV = ₱39,324,297.60 and Payback period = 1.03 years). A more realistic installment strategy with 15% (paid quarterly or annually) and 25% annual interest rates were also explored with their financial parameters quite like but not as good as the 0% interest. The outright purchase of three ventilators came in lower (ROI = 4.53 times, IRR = 55% per year, MIRR = 19% per year, NPV = ₱38,064,297.60 and Payback period = 1.81 years) followed last by staggered purchase with ROI = 3.56 times, IRR = 64% per year, MIRR = 28% per year, NPV = ₱29,905,438.08, and payback period of 2.06 years. As there was no investment needed for the rental strategy, the only financial parameter available for it is the NPV which came out as ₱21,234,057.60.

The qualitative part of the study showed that most of the healthcare workers involved in the care of patients attached to the ventilator were aware of the rental ventilators. The rental ventilators were generally described as of lower functionality and can more easily break down. The respondents almost uniformly expressed a preference for the hospital-owned ventilators.

Conclusion. This analysis showed that the best ventilator ownership strategy from a purely financial perspective for this hospital is by installment with a 50% down payment and 0% interest. Moderate rates of 15% and 25% interest

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per year were also good. These were followed by outright purchase and lastly by staggered purchase. The rental strategy gave the lowest cumulative 10-year income compared to any of the ownership strategies, but may still be considered good income because the hospital did not make any investment. However, it seems that most of the healthcare workers involved in taking care of patients on ventilators thought the rental ventilators were of lower quality and preferred the hospital-owned ventilators.

Keywords: mechanical ventilators, ventilator acquisition, payback period, financial analysis, Monte Carlo Simulation

INTRODUCTION

Most privately-owned hospitals are primarily established as a sustainable business venture that will generate profits for its owners. Such profits can be used for further investments to improve and expand its patient services. Its sustainability is also vital to the community it serves because of the assurance of high quality, continuous patient care when and where it is needed. Like many other business ventures, however, the quality of its main product - patient care - ultimately defines whether customers (patients, doctors, and payors such as health maintenance organizations, insurance providers, and employers) will patronize the said hospital or avoid it entirely.[1]

Patient care has progressed significantly in the last few years so much so that disease conditions that would have otherwise resulted in the demise of a patient just several years ago, can now be offered some remedy. Paradoxically, because of this, many diseases can then become more severe and would require higher levels of patient care.[2-4] Very serious illnesses can often result in extensive damage to several vital organs in the human body, including the lungs. In these settings, supportive measures that help a patient cope with his critical condition help gain more time for the therapeutic interventions to take effect and/or allow partial or complete recovery. One such vital supportive modality is the mechanical ventilator for patients with respiratory failure.[5,6] The availability of mechanical ventilators is, therefore, an important aspect nowadays of a tertiary medical center's mandate to provide proper care to patients who go there.

This study was undertaken to explore several financial strategies that a tertiary medical center can choose to acquire additional mechanical ventilators. Because of the expense in acquiring new ventilators and the unpredictable nature of the need for it, the hospital needs to decide on the optimal number of machines that need to be procured to provide superior patient care while minimizing investment in idle equipment. This paper investigated what is the best strategy to ensure the high quality of patient care possible with adequate numbers of good ventilators made available by the hospital while maintaining the most profitability with the least number of idle equipment.

The specific objectives of this paper are threefold: a) Determine the optimal number of ventilators that will be sufficient 90% of the days in any given month, using the ventilator utilization data from the previous 4-year period; b) Determine through Monte Carlo Simulation which strategy will provide the best financial benefit to the hospital using the following parameters: Return on Investment (ROI), Internal Rate of Return (IRR), Modified Internal Rate of Return (MIRR), Net Present Value (NPV), and Payback period; and c) Obtain qualitative feedback through a survey of doctors, nurses, and respiratory therapists on their experiences with the use of the hospital-owned vs rental respirators.

METHODS

Study Setting

The study utilized ventilator usage data for the previous four consecutive years from the Pulmonary Unit of a large (250 beds, including 25 ICU beds) private tertiary medical center in Metro Manila, the Philippines.

Study Design

The study used a Monte Carlo Simulation which has found application in financial planning in numerous healthcare settings.[7-11] The number of ventilators being used on a day-to-day basis for the last four years were obtained from the records of the hospital's Pulmonary Unit after obtaining permission from the hospital management. Ethics approval was not required as no patient data was used.

Calculations were made using the computer software Excel® 2019 to determine the financial performance of four procurement strategies: 1) outright purchase; 2) 50% down payment with 5-year installments - further broken down to 0%, 15% annual interest paid yearly, 15% annual interest paid quarterly, and 25% annual interest rate paid yearly; 3) staggered purchase of one ventilator every two years; and 4) renting of mechanical ventilators. Strategies 1 to 3 are ownership strategies where the hospital will end up the owner of the machines.

Determination of the Optimal Number of Ventilators

The demand for ventilators is like the demand for hospital beds – only one patient can use a mechanical ventilator once it is connected. Although it is possible to allocate a ventilator for every bed in the intensive care units, this may also mean unnecessary financial investment on the part of the hospital as not all patients in the intensive care units may require ventilatory support.[12] The technology in ventilators is also quickly evolving in recent years so that machines can become obsolete. Conversely, the same ventilators can drop in price and can potentially be acquired at a lower price later.

The hospital therefore needs to determine the right balance of fixed asset investment so as not to deprive its patients of the best healthcare diagnostics and treatments

available and at the same time not to over-capacitate the hospital and end up with idle equipment. Therefore, it would be best to acquire only the optimal number of ventilators that patients admitted to the hospital will need. To determine this, an arbitrary target set for this study was to be able to provide ventilators to all patients who need them at least 90% of the time as an appropriate goal. With this target, any patient in the hospital who needs a ventilator can be attached to a hospital-owned ventilator, during any 27 days out of every month. Anytime that the ventilator requirement exceeds eight (the number of hospital-owned ventilators) for more than any three days of a particular month is an indication that the stated target is not being met.

The historical number of ventilators used per day was utilized to estimate the number of additional ventilators, like how studies on predicting ventilator requirements during an influenza epidemic.[13] The number of ventilators used per day for the past four years was collected. Then the number of days where the number of ventilators being used per day (ventilators/day) exceeded the number of hospital-owned ventilators was determined. Since the hospital already owned eight ventilators, the number of days when the number of ventilators used per day exceeded eight, nine, 10, 11, and 12 were looked into. The number of instances when the target threshold of more than three days per month were then counted. The number of instances per year was then used to determine the number of additional ventilators needed depending on what number of ventilators such instances were noted.

Financial Analysis

Based on the optimal number of ventilators arrived at in the previous section, financial analysis was then done to compute for Return on Investment (ROI), Internal Rate of Return (IRR), Modified Internal Rate of Return (MIRR), and Net Present Value (NPV) (See Definition of Terms in Appendix A) for the four acquisition strategies. The appropriate function for these parameters in Excel® 2019 was used to compute the values. Loan payment calculations were also made by using the PMT function of Excel® 2019.[a] The payback period was determined by counting the complete years when cumulated cash flows were last negative added to the fraction of the following year when it became zero (Breakeven Point).

Using current practice for business decision-making, the strategy with the best overall financial metrics, subject to further non-financial considerations, was recommended.

A duration of 10 years was used in the analysis as this is the usual time using the hospital's practice to fully depreciate hospital equipment.

[a] *https://www.ablebits.com/office-addins-blog/excel-pmt-function-formula-examples/*

Assumptions

The following assumptions were made to come up with the financial simulation:

Historical ventilator usage data in the previous four years was used to predict the optimal number of ventilators. The assumption of a 100% utilization rate of the new ventilators was made to maximize the returns from the newly acquired ventilators. The eight hospital-owned ventilators are by now already fully depreciated. Based on this, it is realistic to prioritize the use of the new ventilators to maximize the financial returns. Even from the clinical perspective, such an approach is good because patients would benefit more from, and their doctors can better appreciate, the superior functionalities that the newer ventilators can offer. Being newer, the additional ventilators would be also expected to break down less. This can help minimize downtime for the equipment, additional expenses to repair the equipment, and loss of income due to non-availability of the ventilator. Assuming a 100% usage of the three additional ventilators for 27 days a month results in 81 procedures per month for the newly acquired ventilators.

Other historical data, such as salaries and cost for the high-end ventilator can also change. This can also impact the financial analysis made. Aside from the 0% interest, some variations were also looked into (e.g., 15% quarterly and 25% annually). Any difference in the installment interest rates can change the financial parameters.

Currently, the hospital charges a patient ₱11,600.00 for each day of use of a ventilator. This is benchmarked with similar services from other high-level tertiary medical centers in Metro Manila, Philippines. The cost of consumables such as electricity, respiratory tubings, and connections, as well as compressed gases like oxygen and air, which amounts to ₱3,505.60 per 24 hours usage, is included in this charge.

Labor costs related to maintaining a patient on a ventilator were based on the salaries of the Respiratory Therapists (currently at an average of ₱10,000.00 per month per staff). Using the recommendation that one Respiratory Therapist (RT) is needed per three ventilators, with three shifts per day, the annual labor cost came out at ₱390,000.00 for three ventilators. No additional labor costs for the nurses were added as they are not primarily involved in ventilator care – which is a task for the RTs. The number of nurses will not normally be based on the need of patients for mechanical ventilation. Maintenance costs (or warranties) are included already as part of the projected purchase price of the high-end ventilators, valued at ₱2.8 million per machine, so are no longer costed separately as well. Consisting mostly of electronic parts, the higher-end machines rarely break down. The analysis also used the standard 10% depreciation which the hospital applies to all its equipment. Finally, 30% corporate income tax is used, given the net income bracket of the hospital.

On the other hand, for the rental respirators, as they are used as backup only, the same assumption of preferred use is

not realistic. To arrive at the reasonable utilization of rental ventilators, the data on the need for extra ventilators (>8 per day) for the 4-year reckoning period were used. Based on this, an average number of 56 ventilator procedures per month for rental respirators was arrived at.

Qualitative Feedback from Stakeholders

Qualitative feedback comparing the hospital-owned vs rental respirators was also obtained from the healthcare workers involved in providing the mechanical ventilator service to patients: doctors, nurses, and respiratory therapists. The identities of the respondents were anonymized. A one-page questionnaire specific to each profession was provided for the respondents to place their answers. This was solicited to find out if there are non-financial considerations in deciding between the hospital-owned as compared to the rental strategies.

Ethics Approval

Ethics approval was not required because there was no patient intervention nor was patient data used. Data involved only the ventilator usage per day with no patient identification. The decision to put patients on a mechanical ventilator was made entirely by the attending physicians. In the case of the survey, informed consent was not necessary based on the 2016 Philippine Health Research Ethics Board Guidelines which states that a respondents' filling up of a survey can be considered his consent to participate.[14]

RESULTS

Optimal Number of Ventilators

Ventilator usage is tracked by the Pulmonary Unit according to the number of ventilators that are being used daily. The data for four years were obtained and summarized per month to get an average usage per month (Figure 1). The utilization of ventilators is seen to be very variable and does not appear to follow any trend over the four years investigated. There does not seem to be any seasonality nor discernible cycle to predict usage.

Since the target for the study is to provide ventilators to all patients who need them 90% of the time, it translates to 27 days of each month. Looked at in reverse, this further translates to have three days or less per month that a hospital-owned ventilator is not available. Therefore, the number of days when more than eight ventilators were needed was analyzed since the hospital already had eight functioning ventilators. The number of days per month was tracked as to the number of ventilators being used per day. These were further analyzed as to the number of ventilators used per day according to significant thresholds (i.e., >8, >9, >10, >11, and >12 ventilators being used per day) (Table 1).

The number of instances per year that the number of days per month exceeded three days per month according to the corresponding number of ventilators was then counted and reflected in the bottom row of the table. For the four-year study duration, there were 18 instances when >8 ventilators were used, 12 instances when >9 ventilators were used, six instances when >10 ventilators were used, two instances when >11 ventilators were used, and one instance when >12 ventilators were used. Based on these data, it was felt that provisioning for 11 ventilators would be the most appropriate for the financial simulation. Having more than 11 or 12 ventilators would mean only two or one instance, respectively during the four-year duration, which may not be practical.

It was notable that over the four years, (from Year 1 to Year 4) there was an increasing need for more ventilators. This was explained by the increase in the number of ICU beds in

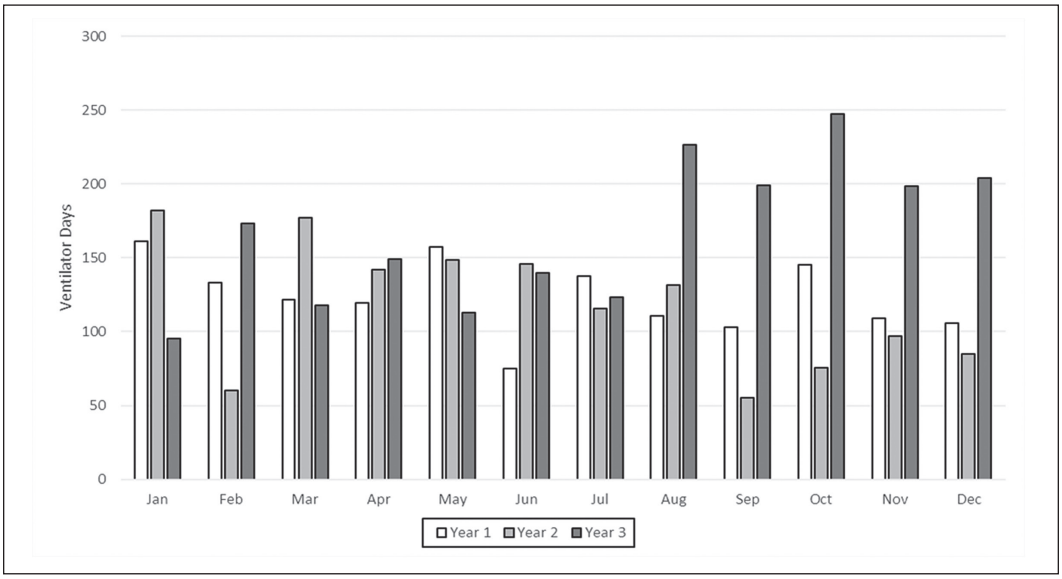

Figure 1. Ventilator days per month during the three-year study period.

Table 1. Number of Days per Month According to the Number of Ventilators Being Used per Year (Historical Usage of Ventilators in the Hospital under Study)

Year	Number of Ventilators Being Used per Day																			
	>8 Ventilators				>9 Ventilators				>10 Ventilators				>11 Ventilators				>12 Ventilators			
	Year 1	Year 2	Year 3	Year 4	Year 1	Year 2	Year 3	Year 4	Year 1	Year 2	Year 3	Year 4	Year 1	Year 2	Year 3	Year 4	Year 1	Year 2	Year 3	Year 4
January	0	8	0	7	0	6	0	2	0	4	0	0	0	0	0	0	0	0	0	0
February	0	0	2	18	0	0	1	13	0	0	0	7	0	0	0	1	0	0	0	1
March	0	0	0	19	0	0	0	13	0	0	0	9	0	0	0	4	0	0	0	2
April	0	0	0	14	0	0	0	8	0	0	0	2	0	0	0	1	0	0	0	1
May	0	0	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
June	0	2	1	8	0	0	0	7	0	0	0	6	0	0	0	2	0	0	0	1
July	5	0	0	10	2	0	0	7	0	0	0	1	0	0	0	0	0	0	0	0
August	0	0	13	6	0	0	2	6	0	0	0	1	0	0	0	0	0	0	0	0
September	0	0	7	16	0	0	1	11	0	0	1	10	0	0	0	8	0	0	0	4
October	0	0	17	6	0	0	13	4	0	0	3	3	0	0	0	1	0	0	0	1
November	0	0	6	8	0	0	3	6	0	0	0	4	0	0	0	2	0	0	0	2
December	0	0	7	5	0	0	5	2	0	0	3	1	0	0	3	0	0	0	3	0
No. of times when >3 days	1	1	5	11	0	1	2	9	0	1	0	5	0	0	0	2	0	0	0	1

Table 2. Summary of the Financial Metrics for the Different Ventilator Provision Strategies

Strategy	ROI	IRR	MIRR	NPV	Payback (years)
50% Down payment + 5-year Installment					
0% interest	9.36	97%	26%	₱39,324,297.60	1.03
15% interest paid quarterly	9.07	91%	26%	₱38,106,146.96	1.10
15% interest paid annually	9.02	90%	26%	₱37,879,058.98	1.11
25% interest paid annually	8.76	86%	26%	₱36,798,150.52	1.18
Outright Purchase of 3 ventilators	4.53	55%	19%	₱38,064,297.60	1.81
Staggered Purchase of 1 ventilator every 2 years	3.56	64%	28%	₱29,905,438.08	2.06
Rental				₱21,234,057.60	

ROI = Return on Investment; IRR = Internal Rate of Return; MIRR = Modified Internal Rate of Return; NPV = Net Present Value (Appendix A)

the hospital, moving from Year 2 to Year 3. With more ICU beds, there is more demand for ventilator usage, as is to be expected.[12] Therefore, over the years, it may be necessary to continue monitoring the number of ventilators being used per day so that any increase that will require more ventilators can be evaluated.

Based on these analyses, acquiring three additional ventilators would fulfill the goal of being able to provide sufficient hospital-owned ventilators 90% of the time. This will bring the total for hospital-owned ventilators to 11.

Financial Analysis

Calculations for ROI, IRR, MIRR, NPV, and payback period for each strategy are summarized in Table 2. The relative advantages and disadvantages of each strategy are indicated in Appendix A. Assumptions mentioned previously were used to come up with the forecast. A chart was also constructed to better visualize the cumulated cash flows of the different acquisition strategies (Figure 2).

As seen in Table 2, the four different installment strategies together provided the most positive financial performance. The parameters are tightly clustered with the most positive provided by the 0% interest and the least positive one by the 25% installment interest. The outright purchase strategy offers almost the same cumulated cash flows (NPV) as the 15% annual interest rates paid quarterly over five years but offers a lower ROI, IRR, and MIRR and a longer payback period compared to any of the installment strategies. If it is just the cumulated cash flows which are important, the 15% annual interest for five years paid quarterly offers a slight advantage over the outright purchase, although the outright purchase caught up with the cumulated cash flows by the 5th year. The other installment strategies, with 15% and 25% annual interest paid annually for five years performed slightly lower. The comparison of the various financial parameters to help guide a decision are further explained in Appendix B.

Both installment and outright purchase strategies offer the advantage of income from the extra three ventilators from the start, but the extra initial investment with the

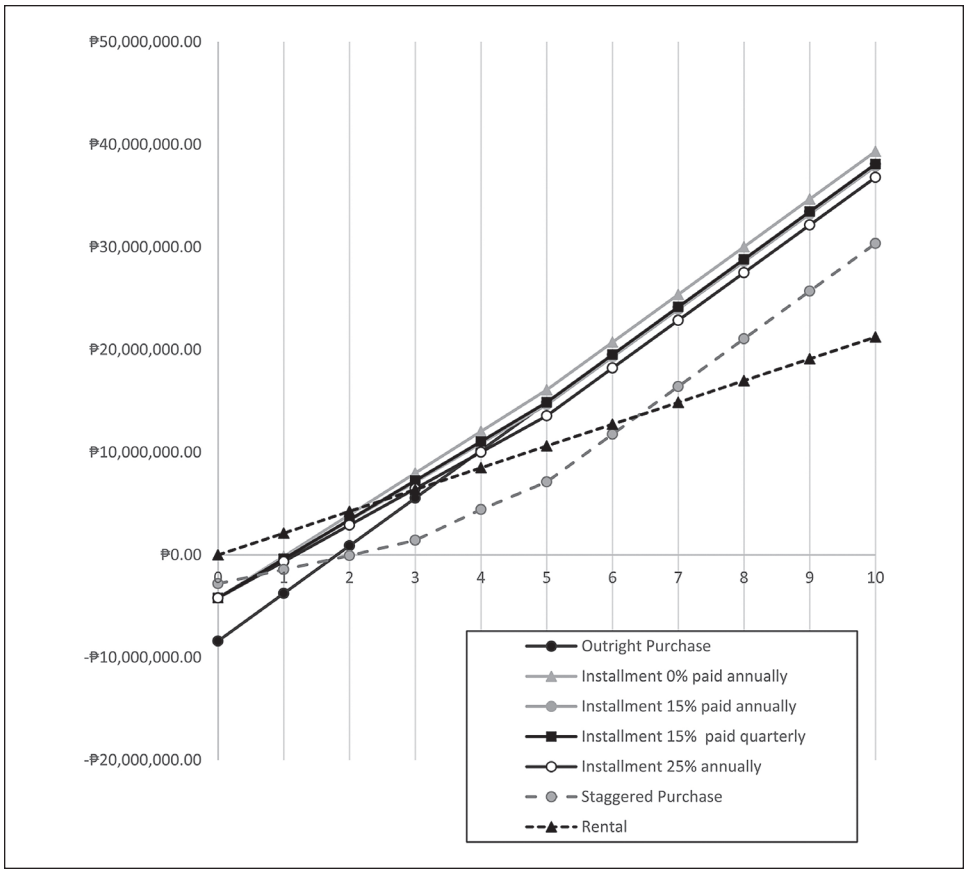

Figure 2. Cumulated cash flows over a 10-year period for the ventilator provision strategies.

outright purchase eventually impacts the other financial parameters, compared to the lower initial cash out in the installment strategies. For the installment strategies, the operating income from the machines even before they are fully paid up helps to increase the ROI, IRR, MIRR; and NPV (cumulated cash flows) with a lower payback period. This indicates the superiority of the installment strategies over the outright purchase, for at least up to 15% interest paid quarterly. The outright purchase provided better NPV than the 15% and 25% annual interests but had lower ROI, IRR, and MIRR, with a longer payback period mostly due to the upfront costs required to buy the ventilators.

Among the ownership strategies, the staggered purchase offers the least positive financial parameters as the additional two ventilators only provide the income at a later period at the start of the 3rd and 5th years at which time they are acquired. Nevertheless, the lower investment upfront allows early income to help fund the later investments on extra ventilators in situations where funds may not be as readily available. In fact, better IRR and MIRR are also seen in the staggered purchase compared to the outright purchase. If the hospital has essential equipment or facilities expansion it needs to do, rather than invest everything in the purchase of three ventilators outright or by installment, then the staggered purchase can be a viable alternative.

The lowest cumulated cash flows are received from the rental strategy. But because it does not require any investment, it can still be a worthwhile alternative for a hospital with limited resources and/or have other investment priorities.

The impact of the big investment early on is seen in the line of the outright purchase (Figure 2). Even a 25% interest installment strategy performs well in terms of cumulated cash flows up to about the end of the fourth year – at which time the hospital just needs to pay one more installment. After that, there is parallel growth in cumulated cash flows when comparing the two (25% interest rate vs outright purchase). The staggered purchase strategy on the other hand has a very slow increase due to the smaller number of ventilators available at the start. It has the longest payback period and the lowest ROI among the ownership strategies.

Based on these analyses, a hospital - regardless of its cash position - may be better off negotiating good interest rates for an installment strategy to fulfill its ventilator requirements at the outset compared to even a staggered purchase strategy.

Qualitative Survey

Several healthcare professionals (doctors, nurses, and respiratory therapists) were invited to answer a short survey regarding their experience in the use of mechanical ventilators. They were asked to share their experiences in using hospital-

Table 3. Demographic Characteristics of Respondents

Parameter	Doctors N = 15	Nurses N = 33	Respiratory Therapists N = 5
Respondents (response rate)	13 (87%)	29 (88%)	5 (100%)
Age, years (Range)	47.7 (38-62)	28.1 (23-37)	24.5 (22-27)
Male:Female	4:9	9:20	2:3
Years of handling patients on ventilator (Range)	11.54 (5-15)	3.5 (1->6)	1.4 (1->6)
No. of patients on ventilators seen per day	3 (1->6)	6 (>6)	6 (>6)
Awareness of rental respirators	13 (100%)	29 (100%)	5 (100%)
Continue with rental respirators (YES)	13 (100%)	29 (100%)	5 (100%)

owned as compared to rental ventilators. The demographics of those who responded are shown in Table 3. The doctors (Pulmonologists and Critical Care Specialists) were generally older and had more experience in handling patients on respirators compared to the other types of HCPs. This was attributed more to the staff turnover among the nurses and respiratory therapists compared to the doctors. There were also more females in all the categories. All the respondents had an awareness that the hospital uses rental respirators and supported their continued use.

The survey questionnaire can be provided upon request.

The following narratives were based on the comments of the stakeholders.

Rental Respirators

Advantages

Renting the machines from vendors helps to avoid the need to buy new ventilators. If incorporated in the rental agreement, maintenance and repair costs can also be avoided. However, such maintenance costs can also be incorporated anyway in the cost of new machines with maintenance costs being absorbed by the chosen vendor. The difference could be in the replacement costs of broken-down parts which a rental agreement can avoid. As long as the availability of the machines can be assured at all times, a rental arrangement can help the management avoid the difficulty of deciding how many machines need to be bought and investing heavily in them.

Disadvantages

The hospital is the one that charges the patient for use of the respirator. Even if it is a rental machine, it is the hospital that assumes the charges. Therefore, if for some reason, a patient is not able to pay their hospital bill, it is the hospital that assumes the rental charges. This is a similar risk anyway in patients who are using hospital-owned respirators if they cannot pay. In general, the proportion of the rental costs is small compared to the rest of the hospital charges, especially if a patient on a respirator happens to be in the ICU. This is very likely as most patients in critical condition are the ones who require ventilators. The hospital also has a policy that patients on respirators need to be in the ICU, unless they are on Do Not Resuscitate (DNR) status, like for example, terminally ill patients.

The ability of a vendor to always provide machines is a big consideration in deciding how much to rely on rental arrangements. As the need for the machines can be generally unpredictable, difficult situations can arise if the vendor cannot deliver or make the machines immediately available. The supplier would certainly have other customers to serve as well and depending on its size would have just a certain number of machines at their disposal.

It might be good practice for the hospital to have contractual arrangements with several suppliers to address this. However, this may not be a perfect solution as suppliers would also tend to favor their biggest customers who rent the greatest number of their machines at the higher fees. Engaging one or two others therefore as a "backup" can decrease the volume of machines rented from a particular vendor and may not allow one to be considered as big enough to warrant special accommodations and/or guaranteed availability.

As new ventilators are expensive, suppliers would also tend to procure only older models which are often bought previously used. As such the machines tend to look more worn out and may not have all the features that higher-end models have. Older machines that have been used more frequently also tend to break down or malfunction more often. If this happens while hooked to a patient, it can create problems for the patient as well as potentially harm the hospital's reputation because of defective equipment. Patient caregivers or visitors have been reported to be most anxious whenever the alarm goes off as it may mean the machine is not working properly.

Those who rent the machines have little to say on which type of ventilators are rented out. In the hospital in this study, patients have high expectations in terms of how modern and/or new the equipment is. Doctors who use the machines are also used to working with higher-end machines, like what the hospital would usually provide. Therefore, to both patients and their doctors, the difference with rental machines is quite glaring and may create an impression that the hospital is saving money and more interested in generating more profits rather than providing good patient care.

Lastly, because rental respirators may be different models compared to the usual hospital machine, those who need to monitor the proper functioning of the machine, as well as modify its settings as needed may also be less familiar with it and less able to do this properly. These include nurses, respiratory technicians, and even doctors. If not learned quickly enough, such unfamiliarity can lead to safety issues for the patient.

Hospital-owned Ventilators

Advantages

Owning a machine and not having to share some of the income provides more profits to the Hospital. Depending on the utilization of the machine, the investment can be quickly recovered as we have shown in our Monte Carlo Simulation. In addition, the Hospital can also choose what model is bought, based on the recommendations of doctors and other stakeholders. This will not only help benefit from the expertise of the doctors but also leverage their experience with other types of respirator models based on their use of the ventilators that may be found in other hospitals. Doctors can feel valued that their opinions are solicited. Maintenance costs and repair – which are not common with new machines anyway – can also be defrayed to the seller as part of the sale. This can help the management address risks of having breakdowns as a problem. Arrangements as part of the sale can also be made to provide a replacement unit in case the new machine has to be pulled out for some off-site services.

Disadvantages

The hospital eventually must spend money to acquire the machines. There are also questions on opportunity costs, with the money possibly being spent better (with more profits) on equipment that would have given a quicker turnaround financially. A bigger issue could be the utilization rate as return on investment is closely monitored. If the machines are left idle and not utilized (e.g., if too many are bought at the same time), such returns will not be quickly realized.

In addition, as technology improvements happen quickly nowadays, buying more machines that can be used can eventually lead to a lot of outmoded equipment. It is also possible that since the machines are bought at the same time, depending on their life cycle and/or the way they are maintained, they can also break down almost at the same time – thus creating more problems for the hospital with the sudden simultaneous non-availability of vital equipment.

In the end, stakeholders have been quite uniform, and consistent with each other, in saying that if it can be avoided, the hospital should not depend too much on rental respirators. Higher-end ventilators make a good impression on patients and are being sought after by doctors. There is recognition of the investments involved but there is a prevailing sentiment that the hospital can afford them anyway.

DISCUSSION

Mechanical ventilators are needed to manage patients who have developed respiratory failure and who are no longer responsive to simple oxygen supplementation. Without the ventilatory support provided to patients, many of them could eventually die. Even patients who do not have a primary pulmonary disease can develop profound respiratory failure, for example in patients with severe congestive heart failure, stroke, and other types of brain injuries, major surgery, extensive trauma, and others.[15-19] Many factors affect the decision to begin mechanical ventilation. As mentioned earlier, mechanical ventilation does not cure a disease process but keeps the patient alive to allow therapeutic interventions to take effect. The patient should have a correctable reason for respiratory failure that can be resolved eventually, thus allowing to be weaned from mechanical ventilation. Otherwise, the patient ends up being dependent on the ventilator for the rest of his life.

Table 4. Common Indications for Mechanical Ventilation

Bradypnea or apnea with respiratory arrest
Acute lung injury and acute respiratory distress syndrome (ARDS)
Tachypnea (respiratory rate >30 breaths per minute)
Vital capacity less than 15 mL/kg
Minute ventilation greater than 10 L/min
Arterial partial pressure of oxygen (PaO_2) with a supplemental fraction of inspired oxygen (FIO_2) <55 mm Hg
Alveolar-arterial gradient of oxygen tension (A-a DO_2) with 100% oxygenation >450 mm Hg
Clinical deterioration
Respiratory muscle fatigue
Obtundation or coma
Hypotension
Acute partial pressure of carbon dioxide ($PaCO_2$) >50 mm Hg with an arterial pH <7.25
Neuromuscular disease

Adapted from Byrd and Roy[20]

A full discussion of the indications for mechanical ventilation is beyond the scope of this report, but may be obtained elsewhere.[20] Some of these indications are listed in Table 4. Although impending respiratory failure can be anticipated, the exact moment when a patient needs to be attached to a ventilator is not easily predicted. When needed, patients must be immediately attached to ventilators or risk their further worsening and/or demise. Therefore, the hospital should always have sufficient ventilators in reserve so that they can be made available anytime.

We have demonstrated in the simulations done in this study that the best way to assess which ventilator acquisition strategy provides the most rewarding financial returns for the hospital. Not surprisingly, an installment strategy turned out with the best advantage, given that the hospital can now earn income from the additional machines while trying to avoid too much investment upfront. The cash saved can be used by the hospital to acquire more equipment and/or expand its facilities. Although other installment scenarios are possible (e.g., lower down payment, lower interests, and/or a longer payment period), the simulation reported here is felt to provide the best balance of maximizing income early on, getting vendor acceptance (who also need to manage their cash flows), addressing obsolescence of equipment, and minimizing paying too much for loan interests. As we saw here, a 15% annual interest at 50% down payment and a 5-year payment period paid quarterly still performed better

than an outright purchase in terms of cumulated cash flows or overall income at the end of 10 years. Other scenarios can be easily explored by using the simulation with Excel® as demonstrated in this report.

A related insight here is that even if a hospital has enough cash on hand to buy outright the additional ventilators, it can still opt to go the installment route (up to 15% to 25% annual interest) as it is, in fact, more financially rewarding even if interests must be paid. The threshold when interests may be less rewarding compared to the outright purchase seems to be in the region just below 25% per year because of the lower cumulated cash flows as compared to the lower interest rates, and even with outright purchase, at the end of 10 years. Even at this rate, installment is still more rewarding compared to outright purchase up to about the 4th year because of the added income from ventilators with less upfront investment. Beyond the 4th year, the outright purchase shows slightly higher cumulated cash flows. But because installment payments are finished by the end of the 5th year, the growth in income parallels the outright purchase being behind only by about 3-4 months.

Of course, the interest rates would have to be agreed upon with the vendor. It is felt that, as in this case, since multiple ventilators are being acquired, the vendor may still find it acceptable and agree to a lower interest rate as the multiple installments can still provide a comfortable cash flow. The guaranteed purchase of three ventilators can therefore be leveraged to convince a vendor to agree with lower interest rates. Also, a vendor may be inclined to sell his inventory of machines anyway since their technology can soon be replaced by better ones.

However, it is still up to the hospital management to decide, after consideration of these financial parameters, which of the acquisition strategies would be most acceptable for the hospital. There may be other considerations aside from the financial rewards of a particular strategy in acquiring additional ventilators. For example, the hospital will still need to compare it to other investment priorities, such as acquiring other hospital equipment or expanding its physical facilities. The current cash position of the hospital may not allow it to pay the 50% down payment for so many ventilators. A vendor might not be willing to provide lower interest rates if a hospital will not purchase multiple units. Thus, although less positive financially, all these restrictions may still push a hospital to opt for a staggered purchase strategy or even one involving rental ventilators that do not require any expense by the hospital. The staggered purchase strategy can provide a future advantage of getting ventilators that have more features at the same price point or the same type of ventilator at a lower price.

The rental strategy appears to be the one with the least financial benefit and was presented at the outset to fill the gap – the remaining 10% of the time when hospital-owned ventilators are not adequate to meet patient requirements. However, it can still provide significant cumulated cash flows at ₱21,234,057.60 over 10 years and with no initial cost at that.

The number of procedures for rental ventilators was arrived at when assuming that there will only be eight hospital-owned ventilators. This will make it more comparable to the other strategies in terms of the number of times the ventilators are used. A preferred use premise was not used – as is the case for the newly acquired ventilators. It would be unrealistic for the hospital to do this as the rental ventilators are really meant as a backup and not to be used continuously. Therefore, the relevant data to predict the need for rental ventilators is the historical usage involving the number of days when >8, >9, >10, and >11 ventilators are needed per month (Table 1). From these, the estimate of an average of 56 ventilator days per month required the use of rental ventilators.

The hospital charges patients the same rate for use of a rental ventilator compared to a hospital-owned one. Since the hospital must pay for the rent of the ventilators, at a rate of ₱3,000.00 per day, this becomes an overhead cost that diminishes the net income. However, since there is no equipment depreciation and initial cost, the cumulated cash flows from rental ventilators are higher compared to any of the ownership strategies in the first two years (Figure 2). This can make it attractive to a hospital that has a more challenging cash position or a liquidity problem. However, in the medium and long term, the performance of the rental strategy starts to suffer. Even the least rewarding ownership strategy – staggered purchase – starts to overtake the rental strategy by the middle of the 7th year. Therefore, as its cash flows improve, a hospital may transition to any of the ownership strategies from a purely rental one.

Although the rental strategy can be a good backup to fill up the 10% gap deliberately left to allow for reasonable utilization of the hospital-owned ventilators, there is a potential danger that the hospital will need to guard against. When a hospital-owned ventilator becomes available, hospital management should ensure that personnel – particularly the respiratory therapists, with the approval of the attending physician(s) – should immediately exchange it with the rental ventilator that is being used. Otherwise, the hospital is losing revenue because of the need to pay for the rental of the ventilator. A patient who is attached to a hospital-owned ventilator may also benefit more from the better features of the ventilator as compared to a rental ventilator. Staff may fail to transfer patients using rental ventilators to a hospital-owned one unless there is a clear hospital policy to do so since it can entail additional work on their part.

Qualitative Feedback from Stakeholders

Aside from purely financial considerations, there may be other factors that can help define the difference between an ownership and a rental strategy. Even though a rental strategy does look attractive because of the absence of initial investments by the hospital, other conditions related to the use of rental as compared to hospital-owned ventilators should

be considered. It was for this reason that several healthcare workers from different disciplines who are involved in the use of the ventilators were consulted.

One of the consistent comments among the various categories of healthcare worker professionals involved in the patients attached to a ventilator appears to be the features of the ventilators being used. Since rental respirators are mostly of older models, they also tend to have fewer features or options for settings that may be used to support the ventilator needs of a patient. The more features that a ventilator has, the more costly it can be.

There are several types of ventilators but most work by delivering positive pressure of air and oxygen that are mixed according to a preset value determined by the patient's needs. More modern machines can provide different types of ventilation modes in addition to the simpler volume modes: pressure support ventilation (PSV), synchronous intermittent mandatory ventilation, (SIMV), rapid ventilation, prone ventilation, etc. Various parameters (e.g., pressures, flow rates, volumes, etc.) are monitored and displayed either through a numerical display, or more commonly nowadays with LED screens that show the actual changes through time (so-called flow-volume loops or cycles). Although commonly used together with the term "mechanical," most modern-day ventilators are combined with sophisticated electronics that allow them to be set according to what is considered to be good for the patient. More expensive machines have more sophisticated air delivery systems, more options for different types of ventilatory modes, and a larger array of adjustable parameters.[21,22]

Although theoretically valid, no clinical studies have shown any improvement in clinical outcomes among patients who are placed on these more recent types of ventilatory mode.[23,24] However, most patients can tolerate some of these modes better. They are mostly designed to address maintaining a patient's own respiratory efforts and synchronize the rather varied patient pulmonary mechanics, which can also depend on the combinations of underlying conditions they may have. Therefore, many physicians who take care of these patients also desire to use or at least experiment with such types of ventilator modes, especially among patients who require more chronic use of mechanical ventilators or present difficulties while attempting to wean.[25-28]

Further discussion of this very important clinical debate is beyond the scope of this article. It just illustrates that the various stakeholders are currently looking for what they think are the best features in the ventilators they prefer to use. Since more features can lead to higher ventilator costs, and most rental ventilators have fewer features to lower their cost, investing in hospital-owned ventilators that may cost higher can promote their preferred use. It also helps to justify a policy of shifting rental respirators to hospital-owned ones when the latter becomes available. The additional features of hospital-owned ventilators can potentially help deliver better patient care and remains under investigation.

The decision to purchase expensive ventilators obviously determines the hospital's decision of how much to pass on these costs to patients. As it is, several studies have shown the significant impact of the use of mechanical ventilation on the cost of hospitalization.[29-35] It is hoped that a hospital will offer more patient-friendly pricing on the use of mechanical ventilators if it is guided by a more financially sustainable ventilator procurement strategy.

Limitations

The study recognizes several limitations. As a simulation exercise, there were several assumptions made to come up with the results discussed here. Any difference in these assumptions can change these results.

Among these factors are the costs charged to patients for ventilator use, the acquisition cost of the new ventilators, utilization rates for the ventilators, and salaries of staff who are involved.

Once these key assumptions are decided by the hospital, use of software such as Excel™ can easily provide these details such as the initial ventilator cost, interest payments, employee salaries, utilization of ventilators, and other considerations that impact the final cost of investment and income (see Appendix).

CONCLUSION

This study has shown the utility of the Monte Carlo Simulation to evaluate the financial returns of seven ventilator acquisition strategies for a large private tertiary medical center. Based on the goal to provide mechanical ventilatory support for patients at least 90% of the time, three additional ventilators were found to be needed in this hospital based on the usage during the last four years. The best financially positive acquisition strategy using ROI, IRR, MIRR, NPV, and payback period, proved to be an installment approach with 50% down payment and a 5-year payment period with 0% interest. This allowed recovery of the investments as early as just a little over one year. These were followed by a similar 50% down-payment installment strategy, but with a more realistic 15% annual interest (paid quarterly or annually) and a 25% annual interest, both paid also for five years. Most interestingly, an outright purchase strategy that can theoretically avoid interest payments did not prove to be an advantage over the installment strategies, especially up to about 15% to 25% annual interest. The least advantageous financially was a staggered purchase strategy where revenues cannot be realized until such time that additional ventilator units are acquired.

A rental strategy on the other hand is the least financially rewarding strategy but could be useful if the hospital's cash position is poor. However, the rental strategy can also be retained as a backup strategy for providing ventilatory support in case the requirements suddenly increase beyond the number of hospital-owned ventilators. Patients should

however be transferred to hospital-owned ventilators once these have become available. Doctors, nurses, and RTs, in general, preferred the better features of the hospital-owned ventilators compared to the rental ones.

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Statement of Authorship

Both authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

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APPENDICES

Appendix A. Definition of Terms

Ventilators per day. This parameter was used in this study to find a measure to see how many ventilators are needed by the hospital. It should not be confused with a similar term that reports how many days a patient stays on a ventilator. Rather this is *a number that indicates how many ventilators are being used in any given day.* For illustration purposes, this is summarized over a given period (one month was used for this study). Since a ventilator once attached to a particular patient is no longer available for use by another patient, the number of ventilators used per day is a measure of how many patients require a ventilator per day.

Using actual numbers can also help measure how many days in a given period (e.g., a month or 30 days) does the ventilator requirements per day exceed a given number (for example the number of ventilators owned by the hospital). This will allow projections of the number of ventilators needed to ensure good utilization while balanced with providing for the patient requirements.

Return on Investment (ROI):[36] The term is used to refer to earning power of assets measured as the ratio of the net income (profit less depreciation) to the average capital employed (or equity capital) in a company or project. Expressed usually as a percentage, return on investment is a measure of profitability that indicates whether or not a company is using its resources in an efficient manner. Also called rate of return, or yield.

Internal Rate of Return (IRR):[37] This is a metric used in capital budgeting measuring the profitability of potential investments. Internal rate of return is a discount rate that makes the net present value (NPV) of all cash flows from a particular project equal to zero. This can help answer the question: What discount rate would cause the net present value (NPV) of a project to be zero? We expect those projects to grow our business will give us some return over time, so what is the lowest level of return we can tolerate? The lowest level is always the cost of capital to fund the project (i.e., NPV = 0).

Appendix A. Definition of Terms *(continued)*

Generally speaking, the higher a project's internal rate of return, the more desirable it is to undertake the project. IRR is uniform for investments of varying types and, as such, IRR can be used to rank multiple prospective projects a firm is considering on a relatively even basis. Assuming the costs of investment are equal among the various projects, the project with the highest IRR would probably be considered the best and undertaken first. IRR is sometimes referred to as "*economic rate of return*" (ERR).

Modified Internal Rate of Return (MIRR).[38] Modified internal rate of return (MIRR) assumes that positive cash flows are reinvested at the firm's cost of capital, and the initial outlays are financed at the firm's financing cost. By contrast, the traditional internal rate of return (IRR) assumes the cash flows from a project are reinvested at the IRR. The MIRR is considered to more accurately reflect the cost and profitability of a project. The MIRR is used to rank investments or projects of unequal size. The calculation is a solution to two major problems that exist with the popular IRR calculation. The first main problem with IRR is that multiple solutions can be found for the same project. The second problem is that the assumption that positive cash flows are reinvested at the IRR is considered impractical in practice. With the MIRR, only a single solution exists for a given project, and reinvestment rate of positive cash flows is much more valid in practice.

Net Present Value (NPV):[39] Net Present Value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows. NPV is used in capital budgeting to analyze the profitability of a projected investment or project. A positive net present value indicates that the projected earnings generated by a project or investment exceeds the anticipated costs. Generally, an investment with a positive NPV will be a profitable one and one with a negative NPV will result in a net loss. This concept is the basis for the Net Present Value Rule, which dictates that the only investments that should be made are those with positive NPV values.

Payback period.[40] Payback period is frequently used as an alternative to net present value. It is much simpler than NPV, mainly gauging the time required after an investment to recoup the initial costs of that investment. Unlike NPV, the payback period (or "payback method") fails to account for the time value of money. For this reason, payback periods calculated for longer investments have a greater potential for inaccuracy, as they encompass more time during which inflation may occur and skew projected earnings and, thus, the real payback period as well.

Moreover, the payback period is strictly limited to the amount of time required to earn back initial investment costs. As such, it also fails to account for the profitability of an investment after that investment has reached the end of its payback period. It is possible that the investment's rate of return could subsequently experience a sharp drop, a sharp increase or anything in between. Comparisons of investments' payback periods, then, will not necessarily yield an accurate portrayal of the profitability of those investments.

Appendix B. Comparative Advantages and Disadvantages of the Ventilator Acquisition Strategies

Acquisition Strategy	Advantages	Disadvantages
Outright Purchase	• No additional costs acquiring ventilator units • Income generated from using additional ventilators over time can be used to offset acquisition costs	• Big investment upfront depending on cash position of Hospital
Installment	• Acquisition cost can be distributed over a period of time • Income generated from using additional ventilators over time can be used to offset acquisition costs including interests	• Interest paid for the loan is added to the total cost of acquisition of ventilator • Profitability will depend on the negotiated rate of interest
Staggered Purchase	• Smaller upfront investment for purchase of one (1) ventilator unit at a time • Income generated from using additional ventilators over time can be used to offset acquisition costs • Acquisition of additional ventilators over time can add to the total income	• Ventilator requirements may not be completely addressed at the outset • Rental strategy (see below) may be resorted to if additional ventilators are needed
Rental	• No investment costs to the Hospital • No maintenance and/or repair costs in case ventilators require it	• May compromise patient care if rental ventilator units are not immediately available • Less sophisticated ventilators may be available for use • Less income overall for Hospital