Office of the Washington State Auditor
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Performance Audit

Improving Cannabis Risk Management Tools Using Business Transaction Data

August 27, 2018

This audit examined how the Washington State Liquor and Cannabis Board (LCB) could use automated risk management tools in its new marijuana tracking system to ensure both a tightly regulated cannabis market and the most efficient, effective use of its internal audit and enforcement staff. LCB welcomed this audit and its timing because the results could help the agency as it continues to develop its new system.

LCB licenses cannabis businesses and regulates the industry. Licensees document every step of producing, processing and selling cannabis products in LCB's data tracking system. Retail stores collect the 37 percent excise tax on sales of marijuana and THC-infused products, which contributes more than half a billion dollars every two years to the state's revenues.

The audit found that LCB could use the data it already collects to calculate reasonable and unreasonable values for marijuana processing yields, inventory adjustments, sales and other transactions at steps where the risk for diverting product to the illegal market is particularly high. Consistent with LCB's plans, we recommend LCB establish reasonable threshold calculations in its new system that automatically alert staff when a licensee enters data outside those thresholds. By more readily identifying potentially unlawful activity, LCB can prioritize its audits and enforcement investigations.

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Executive Summary

Washington voters legalized recreational use of marijuana in 2012, joining Colorado as one of the first two states to do so. Seven other states have followed and are looking to Washington and Colorado to learn from their experiences in this new industry. In Washington, the Liquor and Cannabis Board (LCB) administers cannabis business licenses, enforces relevant laws, and creates regulations related to the production, processing and sale of cannabis. Excise taxes collected on retail sales are forecasted to total $740 million in the 2017-19 biennium.

This performance audit examined how LCB could build and automate risk management tools to ensure a tightly regulated cannabis market and the most efficient and effective use of its internal audit and enforcement staff. LCB management welcomed the audit's analysis, as it informed their decisions in how best to use the industry data it collects to identify areas of risk.

We completed this audit amid a number of changing events in the regulatory environment, both at the federal and state level. First, the audit took place during a federal policy reversal about the legalization of marijuana. In January 2018, the U.S. Department of Justice rescinded its previous policies on how it would enforce federal marijuana laws in states that had legalized cannabis. Prior to the audit, LCB began replacing its existing data tracking system, in part because it wanted greater data analysis capabilities. During the audit, LCB began implementing the new system. LCB faced multiple challenges as it did, including an incident in February 2018, when someone gained unauthorized access to the system. The audit did not address these events other than to recognize their presence.

To conduct the audit, auditors created maps to track how and when cannabis producers, processors and retailers enter information about their product into the LCB data system. The audit team then identified what steps within that process are most vulnerable to data-entry errors, or could mask the "diversion" of the product; in other words, when cannabis product might disappear from the regulated market. Finally, auditors identified ways for LCB to create monitoring tools that would alert the agency when data entries are out of the ordinary.

Diversion of product occurs when a licensee intentionally redirects cannabis product without entering accurate data into the tracking system. Diversion can mean tax avoidance or distribution to the illegal market.

A robust risk management framework is critical to ensuring LCB maintains a tightly regulated cannabis market

Because Washington was one of the first states to legalize marijuana, LCB had to create its regulatory structure before risk-management standards existed for the marijuana industry. However, government and industry sources offer guidance for effective risk assessment practices.

Audit and enforcement staff plan to use risk management tools to alert them to issues, such as non-compliant businesses, through the identification of irregular data entries by licensees. With the previous data tracking system, LCB audit staff reviewed marijuana transaction data periodically by manually generating and reviewing data reports. Enforcement staff typically responded to unusual activity brought to their attention by outside complaints. Using risk management tools that automatically alert agency staff to irregular data entries made by licensees reporting on their production, processing or retail processes can greatly improve LCB's regulatory efficiency – in both audit and enforcement efforts – while maximizing tax revenue for the state.

Cannabis licensees report data at every step of the process in LCB's tracking system

LCB created a data tracking system to record all cannabis inventory and transaction data from production through final retail sale. The system requires licensees (whose activities are illustrated at right) to enter data at each step of cannabis production, distribution and revenue collection. The system was designed to meet enforcement priorities outlined in a 2013 U.S. Department of Justice memo written by Deputy Attorney General James Cole, which related to state-legal cannabis operations, and to ensure that all taxes owed are collected.

Since February 2018, when the partial system went live, LCB has been finalizing the implementation of a new data tracking system. Agency management said it will ultimately provide more flexibility and reporting capabilities. With the new system in place, management said the agency plans to incorporate an automated risk assessment strategy.

Producers:

- Grow and harvest plants
- Dry and cure plant material
- Bundle material for sale or processing

Processors:

- Convert product to intermediate products
- Convert intermediate products to end products
- Package products for retail sale
- Create samples

Retailers:

- Sell end products
- Collect and pay taxes

Higher-risk steps of producing and selling cannabis occur in three areas

The audit identified three activities in the production and sale of cannabis that pose a higher risk for potential diversion of product. These occur when:

1. Licencees adjust cannabis quantity or weight. LCB said its new data tracking system allows producers, processors and retailers to adjust quantities of cannabis product at virtually any point in the process where data could be entered. Large adjustments could indicate a data entry error or that licensees are diverting product.
2. Product changes form, such as when producers harvest plants or cure flower. In fact, licensees use many different methodologies of extraction and end product creation. Low reported yields could indicate potential diversion. Likewise, low reported yields when processors convert cannabis to intermediate products (such as plant material to oil), or when they convert intermediate products to end products (such as oil to an edible candy) may also signal potential diversion.
3. Cannabis changes hands, such as at the retail level where products are sold to customers and, in some cases, where medical donations are allowed.

Establishing reasonable ranges at higher-risk steps can help LCB identify data entry errors indicating potential diversion of product

Under the former tracking system, LCB staff regularly pulled several reports for enforcement purposes. Until the news system is fully implemented later in 2018, LCB staff must pull data reports manually following a complaint, one incident at a time. By developing tools that automatically notify staff of irregular data at high-risk points, the agency can focus its resources on specific, high-risk transactions and businesses. Reasonable data ranges can be calculated using standard statistical methods. Examples of these types of indicators include unusually large adjustments on data entries or abnormally high amounts of waste. (Appendix D in the audit report describes methods for calculating reasonable ranges.)

LCB's original data tracking system captured significant amounts of critical information from cannabis licensees, but was not designed with any automated tools to identify unusual transactions. By calculating reasonable data ranges for high-risk transactions, LCB staff will be able to pinpoint irregular data. Building automatic notifications into the system to alert staff to irregular data will allow LCB staff to be more efficient in selecting those licensees for audits or potential enforcement. Automatic notifications also can help minimize data errors or diversion of marijuana products, ensuring maximum tax revenues are collected.

Recommendations

To help improve efficiency and more comprehensively review licensee activity, we recommend that LCB complete its plans to:

1. Develop reasonable ranges for data at the higher-risk transactions of the cannabis production, processing and retail processes
2. Establish automatic notifications into its new tracking system that will alert staff when data at those higher-risk transactions fall outside established ranges, indicating potential data entry errors or product diversion

Introduction

Between 2012 and 2018, voters in nine states and Washington DC, including Washington state, passed ballot initiatives legalizing marijuana for recreational use. Each state was immediately faced with developing a regulatory scheme for an industry never before legal in the United States, concerning a substance that is still considered illegal under federal law. Not surprisingly, those states found no regulatory structures for the cannabis industry they could use as models, nor were there risk management standards specific to this new industry to help them develop tools that would foster and sustain regulatory success.

One essential part of regulating any new industry, and particularly the emerging cannabis industry, is the application of a risk management framework to help regulators identify, analyze, respond to and monitor risks within the internal and external environments. Although no risk management standards existed for the cannabis industry when it was legalized, general risk management principles and methods, as well as those used in other types of production industries, such as food processing, can help frame an approach to managing risk in the cannabis industry.

The state must ensure public safety and address the loss of revenue associated with deliberate reporting errors that mask unlawful activity committed by regulated licensees. The use of analytical tools can help cannabis regulators better identify and respond to the risk of unlawful activity.

In Washington, the Liquor and Cannabis Board (LCB, formerly the Liquor Control Board) serves as the regulatory agency for the new industry. LCB administers cannabis business licenses, enforces relevant laws, and creates and enforces rules related to the production, processing and sale of cannabis. Washington's cannabis licensees report detailed information about all transactions in a data tracking system, allowing LCB to monitor cannabis business activity. By identifying transactions where risks of unlawful activity or reporting errors are particularly high, and by monitoring the data reported for those transactions, LCB regulatory staff can help target their enforcement and auditing resources on activities where the data appear to be irregular relative to typical transaction data.

LCB staff reviewed cannabis business activity in the original tracking system by generating data reports on a non-automated, non-recurring basis. Enforcement actions against cannabis businesses are typically reactive and arise from complaints lodged by others. LCB said the new traceability system was designed to allow it to develop risk management tools that will automatically alert agency staff to irregular data reported by cannabis businesses, allowing the agency to be more proactive in identifying potentially noncompliant businesses. Targeted auditing and enforcement efforts could help focus staff resources, thus improving staff efficiency and maximizing tax revenue collection for the state.

We designed this audit to answer the following questions:

1. What data could help identify high-risk cannabis business transactions?
2. How can LCB use cannabis licensee tracking data to focus its audit and enforcement efforts on high-risk transactions?

Background

Washington voters approved ballot Initiative 502 in 2012, which legalized cannabis for recreational use. The initiative authorized the Washington State Liquor and Cannabis Board (LCB) to regulate the Washington cannabis industry and collect excise taxes on retail sales of recreational cannabis. The initiative's intent included taking marijuana out of the hands of illegal drug organizations and bringing it under a tightly regulated, state-licensed system similar to that for controlling alcohol. As of April 2018, the state had more than 1,900 cannabis-related businesses.

LCB's regulatory roles and administrative structure

State law requires LCB to adopt rules that establish the procedures and criteria necessary to implement a regulatory structure for cannabis that aligns with the ballot initiative's intent. When establishing the rules for the regulation of cannabis, state law requires LCB to consider security and safety issues while ensuring that people have adequate access to licensed sources of cannabis and cannabis products. This is meant to discourage purchases from the illegal market. To accomplish this, LCB designed Washington's cannabis regulatory environment to align with federal priorities outlined in the 2013 Cole memo, described in more detail in the section on federal guidance below.

LCB's regulations contain rules regarding the types of licenses it issues. LCB also addresses every major step in cannabis processing, including security requirements for licensees, tax and reporting procedures, serving size and transaction limits, laboratory practices and medical cooperatives. LCB maintains its own audit and enforcement teams to monitor licensee compliance with the rules. The full set of rules that LCB established can be found in Washington Administrative Code 314-55.

LCB is also responsible for collecting a 37 percent excise tax on all retail sales of cannabis, as established and directed by state law. The excise tax revenue is earmarked for a variety of purposes, including education, cannabis research, and some funding for LCB. The excise tax also contributes to the state general fund. Total cannabis excise tax revenue surpassed $500 million in the 2015-2017 biennium.

Within LCB, three primary staff roles — examiners, enforcement staff and financial auditors – are relevant to the regulation of cannabis. Six examiners serve as the agency's data tracking system experts. About 20 enforcement officers are assigned exclusively to investigate nearly 1,400 cannabis producer and processor businesses. Another 90 enforcement officers monitor 500 retail cannabis licensees and approximately 18,000 alcohol-related businesses. Twelve financial auditors also monitor the 500 retail cannabis licensees and 3,000 of the 18,000 alcohol-related businesses

Current federal guidance does not allow for state-licensed cannabis industries

Growing, processing and selling cannabis and its derivatives is illegal under federal law. In 2013, the U. S. Department of Justice issued the Cole Memo to outline the federal government's position on enforcement in states that allow recreational sale and use of cannabis and cannabis products. LCB designed Washington's

regulatory environment to align with federal priorities outlined in that memo, which were to prevent:

- Distribution of marijuana to minors
- Revenue from marijuana sales reaching criminal enterprises, gangs and cartels
- Marijuana diversion from states where it is legal under state law to other states
- State-authorized marijuana activity being used as a cover for the trafficking of other illegal drugs or other illegal activity
- Violence and the use of firearms by those involved in the cultivation and distribution of marijuana
- Drugged driving and the exacerbation of other adverse health consequences
- Growing marijuana on public lands
- Possession or use of marijuana on federal property

The memo also suggested that the prosecution of state-legal businesses in compliance with state regulatory systems was not a priority so long as states were meeting the eight objectives. However, because the memo was not legally binding, prosecution of state legal marijuana businesses under federal law was still possible.

In January 2018, the U.S. Department of Justice rescinded its previous guidance on the enforcement of marijuana laws, including the Cole memo. As of July 2018, the federal-state legal divergence continues, but has not resulted in changes to Washington's laws. However, since the eight enforcement guidelines in the rescinded Cole Memo remain consistent with LCB's mission and goals as set in state law, LCB continues to use them. Audit work begun in early 2017 proceeded, as the need to address state regulatory issues did not abate following the change in federal policy.

Cannabis-related businesses are regulated in a three-tier licensing structure

The 2012 voter initiative that legalized cannabis in Washington required strict regulatory oversight, detailed background checks for cannabis business owners, and a three-tier licensing system, illustrated in **Exhibit 1**. ***Producers*** grow cannabis, ***processors*** turn it into usable products, and ***retailers*** sell those products to consumers. Some licensees may hold both producer and processor designations, but retail licensees may not hold other types of licenses. Unlike Oregon and some other states, Washington prohibits complete vertical integration of cannabis licensees to help prevent the formation of monopoly businesses.

Exhibit 1 – The three tiers of licensed cannabis businesses

Producers:

- Grow and harvest plants
- Dry and cure plant material
- Bundle material for sale or processing

Processors:

- Convert product to intermediate products
- Convert intermediate products to end products
- Package products for retail sale
- Create samples

Retailers:

- Sell end products
- Collect and pay taxes

Producers grow cannabis plants and prepare them for processing

Cannabis producers grow, harvest, trim, dry, cure and package cannabis for wholesale to cannabis processors. Producers may also sell cannabis plants, clones and seeds to other licensed producers, research licensees, qualifying medical patients with a recognition card and registered cooperatives under state laws. Producers may operate either indoor or outdoor growing facilities, and are categorized for regulatory purposes into one of three tiers based on plant canopy, which is a measure of the square footage of plants being grown.

Processors package cannabis and create cannabis-infused products for retail sale

Cannabis processors create, package and label usable flower, concentrates and cannabis-infused products for wholesale to cannabis retailers. Processors may manufacture cannabis-infused edible products in liquid or solid form, though there are additional restrictions on the types of edible products allowed.

Retailers sell cannabis products to consumers and collect an excise tax on all sales

Cannabis retail licensees sell usable cannabis, cannabis-infused products, concentrates and paraphernalia in retail outlets to people at least 21 years old. Retailers are responsible for collecting excise taxes from the buyer and remitting those taxes to LCB. Sales and use taxes must also be collected and remitted to the Department of Revenue. Retailers may also obtain a medical cannabis endorsement and sell cannabis for medical use to qualifying patients and designated providers without sales tax, though the excise tax still applies to these sales. The medical endorsement also allows retailers to donate cannabis at no charge to qualifying patients and providers.

Scope and Methodology

To answer the audit questions, auditors conducted three primary activities.

1. Mapped the processes of cannabis production, processing and retail sales

To fully understand the process of growing, processing and selling cannabis, audit staff created visual maps to demonstrate how and when each of the three types of cannabis licensees — producers, processors and retailers — enter information about their products into LCB's data tracking system. The maps follow the path of a seed or plant clipping through to the retail sale of cannabis products to consumers by illustrating every data-entry point and what data is required. LCB staff verified that the maps are accurate and complete, representing data entry into the original tracking system that licensees used. Although LCB is currently working to complete implementation of its new tracking system, management told us the data entered by licensees into that system will not differ significantly from the maps staff created. The process maps are available in **Appendix C** of this report and on our website at **https://bit.ly/2Mz6qY7**.

2. Identified transaction points in the cannabis production, processing and retail sale processes with high risk of incorrect data entry to mask product diversion

Once the process maps were complete, audit staff relied on discussions with LCB staff to identify the key area of risk within the cannabis production and sale processes: when licensees are most likely to intentionally enter incorrect data into the tracking system to divert product outside the regulated market. Within this risk area, auditors identified the fundamental types of activities in the production and sale of cannabis that pose the highest risk for diversion of product. One example is when licensees adjust the quantities of cannabis product in the tracking system because of loss or miscount.

3. Evaluated how existing data could be used to develop tools to alert regulators of irregular data entries

For each type of activity determined to pose high risk for either product diversion or data entry error by a licensee, auditors used standard statistical approaches to identify how the agency could calculate reasonable ranges for the data based on typical transaction data. Based on risk management guidance from the U.S. Government Accountability Office, risk management practices used by manufacturing industries, knowledge of the data tracking system and professional judgment, auditors determined how LCB could apply the reasonable ranges to help improve the agency's management of risk in regulating the cannabis market.

The audit did not examine the reliability of LCB's new tracking system or the quality and completeness of its data. Nor did the audit examine LCB's effectiveness at implementing the new system. Although the system was placed into operation in February 2018, LCB's implementation efforts are ongoing. For more information about LCB and its data tracking system, visit its website at **lcb.wa.gov/mjtrace/mj-traceability-faq** and the website of the Washington State Office of the Chief Information Officer at **https://bit.ly/2MvkSQY**.

The audit did not examine the extent to which diversion of cannabis occurs among licensees. Finally, the audit did not examine the effectiveness of LCB audit and enforcement efforts beyond their use of available data.

Audit performed to standards

We conducted this performance audit under the authority of state law (RCW 43.09.470), approved as Initiative 900 by Washington voters in 2005, and in accordance with generally accepted government auditing standards as published in Government Auditing Standards (December 2011 revision) issued by the U.S. Government Accountability Office. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. See **Appendix A**, which addresses the I-900 areas covered in the audit. **Appendix B** contains more information about our methodology.

Next steps

Our performance audits of state programs and services are reviewed by the Joint Legislative Audit and Review Committee (JLARC) and/or by other legislative committees whose members wish to consider findings and recommendations on specific topics. Representatives of the State Auditor's Office will review this audit with JLARC's Initiative 900 Subcommittee in Olympia. The public will have the opportunity to comment at this hearing. Please check the JLARC website for the exact date, time, and location (**www.leg.wa.gov/JLARC**). The State Auditor's Office conducts periodic follow-up evaluations to assess the status of recommendations and may conduct follow-up audits at its discretion.

What data could help the Liquor and Cannabis Board (LCB) identify high-risk cannabis business transactions?

Answer in brief

LCB can use cannabis business transaction data it already collects to identify the areas of highest risk, either for data error or the redirection of cannabis into the illegal market. Cannabis licensees are required to report comprehensive data about each cannabis transaction. Data collected at points most vulnerable to deliberate error can be analyzed to highlight irregular reporting. Some examples of these points include adjustments to a product's quantity or weight, or after the creation of a new form of cannabis (such as oil or edible candy), or when cannabis products change hands.

Cannabis licensees report data at every step "from seed to sale" in LCB's tracking system

Licensees are required to enter data on each transaction into LCB's tracking system, "from seed to sale." In its previous system, the agency collected inventory information about every step in production, processing and retail activities, and information such as product weights, adjustments, sales, cannabis conversions and amounts of waste. The system was designed to allow LCB to monitor and track any plant or product at any time, helping to ensure licensee compliance and prevent the diversion of cannabis products to the illegal market. This helped ensure Washington's cannabis regulation aligned with federal priorities outlined in the 2013 Cole Memo.

Funding for a new tracking system was requested in the 2017-19 budget cycle. A requirement for the new system was the ability to set alerts and notifications. New reporting capabilities are expected to include active analytics and thresholds.

Visual process maps for the three types of licensees – producers, processors and retailers – are available in **Appendix C** and at a larger scale on our website at: **https://bit.ly/2Mz6qY7**.

Higher-risk steps in the data tracking process warrant most attention

Working with LCB, auditors confirmed the primary area of risk is where licensees could intentionally enter incorrect data regarding cannabis products into the tracking system to deliberately divert product outside the tracked and regulated market. Within the risk area, auditors further identified three categories of steps in the data tracking process that are most susceptible to problems:

- When licensees adjust the data
- When cannabis changes form, such as from a plant form to an oil
- When cannabis products change hands

Licensee adjustments in the tracking system present a higher risk for diversion of product

Cannabis licensees can adjust the quantity and weight of items in their inventory in the tracking system for any number of reasons. Because products are tracked completely from seed-to-sale, the licensee must account for any product that is lost or damaged, then reflect this in the tracking system.

For example, a licensee may need to adjust inventory because:

- Product was incorrectly weighed when first recorded
- Product was misplaced or lost between data-recording steps
- Typing errors occurred during data entry
- Product was dropped on the floor and cannot be sold

In each of these examples, the tracking system would not accurately reflect the amount of cannabis being produced and sold unless the licensee makes an inventory adjustment. When making an adjustment, the licensee must select a reason from a pre-filled list of options, and must also provide a written description. The pre-filled options include such causes as mistakes, theft and inventory audits.

Multiple inventory adjustments, or inventory adjustments that add up to a large amount, may indicate an effort to divert product or revenue from the legal market. LCB generates inventory reports that show the number of times a licensee makes adjustments and the amount of total cannabis product changes. If those numbers fall outside what is considered a reasonable range, LCB cannabis examiners could provide the information in their reports to the enforcement and audit divisions to help assess targets for investigation or audit.

Each time cannabis changes form there is a higher risk for diversion

Cannabis changes form at many stages in the production process. Each time a change in form occurs, including when it is converted to waste, there is a risk that product will be diverted from the legal market. Both producers and processors may change the form of cannabis.

Harvesting and curing cannabis. When cannabis is in the inventory of producers, it changes form during both harvest and cure. At harvest, all mature cannabis plant components are considered 'wet' because they are fresh plant material that has not yet been dried out. Producers separate flower and other usable plant material from waste and weigh each amount. Wet flower is dried using a variety of methods. After harvested plants are sufficiently dried, producers again separate flower and usable material from dry waste and weigh each type of material again. During this curing process, LCB typically expects plant material to lose between 60 percent and 80 percent of its weight in lost moisture.

For producers, both harvesting and curing create waste, which must be destroyed. Licensees must track destruction of waste in the tracking system, and schedule destruction activities.

Producers could mask diversion of cannabis from the approved marketplace several ways. They could report low ratios of cannabis flower and usable plant material to waste during harvest, or report excessive moisture loss during the curing step. Although LCB has expectations regarding moisture weight lost during curing, the original tracking system did not have a way to flag unusually high waste yields or other exceptional data so that enforcement staff could act on the information. This functionality was a requirement for the new system.

To ***harvest*** cannabis, producers cut down and separate mature cannabis plants to begin drying them. Once plants are sufficiently dry, ***curing*** reclassifies the dry flower material as usable cannabis.

Flower or bud is the part of the cannabis plant that contains the most cannabinoids and can be packaged as usable cannabis. Other plant material may include certain parts of the plant, like leaves or stems, that would not be packaged as usable cannabis but still contains active ingredients that could be extracted.

Waste is excess plant material that is not valuable.

Processing plants into intermediate and end products. Processors change cannabis flower and other plant material into intermediate products, and from intermediate products into end products. Processors may extract cannabinoids from flower and other material to create intermediate products using several extraction techniques, depending on the type of product created. LCB recognizes seven types of intermediate products: hydrocarbon concentrate, CO_2 concentrate, ethanol concentrate, infused cooking medium, non-solvent-based concentrate, food-grade solvent concentrate and marijuana mix. Some extraction methods are more common because they are more efficient or better suited for particular products.

Intermediate products are used as ingredients in preparing end products. End products are sold to consumers. LCB recognizes 10 types of end products besides usable cannabis: infused marijuana mix, packaged marijuana mix, infused topicals, infused liquid edibles, infused edible solids, extracts for inhalation, suppositories, tinctures, transdermal patches, and capsules.

Abnormally low weight yields recorded for either intermediate or end products may indicate that the licensee actually used less product than was reported in the tracking system. This, too, could suggest diversion of product, or licensees showing poor extraction efficiency.

Processing cannabis flower to sell. Processors also change the form of cannabis flower when they prepare it for sale to the public by taking a lot or batch of cannabis flower and dividing it into individual, retail-sized packages of usable cannabis. Producers sell usable cannabis to processors in flower lots, which are typically comprised mostly of usable flower. These lots are not expected to contain significant amounts of waste. Like waste from harvest, cure and processing, this waste must be scheduled for destruction, and also requires a 72-hour waiting period.

Processors are required to record the weight of flower lots, the weight of waste created, and the weight per unit of usable cannabis in the tracking system during conversion from flower lots to usable cannabis. Abnormally high waste yields may indicate diversion of usable cannabis.

Some risk occurs when cannabis or cannabis products change hands

Cannabis products change hands when they are sold between licensees, when they are sold from retail licensee to consumer, and when samples are sent for testing, educational purposes or to retail employees (called budtenders). The audit identified two areas of risk associated with retail or consumer transactions.

Sales to consumers. Retailers collect excise tax at point of sale. Selling product for below its value results in reduced excise tax revenue for the state. State regulation says that licensees cannot sell cannabis products for less than the amount they purchased them for, but the original tracking system did not prevent such entries, nor does the replacement system.

Donated cannabis. Donated cannabis products do not generate collectable excise tax. Retail licensees with a medical marijuana endorsement are able to donate cannabis to qualifying patients and providers. However, the original tracking system did not allow a licensee to record a transaction as a cannabis donation. Instead, a donation was recorded as selling the product for $0 to ensure that the quantity was correctly reflected in the system.

If retailers sell product at below the price they purchased it for, or if they donate cannabis frequently or in large quantities, it may indicate diversion of product or excise tax avoidance.

An ***intermediate product*** is a cannabis product created by producer licensees that can be used as an ingredient to produce end products. An intermediate product may include highly concentrated cannabinoids (any of the various chemical compounds in cannabis) and cannot be sold to retail customers.

An ***end product*** is the cannabis product sold to retail customers. Typically an end product is either flower or a product made with cannabis extract, like a solid edible that contains tetrahydrocannabinol (THC), the chemical responsible for most of marijuana's psychological effects.

Cannabis retailers employ staff known as "budtenders" to help consumers choose cannabis products. The term is used in LCB's administrative rules (WAC 314-55).

How can LCB use cannabis licensee tracking data to focus its audit and enforcement efforts on high-risk transactions?

Answer in brief

By understanding which transactions pose the highest risk for product diversion or data entry errors, LCB can pay close attention to the data at those steps. Expected data ranges at high-risk transaction points can be calculated using standard statistical methods. Risk management tools that automatically alert agency staff to irregular data entries would allow the agency to conduct targeted audits or enforcement actions. The resulting focus using threshold calculations should improve staff efficiency and effectiveness, and maximize tax revenue collection for the state.

Auditing and enforcement activities could be focused by identifying irregular data entries

LCB staff reviewed cannabis business activity in the original tracking system by generating data reports each time they wanted to look at specific transaction data. This approach may not have led to proactive enforcement actions against noncompliant cannabis businesses. Rather, enforcement actions are typically a reaction to complaints by licensee staff or enforcement team suggestions.

LCB said that the system tools that are planned for the new system will automatically notify staff of irregular data entries at high-risk steps in the process, which will bring regulatory staff's attention to problems more swiftly.

Basic statistical calculations can help LCB establish reasonable data ranges

Reasonable data ranges can be calculated using basic statistical methods, such as an average and a standard deviation, a calculation used to quantify the amount of variation or dispersion of a set of data values.

To develop a reasonable range of data for each higher-risk transaction, LCB should follow these steps:

1. Determine the necessary data
2. Identify outliers (a data point that lies outside most others in the data) to ensure large outliers do not affect the reasonableness of the data range
3. Choose a method for calculating a reasonable data range based on the data distribution and the capabilities for follow-up
4. Calculate a reasonable data range and choose cutoff values at the maximum and minimum points such that values outside the cutoffs will be considered irregular data entries

A detailed description of steps needed to calculate the data ranges for various high-risk steps is in **Appendix D**.

Automatic risk notifications could help LCB focus its audit and enforcement efforts

LCB selected licensees for its early audits based on size, proximity to its offices, complaints and enforcement team suggestions. With no automated risk management tools, LCB expects that complaints and suggestions would likely remain a determining factor for choosing auditees, until the alert functionality in the new tracking system is completed later this summer.

Current enforcement tactics focus on public safety rather than compliance checks, though examiners and enforcement staff do coordinate their work. If an examiner notices that tracking system data are highly irregular, the examiner may contact an enforcement officer to follow up with the licensee.

Automatic notification of an irregular data entry would enable LCB to follow up with a specific licensee about specific transactions. By periodically reviewing the ranges and their cutoff values over time, LCB could greatly improve its management of risk in the regulated cannabis market.

LCB managers said the new tracking system is more flexible than the previous system, and they expect it will be able to accommodate automatic notifications or flags based on recommended threshold calculations.

Recommendations

The Liquor and Cannabis Board's data tracking system was designed to capture significant amounts of critical information from cannabis licensees. By identifying higher-risk transactions and calculating reasonable ranges for data for those transactions, LCB staff will be able to pinpoint irregular data. Building automatic notifications into the system to alert staff to irregular data would allow LCB staff to be more efficient in selecting licensees for audits or potential enforcement and could help minimize data errors or diversion of cannabis products, ensuring maximum tax revenues are collected.

To help improve efficiency and more comprehensively review licensee activity, we recommend that LCB complete its plans to:

1. Develop reasonable ranges for data at the higher-risk transactions of the cannabis production, processing and retail processes
2. Establish automatic notifications into its new tracking system that will alert staff when data at those higher-risk transactions fall outside established ranges, indicating potential data entry errors or product diversion

Agency Response

STATE OF WASHINGTON

August 1, 2018

The Honorable Pat McCarthy
Washington State Auditor
P.O. Box 40021
Olympia, WA 98504-0021

Dear Auditor McCarthy:

Thank you for the opportunity to review and respond to the State Auditor's Office (SAO) performance audit report, "Improving Cannabis Risk Management Tools Using Business Transaction Data."

This SAO report is in response to a 2016 request for assistance by the Washington State Liquor and Cannabis Board (WSLCB). At that time, the WSLCB had requested analytical and technical assistance from the SAO with reporting capabilities of the state's marijuana traceability system to further enhance auditing and enforcement efforts, such as markers that would indicate suspicious activity warranting additional investigation.

Since the initial request, the WSLCB has procured a new traceability system. A contract was awarded in July 2017 and the new traceability system was implemented on February 1, 2018. The WSLCB and its vendor will roll out additional software updates, completing the full system implementation by year's end.

The functionality of the new system is aligned with the recommendations in this report. While the system today has the ability to analyze data for compliance, it will provide much greater capacity and functionality to assist with auditing functions when it is complete. Additionally, the system customer support functions, such as troubleshooting for licensees using the system, are now contracted with the vendor, allowing select WSLCB staff to devote more resources to data analysis.

Ensuring a tightly regulated, legal marijuana marketplace is central to our public safety mission. The WSLCB is committed to continuous improvement of our system and ensuring its flexibility to meet the needs of a dynamic regulatory environment.

Sincerely,

David Schumacher
Director
Office of Financial Management

Rick Garza
Director
Liquor and Cannabis Board

cc: David Postman, Chief of Staff, Office of the Governor
Kelly Wicker, Deputy Chief of Staff, Office of the Governor
Keith Phillips, Director of Policy, Office of the Governor
Inger Brinck, Director, Results Washington, Office of the Governor
Tammy Firkins, Performance Audit Liaison, Results Washington, Office of the Governor
Scott Frank, Director of Performance Audit, State Auditor's Office

Official State Cabinet Agency Response to Performance Audit on Improving Cannabis Risk Management Tools Using Business Transaction Data – August 1, 2018

This management response to the State Auditor's Office (SAO) performance audit report received July 9, 2018, is provided by the Office of Financial Management and the Liquor and Cannabis Board.

SAO Performance Audit Objectives:

The SAO sought to answer these questions:

1. What data could help identify high-risk cannabis business transactions?
2. How can LCB use cannabis licensee tracking data to focus its audit and enforcement efforts on high-risk transactions?

SAO Recommendation 1: LCB should complete its plans to develop reasonable ranges for data at the higher-risk transactions of the cannabis production, processing and retail processes.

STATE RESPONSE: We agree with the opportunity for improvement identified by the SAO. In alignment with the full traceability system realization scheduled for fall 2018, the LCB will complete the development of its data utilization plan and the thresholds therein.

Action Steps and Time Frame

By October 31, 2018:

- Analyze research and information to inform our methodology for range establishment.
- Review and ensure alignment of thresholds with Washington state policy.
- Review and confirm information with agency division subject-matter experts.
- Align final data policies (including reasonable ranges) with traceability system functionality and confirm with IT and product vendor.

SAO Recommendation 2: LCB should complete its plans to establish automatic notifications in its new tracking system that will alert staff when data at those higher-risk transactions fall outside established ranges, indicating potential data entry errors or product diversion.

STATE RESPONSE: We agree with the opportunity for improvement identified by the SAO and believe that it aligns with the agency's plans for the highest and best use of the system configuration. To that end, the traceability system in progress has alert capabilities. Full alert development is part of the IT project implementation plan, and simplified alerts have already been established. A more robust suite of alerts will be developed upon completion of the data utilization plan and analysis of the alerts needed as part of the response to Recommendation 1.

Action Steps and Time Frame

- Contingent upon evaluation of the data needed and plan created in response to Recommendation 1, the LCB will implement automatic notifications in the traceability system. *By December 31, 2018.*

Appendix A: Initiative 900

Initiative 900, approved by Washington voters in 2005 and enacted into state law in 2006, authorized the State Auditor's Office to conduct independent, comprehensive performance audits of state and local governments. Specifically, the law directs the Auditor's Office to "review and analyze the economy, efficiency, and effectiveness of the policies, management, fiscal affairs, and operations of state and local governments, agencies, programs, and accounts." Performance audits are to be conducted according to U.S. Government Accountability Office government auditing standards.

In addition, the law identifies nine elements that are to be considered within the scope of each performance audit. The State Auditor's Office evaluates the relevance of all nine elements to each audit. The table below indicates which elements are addressed in the audit. Specific issues are discussed in the Audit Results section of this report.

I-900 element	Addressed in the audit
1. Identify cost savings	The amount of savings were not estimated. The audit provides recommendations to help the Liquor and Cannabis Board (LCB) focus the work of its audit and enforcement staff, improving both efficiency and effectiveness, saving staff time and maximizing tax revenue. However, the audit makes no estimate of the value of these savings.
2. Identify services that can be reduced or eliminated	**No.** Recommendations address making regulatory activities more effective and efficient rather than reducing or eliminating them**.**
3. Identify programs or services that can be transferred to the private sector	**No.** The benefit of moving any regulatory activities to the private sector is outside the scope of this audit.
4. Analyze gaps or overlaps in programs or services and provide recommendations to correct them	**Yes.** By improving efficiency and effectiveness of cannabis audit and enforcement staff, LCB could better capture all irregular transactions by cannabis licensees.
5. Assess feasibility of pooling information technology systems within the department	**No.** The audit did not address pooling of IT systems, but it does recommend ways LCB can better use its cannabis tracking system.
6. Analyze departmental roles and functions, and provide recommendations to change or eliminate them	**Yes.** The audit provides recommendations to improve the efficiency and effectiveness of cannabis audit and enforcement functions.
7. Provide recommendations for statutory or regulatory changes that may be necessary for the department to properly carry out its functions	**No.** The audit does not address statutory or regulatory changes.
8 Analyze departmental performance, data performance measures, and self-assessment systems	**No.** While the audit recommends improvements to effectiveness and efficiency, it does not specifically address LCB's performance measures. Instead, the audit's recommendations would enable LCB audit staff to identify unusual transaction activities across cannabis growing, processing and retailing business lines.
9 Identify relevant best practices	**Yes.** The audit identifies some general industry standard risk management practices.

Appendix B: Methodology

The audit employed three primary activities to answer the two audit questions. To answer the question "What data could help identify high-risk cannabis business transactions?" auditors:

- Mapped the processes of cannabis production, processing and retail sales
- Identified transaction points in the cannabis production, processing and retail sales processes with high risk of product diversion or data entry

To answer the question "How can LCB use cannabis licensee tracking data to focus its audit and enforcement efforts on high-risk transactions?" auditors:

- Evaluated how existing data could be used to develop tools to alert regulators of irregular data entries

Mapping the processes of cannabis production, processing and retail sales

The audit team worked closely with LCB staff to gain a full understanding of the regulated cannabis market in Washington. To introduce the tracking system, LCB gave auditors an overview of the background of legalization in the state and its approach to regulation. After the presentation, LCB granted auditors access to the tracking system that allowed us to navigate the system as if we were licensees. Auditors accessed the system as each type of licensee: producer, processor, producer/processor, and retailer. We followed the process using the tracking system manuals along with tracking system access in training mode to gain a thorough understanding of the system and allowable transactions. We conducted hypothetical business activities for many types of transactions to understand inputs, outputs, products created, how product moves through the system, how product inventories are measured, and how licensees can make adjustments to their data. This access allowed us to become familiar with the level of tracking from the perspective of a business user.

In addition to accessing and using the tracking system, auditors worked with LCB's Marijuana Examiner Unit staff to better understand the system's tools and the data it collected. We asked follow-up questions about specific transactions to determine which might have a higher risk of diversion. Using the system and interviewing LCB staff allowed auditors to understand the cannabis process from the time cannabis is planted through harvest, cure and product creation, through to the final steps when the product is sold to a retail consumer.

To help us understand the seed-to-sale process for each type of licensee, we mapped the movement of cannabis products through the tracking system, with all of the steps, measurements, and data collected through the process. LCB staff confirmed the visualizations were accurate and complete (see Appendix C).

Identifying transaction points with high risk of product diversion

We worked with LCB staff so we could determine high-risk points for cannabis regulation. Every licensee must report detailed cannabis tracking data. The sheer volume of information collected means LCB cannot check every transaction for accuracy. Consequently, LCB must rely on licensees to check their own data entries for errors.

Applying government standards to/for risk assessments

We also used the Government Accountability Office's Standards for Internal Control in the Federal Government (known as the Green Book) to understand how risk assessment tools could benefit LCB. The Green Book states that risk assessment is the identification and analysis of risks related to achieving the defined objectives to form a basis for designing risk responses.

LCB's objectives include preventing diversion of cannabis product to the illegal market through a robust regulatory framework. The tracking system was designed to track cannabis at a detailed level to achieve this objective. We used auditor judgment to review the cannabis processes for alignment with LCB's goals of preventing diversion and collecting all excise tax revenue. We focused on where product changes hands, changes form, or is adjusted.

Evaluating how existing data could be used to develop tools that alert LCB regulators to irregular data entries

After understanding the process and high-risk transaction points, we determined how standard statistical methods could help LCB use its data to identify unusual transactions at high-risk points.

Using auditor expertise and in consultation with the Office's methodologist, we proposed multiple calculations in each risk area. Each of these calculations involves determining reasonable ranges for data values. Once LCB has determined reasonable ranges for data values, staff can identify irregular data entries. In the future, LCB can build automatic flags into their tracking system so that staff are notified when licensees enter unusual data that falls outside of expected ranges. Auditors also suggested ways LCB could determine when licensees repeatedly enter data that seems abnormal. In these instances, LCB management may involve expertise from its audit or enforcement teams.

Appendix C: Cannabis Process Maps

The following three maps (**Figures 1, 2** and **3**) provide detailed information about each transaction that the three types of licensees — producers, processors and retailers — conduct, and the data that they are required to provide in LCB's data tracking system. For each data entry, icons provide information about how the data is represented in the system (for example, number of items or weight), whether the data can be further broken down into smaller units, called sub-lots or sub-batches, and whether the data entry can include an adjustment value. The maps are available in larger scale on the State Auditor's website at **https://bit.ly/2Mz6qY7.**

Key to symbols featured in the process maps

Count of units — *Number of items of the product, such as the number of individual samples*

Weight of unit — *Weight in grams of each unit of the product, such as the weight of a flower "lot"*

New traceability number assigned — *When the product is entered into the tracking system, it receives a new unique identification number*

Adjustments allowed — *The quantity or weight of the product can be adjusted for any number of reasons, such as confiscation or loss*

Sub-lot/sub-batch allowed — *The product can be further divided into smaller portions and sold by those smaller portions*

Figure 1 – Process map for cannabis producers

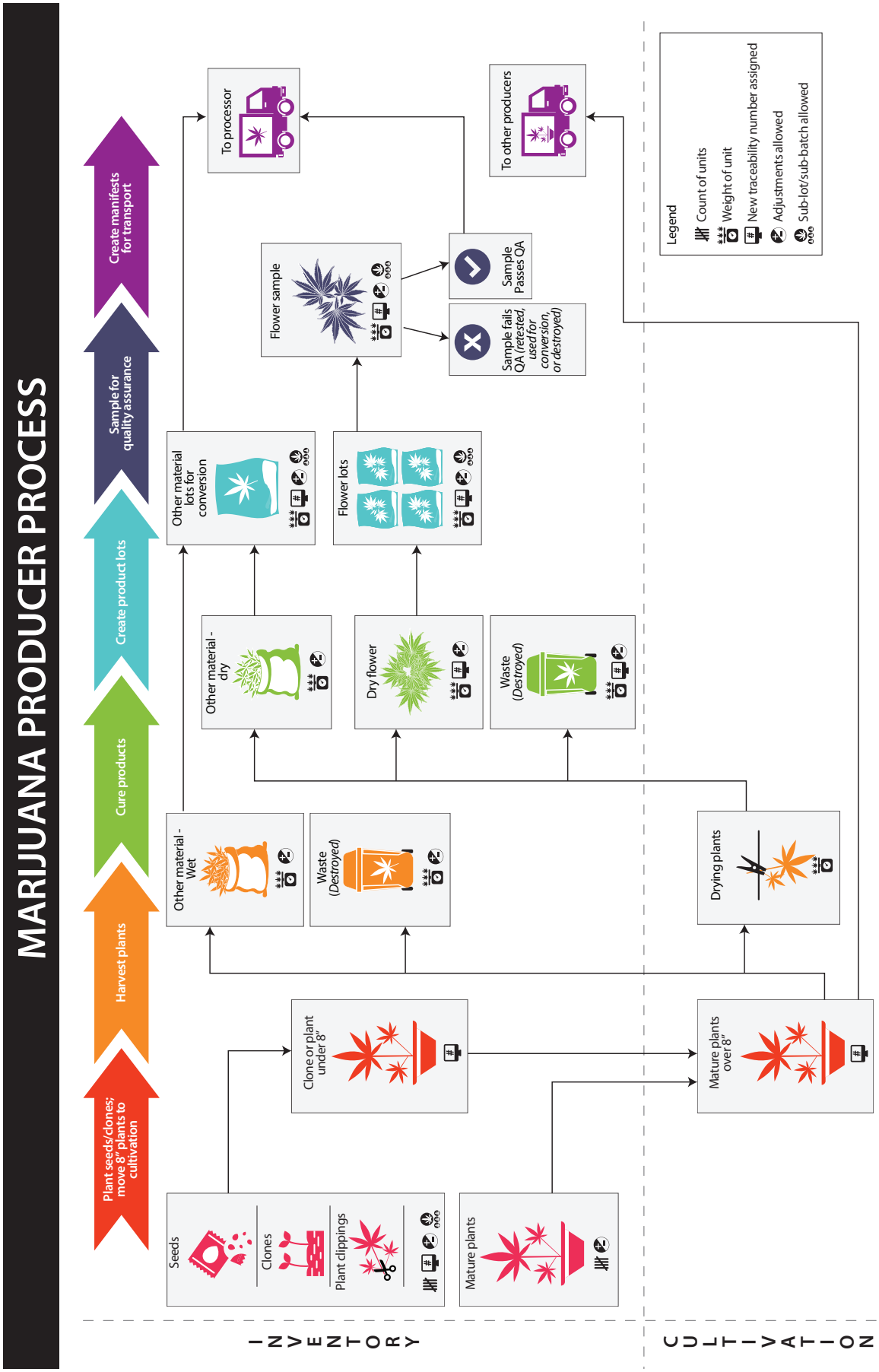


Figure 2 – Process map for cannabis processors

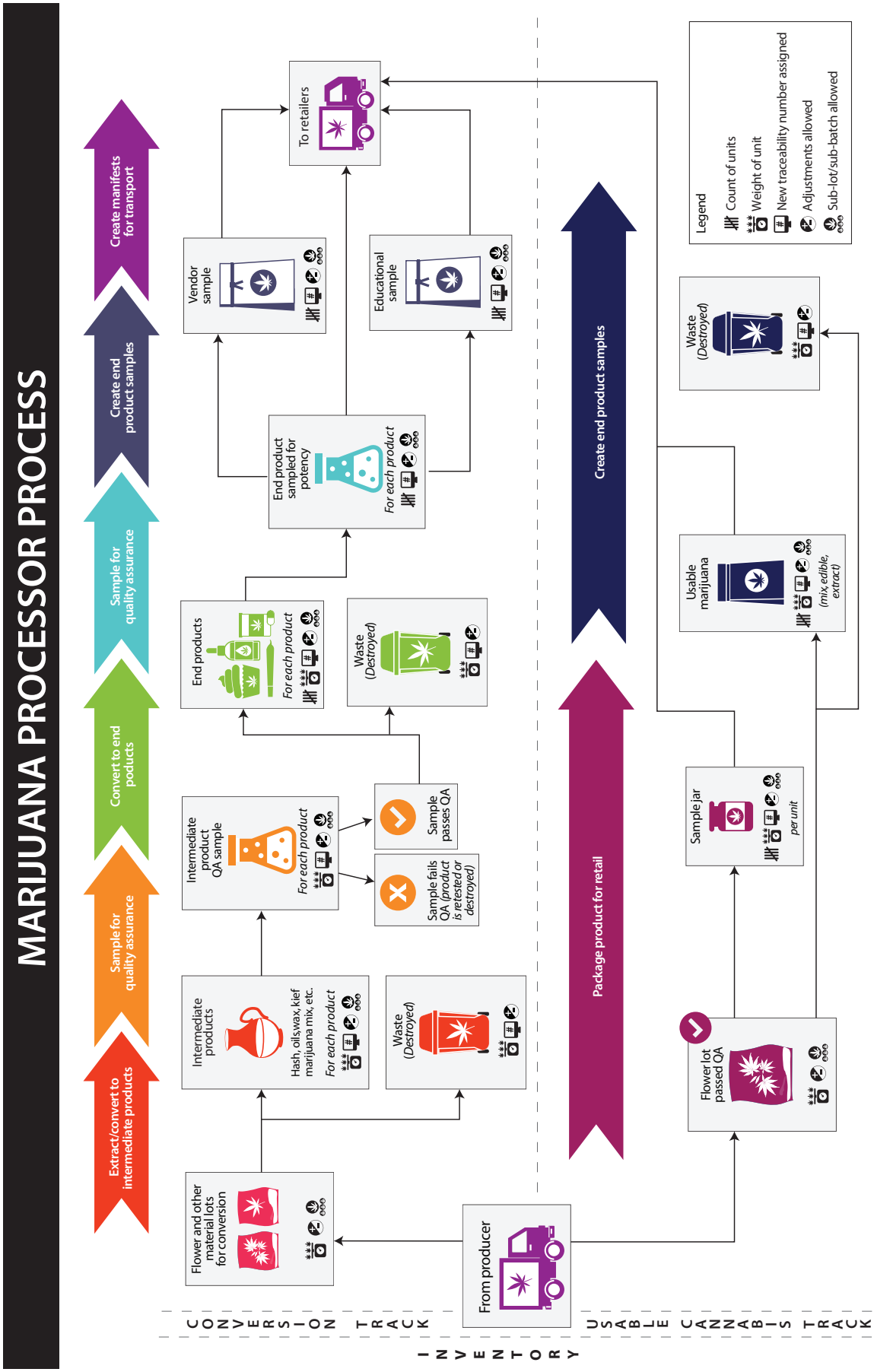
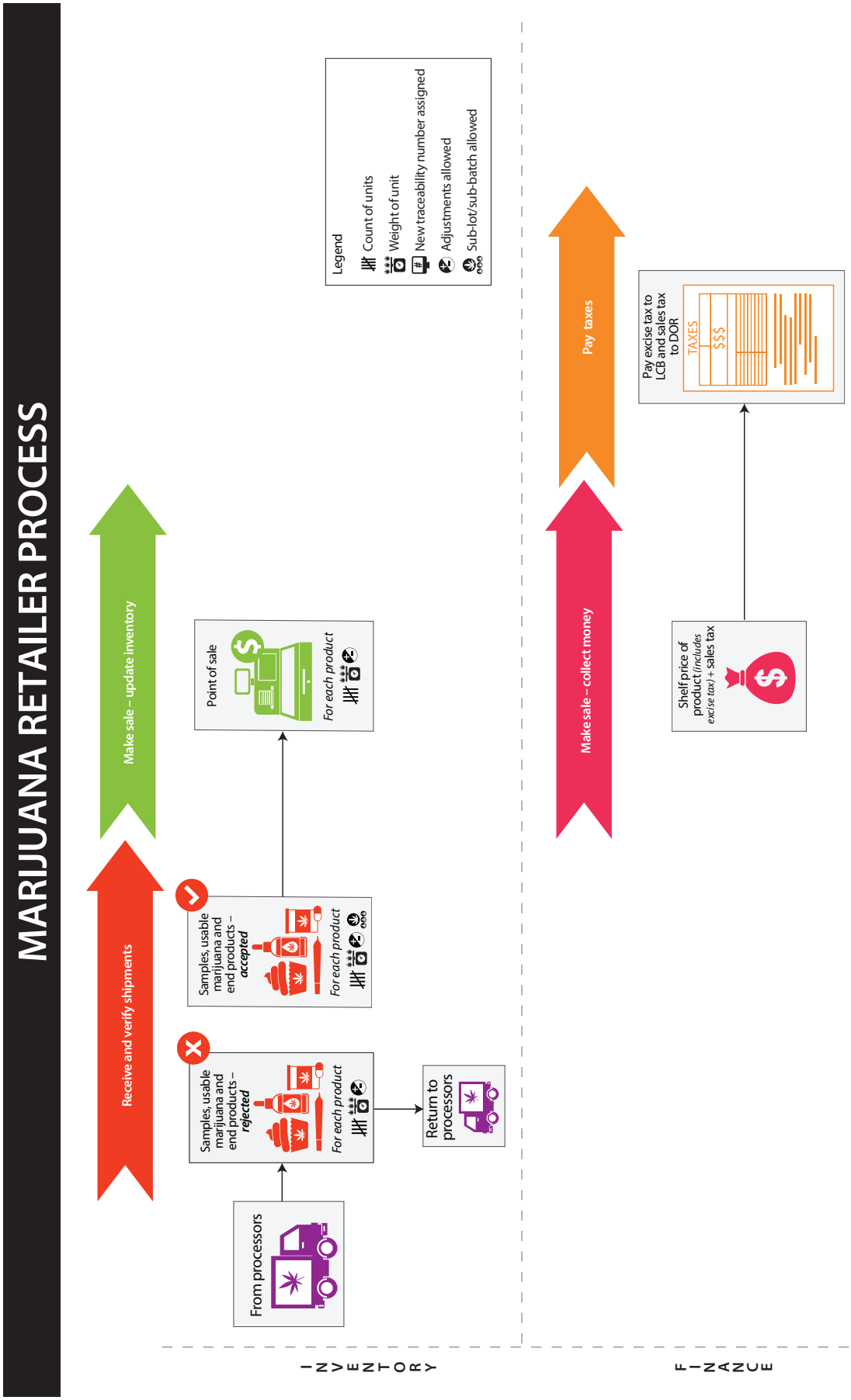


Figure 3 – Process map for cannabis retailers



Appendix D: Suggested calculations for reasonable ranges of high-risk transaction data

The sections that follow provide a roadmap to developing tools that can help LCB know when a licensee has entered irregular data into the tracking system. The information contained in this appendix is technical in nature, and is intended primarily for agency staff with extensive knowledge of the cannabis data, and some proficiency with basic statistical methods. The sections are organized as follows:

Topic	*page*
Introduction to calculations	28
General approach to identifying outliers and choosing reasonable data ranges	29
Suggested calculations for reasonable ranges of adjustment values	31
Suggested calculations for data ranges where cannabis has changed form	32
Suggested calculations for data ranges where cannabis changed hands	36
Methods for identifying outliers	38

Introduction to calculations

In this appendix, we suggest calculations using basic statistics that can help LCB establish reasonable data ranges at high-risk points in the seed-to-sale process. For each risk point, LCB should establish reasonable data ranges. Once LCB has chosen cutoff values for reasonable data ranges such that data outside of the cutoffs is considered irregular, it can build automatic indicators into the tracking system.

The appendix offers a general approach to establishing reasonable data ranges and identifying irregular data entries. We suggest specific calculations at each risk point using the general approach. These suggestions are not meant to be prescriptive, but are meant to serve as a starting point for LCB to begin using data as a risk management tool. They require that LCB has staff capable of implementing these calculations, access to statistical software, and the flexibility in the tracking system to build in automatic indicators.

To describe the calculations, we first present a general approach to identifying outliers and choosing reasonable data ranges. Next, we provide suggestions for how to use the approach at specific risk-points, including what data is required. Finally, we provide specific considerations for steps in the general process, like multiple methods that LCB could use to identify outliers.

General approach to identifying outliers and choosing reasonable data ranges

LCB should calculate a range of values such that any data inside the range is considered reasonable, and any data outside the range is considered an irregular data entry.

LCB may choose between multiple methods to determine reasonable data ranges. Note that some methods include the use of the mean (such as considering data two to three standard deviations away from the mean to be irregular), which may be sensitive to extreme outliers. For example, an extreme outlier may greatly affect the mean and standard deviation, which would affect the data range and may change which data falls outside of the range and is considered irregular.

LCB should begin by considering the shape of the data at each risk point, then choose a method to identify outliers and determine if the outliers affect the calculation of a reasonable data range. LCB will need to decide whether to include the outliers when calculating the reasonable data range, and select an appropriate method to calculate a reasonable data range.

1. Determine which data is needed for the selected risk point

To help LCB decide which data to consider when determining reasonable ranges and identifying high-risk transactions, each following subsection suggests suitable/useful types of data we refer to as the selected data.

For each reasonable range calculation, LCB may want to combine licensees with similar characteristics into groups. For example, producers are issued licenses based on their total canopy size, which provides a natural grouping. Processors and retailers may be grouped based on their average sales data or amount of product moved. For calculations involving medical marijuana patients, LCB may choose to group retailers based on the number of registered medical patients who shop at that retail location. These groupings can also be helpful in determining cutoffs. For example, a large producer may naturally make more adjustments than a very small producer, so LCB may want to consider different cutoffs for businesses of different sizes.

2. Identify outliers using one of the suggested methods

There are many methods for identifying outliers, but their effectiveness will depend on the shape of the distribution of the selected data. For each calculation, determine whether the selected data is normally distributed or highly skewed to one side. Once you make this determination, choose a method for determining outliers. See "Methods for identifying outliers" for details on outlier detection. These methods will provide a range of values such that values outside of the range are outliers.

> To determine the shape of the distribution, plot all values on a histogram or dot plot. A symmetric bell shape is referred to as normally distributed.

3. Calculate a reasonable data range and choose final cutoff values

Once groups have been devised and the outliers have been identified, LCB should consider whether the outliers affect the calculation of reasonable data ranges. Large outliers in the dataset might affect the endpoints of the range. For example, if the outliers in the selected data have a large effect on the mean and standard deviation, LCB may want to recalculate the reasonable range excluding outliers, or may want to use more robust methods, like the median absolute deviation method. Excluding outliers is known as trimming the data. LCB may choose to trim outliers it believes are erroneous, unlikely to occur again, or not representative of what values should be based on staff experience.

Once LCB has determined a reasonable expected range for data, it should choose cutoff values such that data that falls outside of the cutoff values would be considered an irregular data entry. The cutoff values could be the endpoints of the reasonable data ranges, or LCB may choose to adjust the endpoints.

When considering the method used to calculate data ranges or adjust the endpoints, LCB should take into account practical considerations, such as:

a) Do the values seem reasonable given what the agency knows about the subject matter?
b) Would the impact at the suggested cutoff values be significant enough to justify the time and expense of further investigation?
c) Will the suggested cutoff values identify far more cases than the agency has resources for investigation?

For example, if LCB calculates a reasonable range for the selected data to be between -10 and 10 using one of the statistical methods, but knows that the values should never be negative, it may adjust the cutoff values to be 0 and 10. This approach would flag values that are less than zero or greater than ten. Alternatively, if staff have determined that the values of the selected data could be reasonably expected to fall between -10 and 10, but they do not have the resources to follow up every time an input is greater than 10, they may adjust the upper cut off to a greater number that would generate a more manageable number of cases.

4. Build automatic notification into the tracking system

LCB also has options for incorporating automatic notifications into the system depending on the type of calculation.

For one-time abnormal value calculations, such as one extremely large outlier, the system could automatically notify LCB whenever a licensee enters a value outside the cutoffs. Alternatively, the system could automatically generate a monthly report of all the transactions that were outside the cutoffs.

For repeated or frequent abnormal value calculations, such as frequent donations, LCB could build a count of occurrences in the system, and automatically notify staff when the count exceeded the cutoffs. Alternatively, LCB could build metrics into the system to automatically notify staff of the distribution for the selected data and some number of outliers each month.

For build-ups of negative-value calculations, such as total adjustments trending in the negative direction (see specific calculation description for more detail), LCB could modify the system (by adding a data field that summed the relevant selected data) to keep a running total of the values for each licensee, and automatically notify staff when a licensee crosses the threshold. Alternatively, LCB could build these metrics into the system to automatically notify staff of the selected data distribution and some number of outliers each month.

5. Follow up on flagged transactions or licensees

LCB should review values flagged by the system to determine which ones should proceed to investigation by the audit or enforcement teams. Other information in the data system about the specific event or licensee may be helpful with this determination.

6. Periodically review cutoff values over time

To ensure outliers and expected values remain representative of the industry as it evolves and new techniques and practices emerge, LCB should regularly recalculate cutoff values. LCB may consider what timeframe (e.g., several months or several years) it would like to use when calculating reasonable ranges and outliers. For example, staff may find outliers identified are more aligned with their expectations or normally distributed if they use a longer time range.

LCB should also take note of common themes among situations investigated that turn out to be "false positives" – that is, cases that were flagged but upon investigation were found not to be a problem. The criteria for the cutoff value can be refined over time to ensure fewer of these situations are flagged.

Suggested calculations for reasonable ranges of adjustment values

Quantity and weight adjustments

Goal: Create a data range that can be used to automatically notify staff when adjustments generate a significant deficit, or are unusually large or frequent

Adjustments are a step in the process where licensees could mask diversion of product or revenue. Excessive adjustments could indicate an effort to divert product to the black market or to avoid the excise tax. Unusually large adjustments or repeated adjustments that sum to a large deficit may also indicate an effort to divert product and avoid the excise tax.

The following calculations may be relevant for all types of licensee: producers, processors, and retailers.

Data needed for adjustment range calculations

For each adjustment range desired:

- Initial and adjusted quantity
- Adjustment reason
- Count of adjustments

Recommended calculations

1. **Identify total adjustment trends in the negative direction**

   The goal of this calculation is to identify when licensees make adjustments to reduce inventory or weight that sum to a large value, either from a single very large adjustment or from many small adjustments. For example, when a licensee makes 10 adjustments of -1,000, the total adjustment "deficit" would be -10,000. This calculation will capture both one-time unusually large adjustments and excessive cumulative adjustments.

   Selected data: Determine the total adjustment deficit in the selected time period for each licensee by summing all the adjustments in the selected time period. Use this data to determine a reasonable range of values for adjustment deficits, and choose cutoffs such that when a licensee reaches a deficit past the cutoff value, it will be flagged.

2. **Identify one-time unusually large adjustments**

   Although single unusual adjustments will be captured by the previous calculation identifying total adjustment trends, it may also be helpful to consider the distribution of one-time unusually large adjustments. The goal of this calculation is to identify single adjustments that are unusually large.

   Selected data: Identify individual adjustments in the selected time period for each licensee. Use this data to determine a reasonable range of values for single adjustment sizes, and choose cutoffs such that when a licensee makes a single adjustment outside of the cutoff values, it will be flagged.

3. **Identify frequent adjustments**

   Although frequent adjustments that sum to a large value will be captured by looking at total adjustment trends, it may also be helpful to look at licensees who make unusually frequent adjustments, regardless of whether the adjustments sum to a negative value.

   For example, if a retailer makes many adjustments of +1 and -1 to products that cancel each other out, it may be a sign the retailer is charging customers for the wrong products. The goal of this calculation is to identify licensees who make more frequent adjustments than normal.

   Selected data: Determine the total number of adjustments in the selected time period for each licensee. To do this, count each time a licensee makes an adjustment. Use this data to determine a reasonable range of values for frequency of adjustments, and choose cutoffs such that when a licensee makes more adjustments than the cutoff values, it will be flagged.

Suggested calculations for data ranges where cannabis has changed form

A. Conversions from cannabis material to intermediate products or usable marijuana, and from intermediate to end products

Goal: Create a data range that can be used to automatically notify staff when the weight yield after material is converted is abnormally low

The production process typically involves the creation of intermediate products that are ingredients in final "end" products, which are then sold to consumers. The tracking system records the quantity and weight per unit of each type of each intermediate and end product created. Weight yield is the ratio of the output to the input.

To account for the differences in input makeup, consider the weight of THC input and output. Weight yields for specific types of calculations are defined below, but in general:

$$\text{THC weight yield} = \frac{\text{output potency} \times \text{output total weight}}{\text{input potency} \times \text{input total weight}}$$

The perfect conversion of THC from one form to another would result in a yield of 1.0, though this would not likely be attainable in an actual processing setting. Note that THC weight yield could be replaced by cannabidiol (CBD) weight yield, if CBD is the cannabinoid of interest. Note that CBD is the cannabinoid of interest in many medical cannabis products.

Data needed for calculation of ranges where cannabis changed form

Flower lot to usable cannabis conversion calculations:

- Input weight of cannabis to be converted
- Potency of cannabis to be converted
- Weight per unit of usable cannabis created
- Number of units of usable cannabis created
- Potency of cannabis created
- THC weight yield:

$$\text{THC weight yield} = \frac{\text{potency per unit of usable cannabis} \times \text{number of units of usable cannabis} \times \text{weight per unit of usable cannabis}}{\text{potency of input cannabis for conversion} \times \text{input weight of cannabis for conversion}}$$

Cannabis material to intermediate product conversion calculations:

- Flower input weight
- Flower input potency
- Other plant material input weight
- Other plant material input potency
- Conversion method
- Type of intermediate product created
- Weight of intermediate product created
- Potency of intermediate product created
- THC weight yield:

$$\text{THC weight yield} = \frac{\text{potency of intermediate product} \times \text{weight of intermediate product}}{(\text{potency of input flower} \times \text{input weight of flower}) + (\text{potency of input other plant material} \times \text{input weight of other plant material})}$$

Cannabis material to end product conversion calculations:

- Intermediate product input weight
- Intermediate product input potency
- Conversion method
- Type of end product created
- Weight per unit of end product created
- Number of units of end product created
- Potency of end product created
- Weight yield: Ratio of weight of end product created to the input weight of intermediate product for conversion

$$\text{THC weight yield} = \frac{\text{potency of end product} \times \text{number of units of end product} \times \text{weight per unit of end product}}{\text{potency of input intermediate product} \times \text{input weight of intermediate product}}$$

Recommended calculations

1. **Identify a one-time abnormal weight yield**

   The goal of this calculation is to determine reasonable expectations for resulting THC in the creation of intermediate and end products for the most common products and production methods, and to identify abnormal weight yields for follow up. There are two possible methods for this calculation. The first is simpler but has limitations. The chosen method should be applied for each product conversion using the same extraction or conversion method and resulting in the same product.

   Method 1

   Selected data: For each product creation using the same extraction or conversion method and resulting in the same product, calculate the THC (or CBD) weight yield. Use this data to determine a reasonable range of values for THC weight yields for each product type and creation method, and choose cutoffs such that when a weight yield falls outside the cutoff values, it will be flagged.

   The weakness of this method is that it does not consider the makeup of the input and output material. If different ratios of input products, given the same overall THC content, result in different expected THC content in the output, LCB should consider using Method 2.

   Method 2

   For each intermediate and end product, a regression analysis or similar technique could be performed using the percentage of each input and amount of each input to determine the expected output weight. The selected data in this case should be the difference between the actual and expected weight yield.

   Following the steps, LCB could determine a reasonable range of variation between actual and expected weight yield for each product type and creation method, and choose cutoffs such that when the difference falls outside the cutoff values, it will be flagged.

2. **Identify repeated abnormal weight yield using expected range**

   It may not be feasible to follow up on a single occurrence where the actual weight yield is significantly lower than expected. The goal of this calculation is to identify licensees who repeatedly report weight yields less than the lower end of the expected range. This calculation should be performed after the previous calculation determining expected weight yield ranges.

Selected data: Determine the total number of times the reported weight yield falls below the lower end of the expected range in the selected time period for each licensee. Use this data to determine a reasonable range of values for frequency of unusual weight yields, and choose cutoffs such that when a licensee more frequently reports abnormally low weight yields, it will be flagged.

B. Conversions of cannabis products that result in waste

Goal: Create a data range that can be used to automatically notify staff when the amount of waste reported is abnormally large

Waste is created when cannabis changes forms. There is a 72-hour waiting period before licensees can destroy the waste in case LCB wants to observe the destruction. However, LCB staff likely does not have the resources to witness every destruction event. If the ratio of waste to product is abnormally large, it may indicate that the licensee is reporting excess waste in an effort to divert product.

Waste ratio is similar to weight yield. It is the ratio of the amount of waste created to the amount of cannabis input as a percentage.

Data needed for calculation of ranges of cannabis conversions resulting in waste

Waste ratio during harvest calculation:

- Weight of wet flower created
- Weight of wet waste created
- Waste ratio: ratio of weights of wet waste to wet flower created

Waste ratio during cure calculation:

- Weight of dry flower created
- Weight of dry waste created
- Waste ratio: ratio of weights of dry waste to dry flower created

Flower lot to usable cannabis conversion waste ratio calculation:

- Input weight of cannabis to be converted
- Weight of waste created
- Waste ratio: ratio of weights of waste created to input weight of cannabis material

Cannabis material to intermediate product conversion waste yield calculation:

- Flower input weight
- Other plant material input weight
- Conversion method
- Type of intermediate product created
- Weight of waste created
- Waste ratio: ratio of weights of waste created to input weight of flower plus other plant material

Intermediate product to end product conversion waste ratio calculation:

- Intermediate product input weight
- Conversion method
- Type of end product created
- Weight of waste created
- Waste ratio: ratio of weights of waste created to intermediate product input

Recommended calculations

1. **Identify a one-time abnormal waste ratio**

   The goal of this calculation is to identify abnormally high waste ratios for follow up by determining an expected range. This calculation should be performed for each conversion method and type of product created.

   Selected data: For each licensee and each conversion method and type of product created within the selected timeframe, calculate the waste ratio. Use this data to determine a reasonable range of values for waste ratios for each product type and creation method, and choose cutoffs such that when a waste ratio is above the upper cutoff value, it will be flagged.

   For the intermediate and end product conversion calculations, if it is determined the amounts of each input affect the expected amount of waste, LCB may choose to do a regression analysis similar to the Method 2 calculation of one-time abnormal weight yield (see page 33).

2. **Identify repeated abnormal waste ratios using expected range**

   It may not be feasible to follow up on a single occurrence where the actual waste ratio is greater than expected. The goal of this calculation is to identify licensees who repeatedly report waste ratios that exceed the expected range. This calculation should be performed after the previous calculation determining expected waste ratio ranges.

   Selected data: For each product type and production method, determine the total number of times the waste ratio exceeds the expected range for each licensee in the timeframe. Use this data to determine a reasonable range of values for frequency of abnormal waste ratios for each product type and creation method, and choose cutoffs such that when licensee more frequently reports excessive waste ratios, it will be flagged.

Suggested calculations for data ranges where cannabis changed hands

A. Donations of medical cannabis products

Goal: Create a data range that can be used to automatically notify staff when licensees make frequent cannabis donations

Retail licensees with a medical marijuana endorsement are able to donate cannabis to qualifying patients and providers. In the system we accessed, there is no specific option to record that a transaction was a cannabis donation. Instead, a donation is recorded as selling the product for $0 to ensure that the quantity in stock is correctly reflected in the system. The act of a retailer entering patient ID information into the tracking system is the trigger that lets LCB know a sale is medical.

When licensees donate cannabis products, recipients do not pay excise tax. By appearing to donate products, licensees could divert cannabis to avoid paying the excise tax.

Data needed for calculation of ranges where cannabis changed hands

- Sale price for each transaction
- Medical transaction designation, if available

Recommended calculations

1. **Identify large numbers of donations**

   The goal of this calculation is to identify retailers who make an abnormally large number of product donations.

   Selected data: For each retail licensee with a medical marijuana endorsement, calculate the total number of donations by determining the number of sales of cannabis products for $0 in the selected timeframe. Use this data to determine a reasonable number of donations, and choose cutoffs such that when the amount of donations falls outside the cutoff values, the retailer will be flagged.

B. Sales price of cannabis products

Goal: Automatically notify staff when retail licensees frequently sell cannabis for a lower price than they paid

The law specifies that retail licensees may not sell cannabis for a lower price than they paid. However, the tracking system we accessed did not impose this restriction.

Data needed for calculations of ranges of sales price

- Purchase price of the product from processors
- Sale price of the product to consumers

Recommended calculations

1. **Identify sales at prices that are too low**

   The goal of this calculation is to identify retailers who sell products for too low of a price.

   Selected data: For each retail licensee, determine the difference between prices paid by the retailer for each sale and prices paid by the consumer. Identify transactions where the difference is negative: for example, if a retailer purchased a product for $10 and sold it for $1, the difference would be -$9. In this calculation, LCB could simply flag all sales where the difference is negative, instead of following all of the general steps.

2. **Identify average number of sales at prices that are too low**

   It may not be feasible to follow up with every retailer who sells a product for less than they paid. LCB may consider instead just following up with retailers who do this regularly.

   Selected data: For each retail licensee, identify the total number of transactions where the difference between the price paid by the retailer and the price paid by the consumer is a negative value in the selected timeframe. Divide this number by the total number of sales made by the licensee in the selected timeframe. Use the percentage of sales made below cost as the data to determine a reasonable frequency for selling product below the required price, and choose cutoffs such that when a retailer does this abnormally often, it will be flagged.

3. **Identify total price difference deficit trends in the negative direction**

   The goal of this calculation is to identify when licensees repeatedly sell products at prices that are too low so that the deficits sum to a large negative value. For example, if a licensee sells a product for $10 less than they purchased it 10 times, the total difference deficit would be -$100.

   Selected data: For each retail licensee, identify the total number of transactions where the difference between the price paid by the retailer and the price paid by the consumer is a negative value in the selected timeframe. Sum the total dollar deficit for the below-cost transactions in the timeframe. Use these values as the data to determine a reasonable range of values for difference deficits, and choose cutoffs such that when a licensee reaches a deficit past the cutoff value, it will be flagged.

Methods for identifying outliers

Some methods for determining outliers may be more robust than others, depending on the shape of the data distribution. Most common methods work well for data that is generally normally distributed. If the selected data is normally distributed, LCB may use any of the following methods to determine outliers:

- **Box plots** can be used as an initial screening tool for outliers, as they provide an easily recognized visualization of the data distribution and extreme values.
- **Adjusted box plots** are more robust for skewed distributions.
- The **68-95-99.7 rule** states that values that are more than two or three standard deviations from the mean may be considered outliers.
- **Tukey's fences** states that values that are far outside the interquartile range,

  $$[Q_1 - k(Q_3 - Q_1), Q_3 + k(Q_3 - Q_1)]$$

  where k is a non-negative constant and Q_1 and Q_3 are the lower and upper quartiles, may be considered outliers. Specifically, Tukey proposed that k=1.5 indicates an outlier and k=3 indicates data that is "far out." Note that in the k=1.5 case, the range matches the Tukey box plot.
- **Median absolute deviation** is more robust against outliers than mean and standard deviation. Values that are more than two or three median absolute deviations from the median may be considered outliers.

LCB should consider how many data points these various methods would capture, and whether resources would be available to follow up on all outliers.

LCB should also consider the degree to which the data is skewed. LCB may choose to default to a more robust method, like adjusted box plots, which also work for normally distributed data.

In some instances, LCB will only be interested in investigating outliers on a specific end of the distribution, such as unusually large or unusually small values. In these instances, the cutoff for the opposite end of the distribution can be adjusted to an extremely high number or zero as appropriate.