Faculty of Engineering & Applied Science

ENGR 3360U - WINTER 2020

Final Project Submission

Economic and Financial Analysis:

Liquor Control Board of Ontario (LCBO) Warehouse Automation vs. Human Labour

Date: March 27, 2020

Full Name	Student Number	Email
Bhagavan Sivaneswaran (Group Leader)		bhagavan.sivaneswaran@ontariotechu.net
Uzair Ali		uzair.ali1@ontariotechu.net
Biokpo-Samuel Asimiea		biokposamuel.asimiea@ontariotechu.net
Sevag Boghossian		sevag.boghossian@ontariotechu.net
Sean Budhooram		sean.budhooram@ontariotechu.net
Deven Edison		deven.edison@onatariotechu.net
Scott Garland		scott.garland@ontariotechu.net
Myles Ginty		myles.ginty@ontariotechu.net
Chethan Nandakumar		chethan.nandakumar@ontariotechu.net
Chikodili Odinakachukwu		odinakachukwu.chikodili@ontariotechu.net

Table of Contents

Abstract

As autonomous technologies become more prevalent in today's industries, corporations have a greater incentive for incorporating Artificial Intelligence and the likes into their operations.

In many cases, robotic automation is being implemented to perform tasks that make jobs less exhausting and much safer for human labour workers. Products are made efficiently and tasks are completed at a faster rate. Warehouse automation does not come without its drawbacks such as loss of jobs and high cost of implementation.

As the largest retailer of alcoholic beverages in Ontario, Canada, the Liquor Control Board of Ontario (LCBO) supplies over a quarter of a million products to consumers annually.

In this paper, the business needs and alternatives of the LCBO would be analyzed, cost analysis would be performed and an estimate of the total cost of integrating the LCBO warehouses with automation, provincewide, would be calculated.

Introduction and Background

Warehouse automation involves implementing a Warehouse Management System (WMS) that integrates AI and robotics to direct, simplify and track already existing processes in the warehouse. An automated warehouse would involve using labels such as barcodes to track inventory, automated guided vehicles (AGVs) that navigate through the facility and perform functions such as storing pallets, automatic trailer unloading, etc, and an Automated Storage and Retrieval System (AS/RS).

Warehouse automation targets repetitive tasks that are process-oriented, time-consuming and error-prone and generally improve efficiency, speed, accuracy and cost savings in a warehouse. Large e-commerce companies that rely on vast inventory, such as Amazon, have started implementing Autonomous Mobile Robotics (AMRs) to improve the efficiency of their warehouse operations. [1][2][3]

The Liquor Control Board of Ontario (LCBO) is one of the world's largest buyers and retailers of beverage alcohol. The LCBO is the major player in the Ontario liquor market supplying over 28,000 products annually through more than 660 retail stores, catalogues, e-commerce, special order services, etc to consumers and licensed establishments. The LCBO serves as a wholesaler to about 250 grocery stores offering cost-effective, convenient and quality products to consumers. [4]

The goal of any warehouse, LCBO's inclusive, is to improve efficiency and productivity while reducing costs and time. Moving products at higher speeds and reducing time spent on tasks can prove difficult and pose a threat to the health and safety of the employees working in the warehouse. Adopting warehouse automation can solve some problems faced by warehouse workers and managers as well as improve safety. [3]

As with any disruptive technology, there are benefits and disadvantages to automated warehousing. The benefits include increased speed, reduced long-term cost, maximized space, etc. Some of the disadvantages are the loss of jobs to employees and the economic impact this has on the community. The benefits and disadvantages of automated warehousing are explained in detail in this report.

Business Needs and Alternative Options

Objective

The purpose of this assessment is to compare the benefits of the new solution to an outstanding problem not yet addressed in the industry. The focus that has been chosen is the labour required to move and store products for the Ontario LCBO company. All of the effects that making this change needs to be explored in order to determine if it is a viable solution for this company. This change can also take on using different alternatives that will have effects that would benefit the company more when compared with the required expense.

Alternatives

The first alternative would be the "do nothing case". All storing and managing inventory would continue to be overseen by labour workers. There would be no automation at all. This would result in a continuation of the dispute over work hours. The second alternative would be to introduce automation in some areas of the warehouse (semi-automation). Tasks like storing and tracking inventory could become automated while other tasks like transportation can still be managed by labour workers. This would lead to a slight increase in efficiency as well as a reduction in the dispute over work hours. The third alternative would be to re-engineer the current manufacturing process. No automation would be introduced but changes to how tasks such as storing, inventory, and transportation are performed would be improved. Enhancements would include logistics, layout of warehouse and more.

The preferred method would be complete automation. A fully autonomous warehouse would enhance the speed and accuracy of repetitive tasks resulting in an overall improvement to the efficiency as well as productivity of the warehouse. Complete automation would also be cost-efficient as it would eliminate the need to pay for workers' salaries, benefits and more.

Cost Estimates

The estimated implementation costs for autonomy are assuming that the L.C.B.O already has storage space, inventory, utilities, their respective licenses and permits, the staff of lawyers and accountants, employee salaries and office space.

In order to effectively implement autonomous mobile robotics (AMRs) in the warehouse setting, it is important to define the warehouse and inventory parameters. When in storage, the warehouse inventory is stored on pallets and is placed on shelving units. The pallet sizes are standardized in either 48"x48" or 42"x42" configurations with a maximum weight of approximately 2086.53kg [5]. The L.C.B.O facility in Whitby, ON has a warehouse floor area of approximately 33,425.14m^2 and a usable height of approximately 8m.
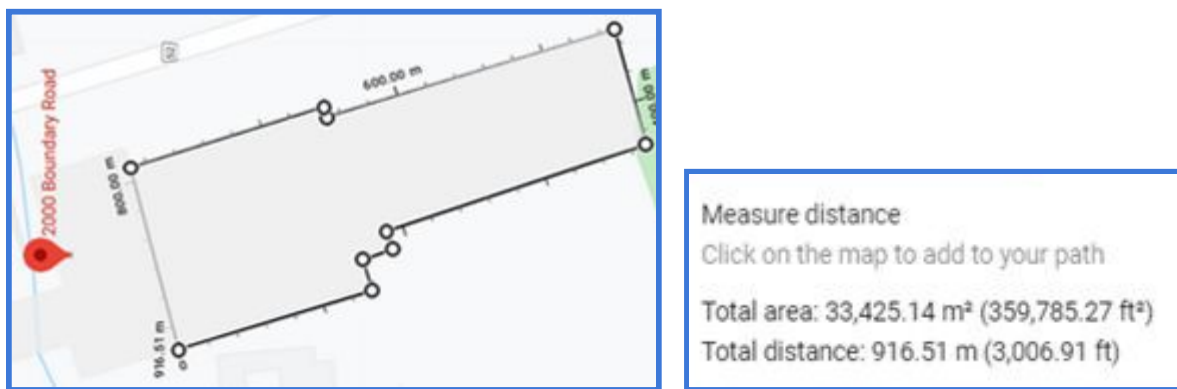

Figure 1: Google Maps measured approximation of the LCBO warehouse area.

Currently, in a facility of this size, there are many employees instated to track warehouse inventory, to operate the machinery to transport stock and manage the facility. In this "Do Nothing" case, there are no initial upfront costs but rather the annual costs associated with staff salaries and for maintenance fees. Additionally, staff is required to work shifts in order for continual warehouse operation. For this reason, the number of hired staff at one time is relatively high and these costs accumulate quickly over time.

Table 1: Estimated annually recurring costs with the "do nothing" approach

Manual Labor Staff	Purpose of Employment	QTY.	Estimated Yearly Salary (CAD)
Inventory Tracking Staff	- Ensure skids of stock are incoming and outgoing as needed - Locate misplaced inventory - Flag discrepancies	4	$32,150 [6]
Forklift Operator	- Transporting skids of inventory to and from loading bays as well as to storage locations	4	$36,590 [7]
General Laborer	- Perform manual tasks such as lifting, sorting, and moving small inventory	5	$32,150 [6]
Estimated Vehicle Maintenance Fees			$3,000
Total Approximate Annually Recurring Costs			$438,710

If autonomy is implemented, inefficiencies can be eliminated and the following AMRs should be implemented in order to effectively track, manage and transport inventory in the warehouse facility.

Table 2: Fixed upfront costs related to the implementation of autonomous mobile robotics

AMR	Reason to Acquire	Qty.	Approximate Cost (CAD)/unit
Tag Surveyor	- Continuous inventory monitoring - FOV: 82 deg and 25ft high - Autonomous Charging	2	$45,000
Toyota Reflex RAE250 Autopilot	- High reach capabilities (up to 10m) - Max load capacity is 2500kg	1	$90,000
Toyota Optio OAE120CB Autopilot	- Universal load handling solution - Use for low lying pallet transport	2	$65,000
Total Estimated Upfront Cost			$310,000

Implementation of two Tag Surveyor RFID inventory trackers are suggested in order to prevent gaps in scanning due to charge times. The two Toyota Optio will be frequently used in the facility to transport the low lying, fast-moving skids to loading bays or to the necessary temporary storage location.

The single high reach Toyota Reflex will be used periodically in order to obtain the slow-moving inventory that is stored higher on the warehouse shelving units.

In order to effectively introduce and continually operate the fleet of autonomous vehicles, technical professionals must be hired. In addition, maintenance fees for the autonomous mobile robots will need to be considered as a variable recurring expense.

Table 3: Estimated annually recurring costs with implementation of AMRs

| Technical Staff	Purpose of Employment	QTY.	Estimated Yearly Salary (CAD)
Senior Mechatronics Engineer	- Supervise and manage team of technical staff responsible for operation of autonomous fleet	1	$126, 200 [8]
Autonomous Vehicle Field Technician	- Always on-site to ensure that autonomous fleet is maintained and operating correctly	2	$60,000 [9]
Networking and Test Technician	- On-site or on call to ensure that the autonomous fleet maintains the network connection - Diagnose communication or network problems - Optimize vehicle operating hours	1	$88,704 [9]
Estimated Vehicle Maintenance Fees			$3,000
Total Approximate Annually Recurring Costs			$349,200
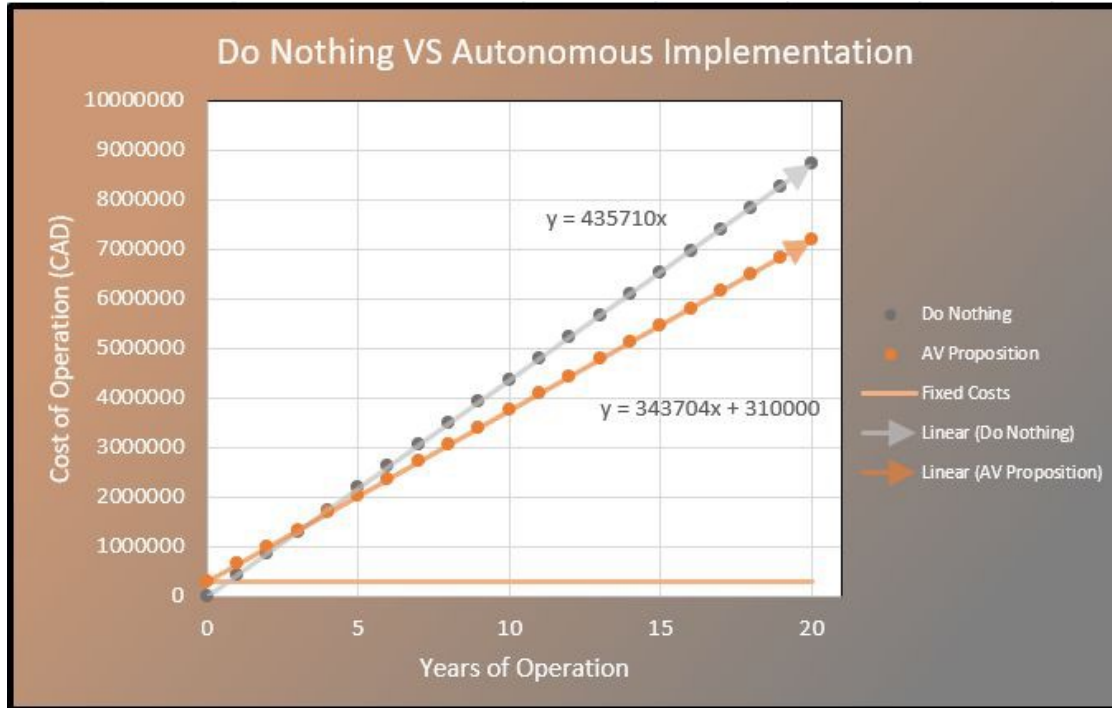
Figure 2: Plotted annual operating costs with implemented AMRs and with the Do Nothing approach

Break-Even Analysis

As seen in the above figure, if the L.C.B.O warehouse implements an AMR facility, it will take approximately 3.5 years to break even with the "do nothing" approach. With the autonomous fleet, the L.C.B.O will have saved $497,100 in ten years and 1,304,200 in twenty years' time. Not only are the long term cost savings quite large but the facility operation will also run more efficiently.

Financial Comparison

The cost of an automation investment falls into two categories: capital costs, and operating and maintenance (O&M) costs. Capital costs are the start-up costs for the project, including the costs of transitioning to automation, vehicles, and any system facilities necessary before the project can begin operation. Operating and maintenance costs are the costs associated with the regular running of a new transportation facility. Costs such as labour, vehicle maintenance, and overall facility maintenance all fall into this category.

Annual Benefits

Table 4: Annual Benefits for each option and the total present worth of each option

Alternative	Do Nothing	Partial Automation
Travel Time Savings	$6 167 000	$59 500 000
Automotive Cost Savings	$6 617 000	$18 700 000
Accident Reductions	$987 000	$1 600 000
Greenhouse Gas Reductions	$99 000	$224 500
Total Annual Benefits	$13 870 000	$80 024 500
Present Worth of Benefits	$243 418 500	$1 404 429 975

*These numbers were calculated from 2017-2018 LCBO data [14]

Non-Financial Pros and Cons

Non-financial factors are integral aspects of business analysis that play a huge role in accessing the growth potential and value of a company. These factors are very crucial for a successful business strategy and contribute positively to the company's operations and financial performance when considered.

Health and Safety

The safety of all persons is paramount in any workplace. LCBO prides itself on creating a safe work environment for its employees so much that it was added to their core values and held as a topmost priority in 2010. [10]

Pros	Cons
* Automation and the use of machines in the warehouse reduces significantly the amount of physical labour undertaken by the warehouse employees on a daily basis [10]. There's no loss time due to employee injuries, tiredness, strain, or overexertion.	* High racking machines used for product stacking and fast-moving objects present in the warehouse continuously pose a hazard to the warehouse employees [10]. Regular inspection and maintenance of these machines have to be done which adds to the O&M costs.

Environmental Impact and Sustainability

LCBO is committed to minimizing its environmental impacts by implementing initiatives such as the Lightweight Bottle Program, Bag It Back, recycling and many more. These programs have tremendously reduced costs and strengthened LCBO's reputation as an innovative enterprise. [12]

Pros	Cons
* New LCBO stores as of 2018 are 25 - 30 percent more energy efficient than 10 years ago; reducing carbon and human greenhouse gas emissions [11]. This creates a safer work environment for employees and increases productivity. * Recycling has decreased LCBO's waste by 60 percent. The enterprise has reduced its annual waste by more than six million kilograms as of today [12]. This move greatly reduces the cost of waste disposal. The funds allocated for waste disposal can alternatively be used for future investments and promising projects that would yield greater benefits for the enterprise.	* Sustainable initiatives such as greener stores and buildings incur more cost. These usually rely on emerging technologies and materials that are more expensive than their traditional counterparts. * With sustainable approaches comes increased environmental regulations and stricter standards for businesses to comply with.

Reputation

Pros	Cons
* Having a polished/good reputation and improving the brand's image gives LCBO competitive advantage in the global market with competitors * It draws in investors and generates new business opportunities	* Unpredictable situations such as slander may arise which cause difficulties and affect sales. It would be difficult for the affected company to recover. * Reputation Management is very tough and requires great work to maintain

Customer Satisfaction

This measures how well LCBO meets the needs of its consumers. From the quality of the products and services provided to the price and value of the products. All of these contribute to the overall experience of their customers and improves the relationship between staff and consumers.

Pros	Cons
* It increases customer loyalty. Loyal customers would value their overall experience when assessing a	* It is difficult to satisfy all customers as different customers have different needs

product or company so there is reduced price sensitivity. * There are more stable sales and new products have a high chance of success * Attracts new customers, maximizes returns and improves product sales	* Consumers' needs are constantly changing and the company would have to continuously adapt to this change. This could lead to a negative financial impact if LCBO is not able to keep up

Societal Impact

How a company impacts and affects society dictates its success both in its immediate surroundings and the society as a whole. A company should strive to positively impact the society for long term profitability.

Pros	Cons
* Products are handled and delivered efficiently at a faster rate * Creative and innovative methods are employed to achieve everyday tasks which would improve the standard of living	* The use of automation negatively impacts the labour market as employees are laid-off which increases the unemployment rate in the society. * There is resistance that comes with implementing change in society. People that resist change make it difficult for such transitions in society.

Risk Analysis

Non-Financial Risks

A lot of focus has been emphasized on the financial risks that come with a process such as this. However, the fact that we are analyzing an unproven technology raises serious questions, not only of the financial risks involved, but also the non-financial risks that might arise.

The continuing trend towards IoT (Internet-of-Things) technology in the workplace introduces the risk of machinery or servers getting hacked. "62% of businesses experienced phishing and social engineering attacks in 2018" [13]. Unauthorized users who breach these systems pose a risk, not only to the warehouse, but also the data that might be stored which might include personal information about employees or customers.

When these automated machines coexist with other human employees in the same environment, human injury due to these robots is inevitable. The employees working around these machines are at constant risk of injury due to potential technical problems that might arise, leading the machinery to harm an employee. Even if all of the autonomous vehicles do not malfunction, they will still pose a risk to the workers due to their size and speed.

The implementation of these systems also poses some operational constraints to the warehouse. The installations are permanent, and might even call for changes in the existing structure. Once installed, they take up a large footprint, which will limit the mobility in the warehouse to the existing human operators. If any upgrades or redesigns to the facility are needed in the future, they will be more expensive and time-costly if this system exists in the facility.

Sensitivity Analysis

Seen in Fig 6 below, the Tornado diagram outlines the influences that the variables outlined in the Cost Estimates section would have on the overall cost of implementing autonomous vehicles in an LCBO facility. The interpretation of this chart would be that given what was outlined in the Cost Estimates section, the salary of a Senior Mechatronics Engineer would actually have the most influence on the overall cost of AV implementation given the bottom three values are fixed costs, as well as the range in salary allocated for the position.
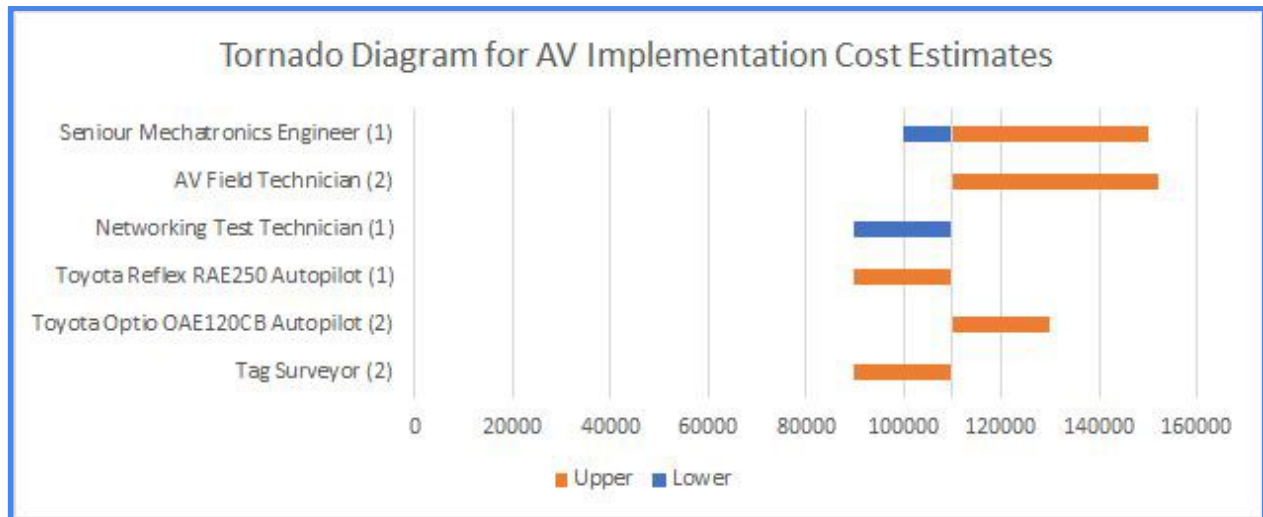

Fig 3: Tornado diagram outlines cost estimate influences. Numbers in parentheses refer to the amount.

Monte Carlo Simulation

A Monte Carlo method is a numerical approach for solving a wide variety of statistical problems. The method incorporates stochastic simulation where a random sampling of inputs is used in order to model the probability of a process that is not so easy to predict due to the presence of random variables. For the purposes of this report, the Monte Carlo method is used to simulate future events involving the economic impact of incorporating warehouse automation into LCBO's infrastructure. Random numbers will be generated using the Python programming language. These random numbers will be generated using the normal distribution and applied to a given model in order to simulate volatility into the future. To showcase the capabilities of this type of analysis with a large data set, the attached Appendix has a separate worked example for a Monte Carlo simulation scenario.
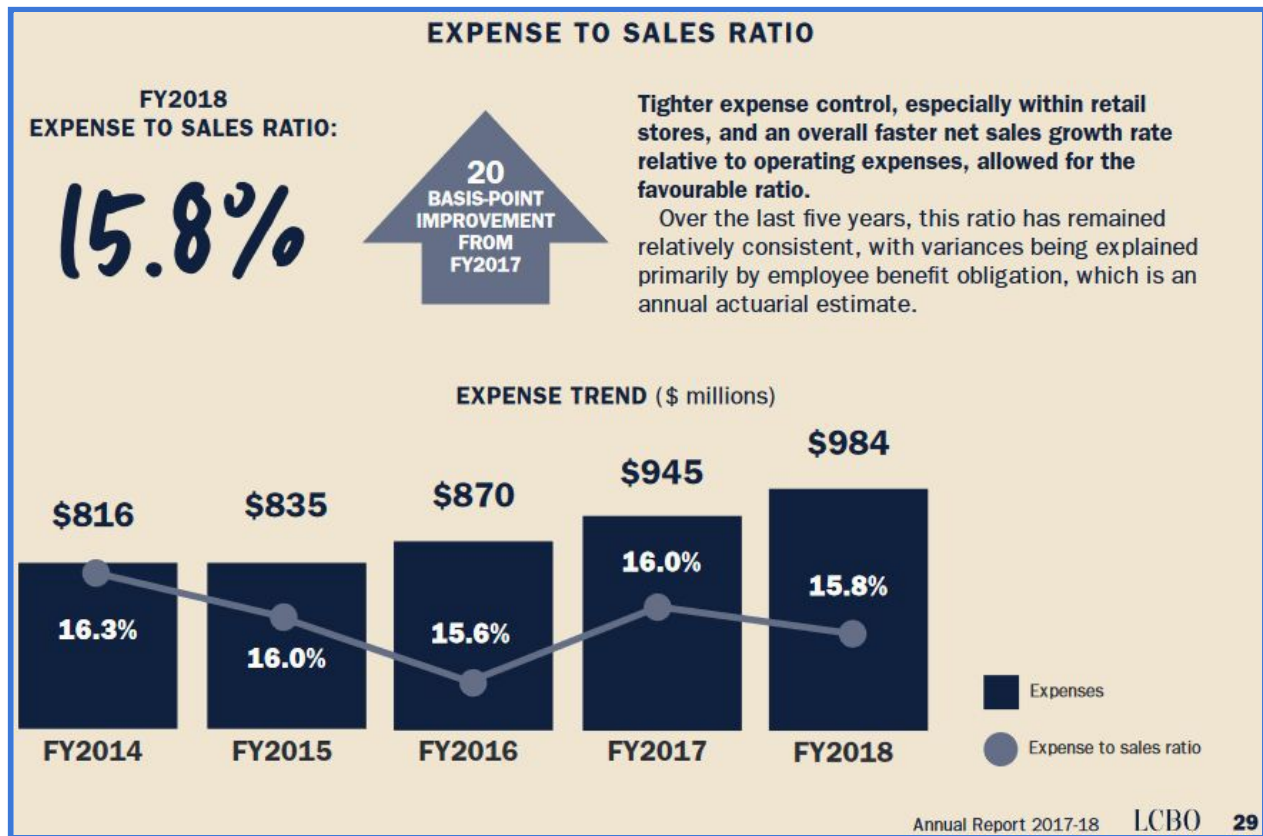
Figure 4: Expense to Sales Ratio from LCBO Annual Report 2017-2018 [14].

For the purposes of this report, data for the Monte Carlo simulations was gathered from the 2017-2018 Annual Report that LCBO publishes [14]. This can be seen in the figure above. The source code for this process can also be found in the attached Appendix. Taking this set of data for the provided fiscal years, the mean, standard deviation, variance, and drift values were calculated in order to be used for the equation which generated the simulation data. This generated simulation data was then fit to an associated normal distribution. The output plots can be shown in the figures below. Assuming after the time value outlined in the Break-Even Analysis has passed, the fiscal years afterwards can be expected to follow a similar distribution for the expense to sales ratios, but shifted to the left. If the Cost of Operation estimates outlined in the Break-Even Analysis follows the projected linear path over time, the shift to the left would be due to the shrinking expenses. This would be assuming that all facilities adopt machine automation in a short time period.
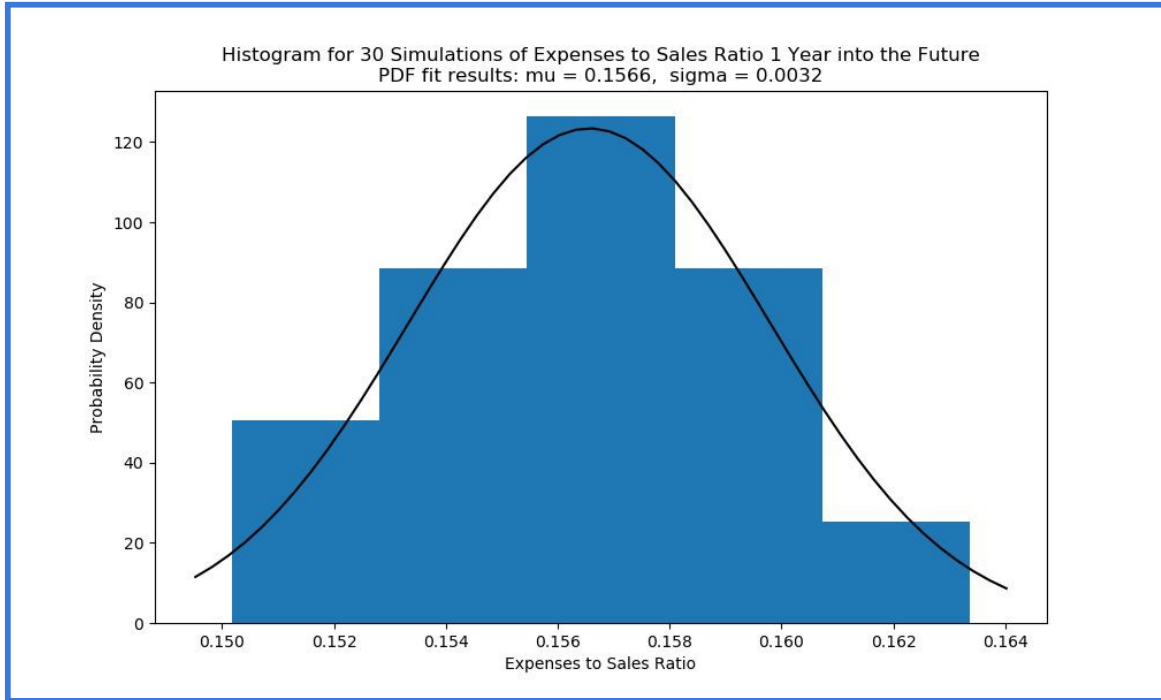
Fig 5: Histogram output plot generated from the Python source code shown in the Appendix. This takes the take from the first simulation and a normal distribution is fit to the data.
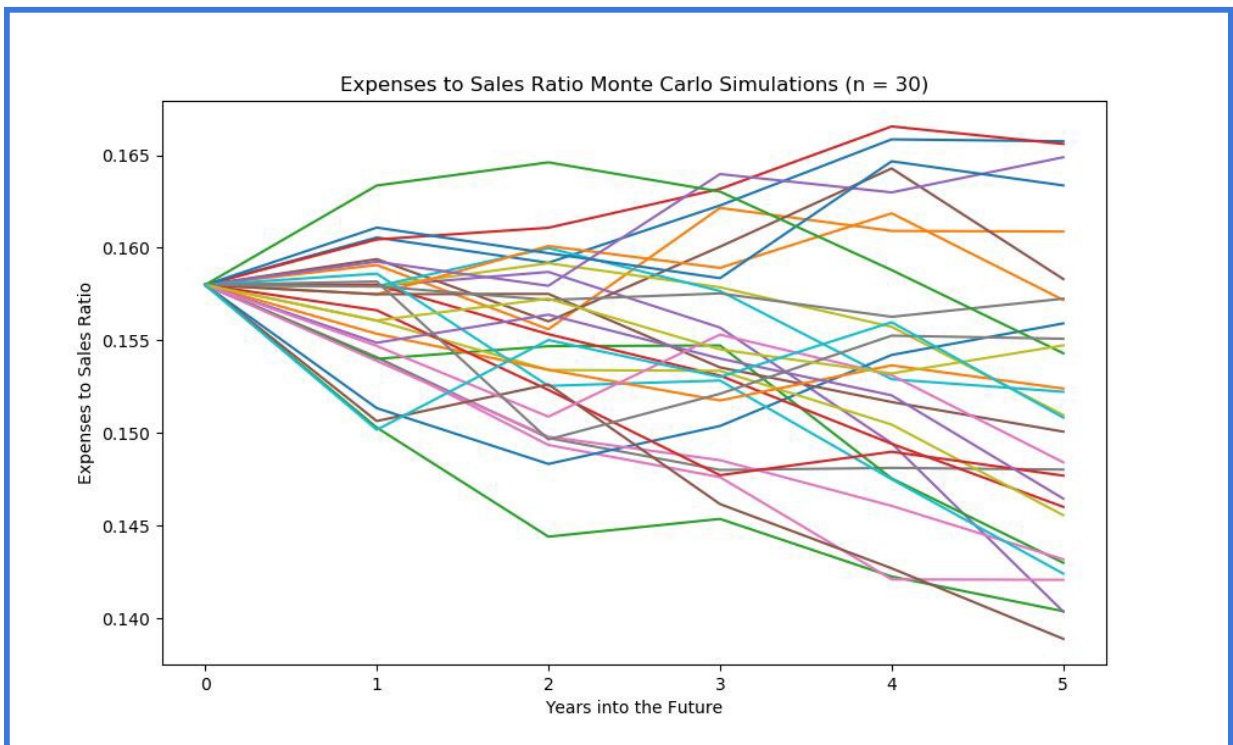

Fig 6: Output plot generated from the Python source code of the Monte Carlo Simulations for the Expenses to Sales Ratio, projected 5 years into the future (n = 30).

Conclusion

In summary, the based on the available alternatives after evaluating the cost estimates with both financial and non-financial comparison and the risk analysis. The conclusion is that while the company selected is very keen on environmental and economic alternatives. Implementing new standards of automation would require a larger investment in new standards in regard to the safety and training of a different skill set of employees to manage the new automation of products.

References

[1] N. Pontius, "The Complete Guide to Warehouse Automation," *Camcode*, 20-Feb-2020. [Online].
Available: https://www.camcode.com/asset-tags/guide-to-warehouse-automation/.
[Accessed: 21-Feb-2020].

[2] D. Alias, "Automation in the Warehouse: Asset or Obstacle?," *Industry Week*, 13-Jul-2017. [Online].
Available:
https://www.industryweek.com/supply-chain/warehousing-and-distribution/article/22022512/automation-in-the-warehouse-asset-or-obstacle. [Accessed: 21-Feb-2020].

[3] H. Lowe, "Warehouse Automation: Leveraging Automated Warehouse Systems," *SelectHub*.
[Online].
Available: https://www.selecthub.com/warehouse-management/building-automated-warehouse-system/.
[Accessed: 21-Feb-2020].

[4]"About LCBO," *About LCBO*.[Online].
Available: http://www.lcbo.com/content/lcbo/en/corporate-pages/about.html. [Accessed: 21-Feb-2020].

[5] "Standard Pallet Sizes," Freightquote.com. [Online].
Available: https://www.freightquote.com/how-to-ship-freight/standard-pallet-sizes/.
[Accessed: 23-Feb-2020].

[6] "General Laborer," Salary.com. [Online].
Available: https://www.salary.com/tools/salary-calculator/general-laborer.
[Accessed: 23-Feb-2020].

[7] "Amazon Forklift Warehouse Operator" Indeed.com. [Online].
Available:
https://www.indeed.com/viewjob?jk=3a389f32a1be55ac&tk=1e45ndpng31k3000&from=serp&vjs=3&advn=416823283305161&adid=107965124&sjdu=Wpcylqv7Z4Ebs3NEZ9Kpyk6-xYhffJD8sDpGutV0vc0njYmuYzwV-mleg3L1sBoFU6jzELefuMq6V3cfu0emLvrhzfI7gN1BAEvZuUC-conWD0ZJWeHqomA2y2mY8hR6ccJPqyThhuURUnbYTVheZw.
[Accessed: 23-Feb-2020].

[8] "Mechatronics Engineer Salary," Careerexplorer.com. [Online].
Available: https://www.careerexplorer.com/careers/mechatronics-engineer/salary/.
[Accessed: 23-Feb-2020].

[9] "Autonomous Vehicle Technician Jobs," Simplehired.com. [Online].
Available: https://www.simplyhired.com/search?q=autonomous+vehicle+field+technician.
[Accessed: 23-Feb-2020].

[10] Liquor Control Board of Ontario (LCBO), "LCBO Annual Report 2010 - 11", *Lcbo.com*, 2020. [Online]. Available: https://www.lcbo.com/content/dam/lcbo/corporate-pages/about/pdf/2010_2011.pdf. [Accessed: 18- Feb- 2020].

[11] LCBO "Sustainable Stores", *Lcbo.com*, 2020. [Online]. Available: https://www.lcbo.com/content/lcbo/en/sustainability/good-planet/sustainable-stores.html. [Accessed: 18-Feb- 2020].

[12] L. LCBO, "Lightweight Bottle Program", *Lcbo.com*, 2020. [Online]. Available: https://www.lcbo.com/content/lcbo/en/sustainability/good-planet/lightweight-bottle-program.html. [Accessed: 18- Feb- 2020].

[13] R. Sobers, "Must-Know Cybersecurity Statistics for 2020: Varonis," *Inside Out Security*, 10-Jan-2020. [Online]. Available: https://www.varonis.com/blog/cybersecurity-statistics/. [Accessed: 03-Mar-2020].

[14] "Your LCBO," *LCBO Annual Report 2017-2018*, 2018. [Online]. Available: https://www.lcbo.com/content/dam/lcbo/corporate-pages/about/pdf/LCBO_AR17-18-english.pdf. [Accessed: 21-Mar-2020].

[15] L. Leong, "Python Risk Management: Monte Carlo Simulations," *Medium*, 27-Jan-2020. [Online]. Available: https://towardsdatascience.com/python-risk-management-monte-carlo-simulations-7d41c891cb5. [Accessed: 19-Feb-2020].

[16] W. Kenton, "Monte Carlo Simulation," *Investopedia*, 29-Jan-2020. [Online]. Available: https://www.investopedia.com/terms/m/montecarlosimulation.asp. [Accessed: 19-Feb-2020].

[17] "Yahoo Finance - Stock Market Live, Quotes, Business & Finance News," *Yahoo! Finance*. [Online]. Available: https://ca.finance.yahoo.com/. [Accessed: 19-Feb-2020].

[18] M. G. Wacek, "On the Use of Stock Index Returns from Economic Scenario Generators In ERM Modeling," *casact.org*, Fall 2014. [Online]. Available: https://www.casact.org/pubs/forum/14fforumv2/Wacek.pdf. [Accessed: 22-Feb-2020].

[19] K. Zucchi, "Lognormal and Normal Distribution," *Investopedia*, 29-Jan-2020. [Online]. Available: https://www.investopedia.com/articles/investing/102014/lognormal-and-normal-distribution.asp. [Accessed: 19-Feb-2020].

[20] "Why Log Returns," *Quantivity*, 29-Nov-2012. [Online]. Available: https://quantivity.wordpress.com/2011/02/21/why-log-returns/. [Accessed: 19-Feb-2020].