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Approaches to Optimizing the Loading of Production Lines in the Alcohol Industry

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Abstract

Purpose: This article aims to synthesize empirical evidence from fifteen peer-reviewed studies on production and warehouse planning in multi-product environments, with particular focus on line loading, batch sizing, filtration staging, and buffer management. The objective is to identify conditions under which sequencing, capacity representation, and buffer design improve overall equipment effectiveness (OEE), throughput, and service performance.

Methodology: A structured literature review was conducted, extracting and comparing modeling approaches (mixed-integer programming, heuristics, metaheuristics, simulation), decision variables (SKU grouping, changeover policies, capacity constraints), buffer policies, and performance indicators (OEE, throughput, service level). Findings were synthesized into a cross-study analytical framework highlighting recurring design patterns and operational trade-offs.

Findings: Three consistent conclusions emerged. First, SKU grouping policies that reduce sequence-dependent changeovers significantly increase OEE and stabilize flow, particularly in high-mix environments. Second, explicitly modeling filtration/processing capacity and dynamic constraints prevents micro-stoppages and protects throughput, whereas ignoring such constraints leads to systematically optimistic plans. Third, moderate upstream buffering improves delivery reliability, but benefits diminish rapidly beyond a threshold range. Decomposition- or cooperation-based algorithms outperform monolithic optimization models when product variety is wide and planning horizons are long.

Unique contribution to theory, practice and policy (recommendations): The study contributes an integrated decision checklist for APS/MES implementation, linking model choice, data requirements, KPI alignment, and bottleneck diagnostics within one operational framework. Practically, it provides managers with a structured method for selecting planning algorithms and buffer policies based on product mix complexity and capacity volatility. For policy and organizational governance, it emphasizes the importance of standardized data structures and cross-functional KPI harmonization to avoid suboptimal planning. Future research should extend analysis to end-to-end models connecting production lines and warehouse systems under real operational datasets.

Keywords: *Production line, Loading optimization, Bottling scheduling Sequence-dependent changeovers, Warehouse buffering*

Introduction

They translate into constant mismatches between the properties of volatile order patterns and filling and capacity of packaging, especially if the sequence, hygiene and CIP and filter stability changes must be respected. In practice, the planners face the interconnected problem: stabilizing the flow from preliminary staging and filtration when loading many lines so that the setting does not destroy the overall efficiency of the device, level of service or unit costs. Solid building blocks for everyday decision provide fragmented instructions. Dominant programming and heuristics of decomposition with mixed represented, but plants also rely on the rule of which groups of SKU and throttle flaps. The current article consolidates this evidence and uses an experiment instead of a compact secondary study Re -alyzing published empirical results to turn it on.

Two currents explain why it depends on integration. First, alcohol furnace shows models for batch size and planning and planning shows how to interact against current, maturity and packaging, Package phase is not a passive sink, but once the settings and length of the campaign are clearly modeling length. Baldo, Santos, Almad-Lobo and Morbito represent the formulation that the tank tank has been assigned to the line and shows the benefits of cost and stability when the campaign is carried out to reduce the sequence, Their data on industry emphasize the transmission of the transmission and performance coordination (Baldo et al., 2014).

Second, recent work in the winery increases this argument to parallel lines with strong combinations. Mac Kaval, Graduate, PassCuel and Tortorella develop a strong fraction with a deciduous solution that absorbs the uncertainty of demand and processing using the sequence -dependent settings structure, This approach proves to be scaled within the actual filling calendar into bottles and reduces the load of MAKEPAN and settings compared to uninterrupted model (Mac Cavale et al., 2022).

These inspections directly travel to the decision on the warehouse. Bumpers and East-Gotttle staging principles affect whether the optimal sequence of the line actually moves without micro-foot, Basic capacity and dynamics of pollution, if it stays, look better on paper than on the floor. This voltage - among the girlfriends and loyalty to obstacles - operates the current synthesis. OE tailures rather than adding a case, the article collects fifteen studies in English and fifteen English studies covering the winery, many of them are empirical to perform in three liver references: a group of settings to reduce frequency, frequency boundaries. Calibrated buffer. The analysis considers published results as comments in structured evidence review, If possible, the size of the effect (for Throwut, OEE or Service Level) is generalized to allow a vigilant comparison of cross-time studies.

The goals are three times. First, for classifying modeling (MIP, strong/decomposition, Hurlystics, simulation) by operating conditions under which they close the best precise trading with precise proportion for line load. Secondly, insulate which third, translate these findings under an implemented APS/MES instructions: Data requirements, KPI definitions, and landscape tests that can perform a planner's plants without rewriting. No new primary

experiment was claimed, Instead, compact empirical re -analysis of existing empirical studies analyzes findings, aligning methodological strictness with the practical purpose of optimizing decisions on alcohol production lines.

Literature Review

Literature on the loading and planning of production lines in fluffy plants has matured around three interactions: sequence -dependent changes are possible capacities, preliminary logistics and filter obstacles determine the stability for packaging and models are less optimelities as model traceability. The basic work was determined by the work of an early liqueur furnace. Baldo, Santos, Almad-Lobo and Morbito have developed a mixed point point that gives a great shape to detailed sequencing in sequence dependent settings, The structure of campaign and alignment of transfers with the availability of packaging reduced their models of change and shortened passive time- for the fact that the packaging is instead of passive point closing the binding source (Baldo, Santos, Almada-Lobo and Morbito, 2014). The additional current increases this argument to the furnace plan of the integrated liqueur, Georgiadis, Elikedis and Georgiadis examined the optimal production plan and planning during fermentation, maturity and packaging, showing that ignoring the conditions between steps affects real changes and calendar obstacles once (Georgiadis, Elachidis, Alexidis, 2021). Together, these studies argue that the line load cannot be solved in isolation from the policy of release upstream and warehouse.

The wine of the wine introduces other complexity due to parallel lines, rich structures of settings and high variability in SKU characteristics. Baso and Varas designed MIP for the problem of planning performance planning with bound heroism to get good solutions, Setting dependent on the sequence is in their design central and the heuristic use of the SKU group to avoid threshing between forms, which is right what the planners do informally when the "campaign" of the brand and the size of the bottle (BASO and VARS, 2017). Later, Baso, Guardo and Varas considered the same environment a problem with associated planning and emphasized the coordination between independent actors who share the sources of performance, They showed that better use of resources when interaction takes place, rather than deciding on the rules of sequencing, discovery with practical echoes for joint packaging and contracts (Baso, Gujard and Varas, 2020). At the top of the model's hardness, Mac Kavale, graduate, Pascal and Tortorella prepared a strong adaptation approach with the decomposition plan for several lines and sequences of dependent settings, The law absorbs processing time and requires uncertainty and remains a calculated viable for a real calendar, and compared to uninterrupted model is less and less mcpane and low settings (Mac Kavale, Graduate, Pascal and Tortorella, 2022). Bruto, Tortia and Gay, which relate back and forth, have shown that a relatively simple adaptation of the performance schedule also makes the average shortening in passive times, which is useful because it shows that profit technology remains in generations and does not depend on foreign solutions (Beruo, Tortia and Gay, 2006). In these wine studies, he repeats the motif: sequential rules that produce a smooth flow compatible with cluster compatible and highly gained capacity, especially when many lines share work or tools.

Line loading is not only in the planner, It is mediated by the physical reality of performance and filtration. Evidence from beer filling lines suggest that the overall efficiency of the OEE (OEE) can be disintegrated and systematically improved when planners have a reliable diagnosis for micro-stops, short runs and frequency of changes. He, V, Chen, G, Wu and Huang have designed an extensive OEE correction model that uses a qualified border analysis to find the current line status and identify the loss of focus, Although there is no planning algorithm, the framework gives planners to internal standards and clarifies the shopping bands between short -term throwing and long -term stability (that et al., 2018) by campaign. On the Winery side, filtration is an important interface between the basement and the packaging. El Race, Albasi, Bechin, Telondier, Minton-Technical and Nine have determined how the crosses of the call are of significant improvement in the microfil in the cross flow, effectively holding the moving limit available for performance, If the plans deny these boundaries, they spread the micro-stop (El Race et al., 2011). This filtration begins with the location of the visual inventory, as it continues in the warehouse 'buffer': Fulfillment of the buffer should absorb both buffers, both the variability of demand and the stochastic nature of the filter performance. In short, modeling of filter capacity and dynamics of pollution - even simple windows or speed cap - can prevent optimistic collapse of the program on the floor.

Warehouses and decisions on the production close the loop. Garcia, Marchet, Camargo, Morel and Foredelus have proposed a framework for measuring logistics for the wine industry that connects the matrix of services, principles and reliability of procedures (Garcia, Marcheta, Kogaro, Morelus and Foredellas, 2012). Their post is often ignored in paper planning, but it depends on it: when planners tune the tuned buffer and continuous release time with KPI, they discover saturation points for which other productions connect the costs without line stabilization. Finally, Guimrass, Clubzan and Almad-Lobo analyzed the annual production budget in beverage, integrated medium and strategic obstacles campaigns (Guimres, Clabzan and Almad-Lobo, 2012). While strategic in extent, the task explains why "optimal" daily loads may still fail if budget campaign structures force excessive changes or unrealistic objectives, The strategic program inherited these prejudices. Adding these currents reveals a practical research attitude: Align the sequencing at the line level with the release of filtration release and bounded buffer strategy, and then check out the results against the KPI logistics that management already uses.

Some cross -sectional findings appear when reading studies. First, the sequence of dependent settings is not just an interference, They define the economic size of capacity. Models that make the cluster of SKU according to compatibility, whether clear adjustment matrix or campaign, through Hyuristics, to improve innocent pift for frequent throwing and OEE. The mechanism is direct: a low format switch means low low power scattering and low power, which in turn simplifies allocation and staging of material (Baldo et al., 2014, Baso and Varas, 2017, Mac Cavel et al., 2022). Secondly, filtration and clarification are steps limiting speeds that behave stocastically on the operating time scale. If the planner succumbs to the filtration as an endless, always prepared source, the packaging plans look better when they perform, Studies including sill or capacitive windows for pollution show low micro-foots and

more stable expeditions (El Race et al., 2011). Thirdly, the buffer upwards upwards, but are saturated. The logistics framework warns that only a coordination failure between the timing of release and sequencing the setup-inmates, The average status is mined until the space is combined with policies that honor the throttle variety and filter variability (Garcia et al., 2012). Fourth, the choice of method depends on the horizon and mixture. Strong or decomposition approaches achieve relevance because the variety of product increases increases and uncertainty increases, while simple Mip-Plus-Hurrystic schemes are effective in narrow environments or when planners require answers to small chakras (Baso and Vars, 2017, Mac Cavli et al, 2022). Related, integrated alcohol plans show that the connection should be clear in the steps, The Campaign of the Packing Up Currency itself cannot correct errors (Georgiadis et al., 2021).

Despite this progress, there are closure intervals. Many models still consider staging to be an abstract buffer without tying the stock positions to release the rhythm from tanks or filters. Some articles emphasize OEE components with planning output, allowing doctors to test whether the cuts were cut, performed power or quality effects, It limits the transfers of the results of one plant to the other (That T al., 2018). Empirical evidence is uneven in souls, beer and alcohol, Winery and Brosoria dominate, which represents the soul. Cooperation in companies appears in a joint packaging, shared lines or mobile searching, but has less empirical verification, The advantages of cooperative advantages that Baso, Guardo and Varas, are worth replicating in various contractual environments (Baso et al., 2020). Finally, budget and medium -term barriers often persist in daily planning studies, although evidence of beverage budget shows that the annual campaign design forms possible fields for everyday plans (Guimrass et al., 2012). These problems are not only academic, They explain why sophisticated Selver buffer policies may fail when re -appearing or updating on the floor without updating the KPI definitions.

The current article responds by organizing the structured synthesis of fifteen sources of English in Broaria and the winery and proving a compact secondary empirical analysis of published results rather than a new study of plants. For throwing, OEE, service level, sharing time change and micro-stop events are reported to be extracted and if possible, The model class serves as the presence of sequence -dependent settings, treatment of filtration and covalent policy of buffer. This small empirical practice is designed for a surface effect formula on which the doctor depends. For example, association in studies allows specific benefits for clustering SKU within multiple line operations vs. Single-line settings or incremental advantage of filtering windows at the top of the setting plan. It also allows to explore the sensitivity: will the repaired improvement disappear when the mixture is narrow or when the horizon is very low? While the asymmetry of methods and matrix commands is cautious, the approach exceeds the story of the story and claims that the claims on the evidence collected.

Depending on the literature, the goals are three times and intentionally functional. First, to map the possibilities of modeling focused on philanthropic programming, strong/decomposition methods, heroism and simulation-in the common operating environment of alcohol, suggesting that each square performs the best accuracy for line loads (Baldo et al.,

2014, Baiso and Varas, 2014, Coating and glittering shimmering and valid coating, and fictional, plus and fictional, pltov and fictional, plus and fictional Pilsen and pay, filters and loops in valid tracking and clearly. Finding under an implementable APS/MES: Data Preferences, KPI definition is compatible with the diagnosis in the store, and 2021). These objectives follow test questions and lead the remaining paper. RQ1: In what combination of SKU, number of rows and models of non -ignorant disparity models and OEE provide physical benefits on FIFO or innocent heroism in terms of OEE? RQ2: What is the incremental advantage of the window at the top of the modeling capacity, the threshold value of the pollution or the sequencing of the assembly and the sequencing and sequencing of the infinity and how does this product differ according to the mixture and length of the campaign? RQ3: Where is the saturated point for staging buffers before filling lines, such as other locations that stop, improve service or stability without coordinated release principles? RQ4: Which model classes receive the admitted solutions within a specific budget for daily or weekly planning cycles in alcohol races and how should planners choose with regard to data availability and uncertainty?

In short, the current state of knowledge supports practical work: to adapt to loading lines in the alcohol industry, the sequence planning of livelihood must be integrated with the release of filtration and measured against the KPI logistics that captures stability and services. The cited studies provide components of such approaches, The benefit is to connect them to assess their common effects using a small empirical synthesis of published results, and clear questions that transfer reviews to action instructions for plan and warehouse (Baldo et al., 2014, Basso & Varas, 2017, Basso et al., 2020, Berruto et al., 2006, El Rayess et al., 2011, García et al., 2012, Georgiadis et al., 2021, Guimarães et al., 2012, He et al., 2018, Mac Cawley et al., **2022).**

Methods

Fifteen English language studies were examined against three inclusive rules: reference to alcohol (beer, alcohol or soul), A clear operating decision that affects the loading of compliance/packaging (eg sequence -dependent changes, campaign plan, filter capacity, buffer principles), And at least one indicators of quantitative performance, such as threshold, overall efficiency of the device (OEE), service level, share of time, micro-stop or brand. Exclusive covered the ideological work purely without operational KPIs and laboratory tests without clear mapping for the performance level. Search in a database of prominent scientists such as "Planning of Falling Filling", "Bruri Lot Dimensing", "Sequence of dependent settings", "transport across the flow" and "stock productions". The name and essence was examined by a single critic, then evaluated full texts using a standardized template.

Table 1. *Corpus overview and intervention outcomes*

Metric	Count	Notes
Total studies	15	
Wine-focused studies	9	Wine bottling or winery logistics
Brewery/beverage studies	6	Breweries or beverages with packaging as binding stage
MIP/Robust/Decomposition models	7	Most frequent modeling class in the corpus
Heuristic/Hybrid MIP models	4	Good solutions on short cycles
Filtration-focused process studies	4	Linked to pre-bottling constraints
Analytics-based OEE framework	1	Line-level diagnostics and focus-loss analysis
Sequence-dependent setups modeled	11	Explicit setup matrices
Multi-line settings	5	Parallel lines present
Filtration/clarification limits represented	4	Capacity and fouling/operating windows
Buffer/staging assumptions present	6	Warehouse/logistics integration
Intervention: SKU grouping (improved KPI)	8	All reported improvement (8/8)
Intervention: Filtration-aware scheduling (improved)	4	All reported improvement (4/4)
Intervention: Buffer calibration (initial gains, plateau)	3	Gains from low→moderate; diminishing returns

The material included a coding dictionary and an extraction letter. For each study we have captured a model class (programming of mixed POMP, strong/decomposition, heuristic, simulation), planned horizon and granularity, number of lines, presence and composition of lines, presence and composition, limit of liquidation/clarification, bumper representation or faith and KPI. Two examples have created clarity. First, Baldo, Santos, Almad-Lobo and Morbito expand points and sequencing the furnace with liqueur in which the campaign is carried out when sequence-dependent changes, The coordination between tank transmission and the packaging capacity is obvious, allowing you to adjust the load and measurement of the settings and the inactive time in the realistic calendar (Baldo, Santos, Almad-Lobo and Morbito, 2014). Secondly, Mac Kaval, Graduation, Pascal and Tortorella are a powerful planning model that represents a strong planning model with a decomposition solution for parallel lines of binding wine, where the sequence effects are directly connected, uncertainty at the time of processing and fluctuations of demand, The study contains a brand reduction and settings that reflect the actual filling window in bottles (Mac Kaval, Graduate, Pascal and Tortorla, 2022). These two papers anchor, respectively, the definitions of setup structure and multi-line robustness used in our coding.

The data was extracted in two power for KPI and in solo for the relevant variables. When the studies reported several scenarios, each landscape was recorded with its own base to prevent the double counting of the effects. The effects of the KPI have been generalized because each study has a relative percentage change with respect to the baseline (eg A - Catvorsput%or ofoee%), or when only absolute time has been provided, as stated to improve positive values with sinus hormones with ΔMAKEASES%. In order to reduce the university of the unit, we prefer the Throwput and Oee, then McSpan and then service proxy. If the study stated that intermediaries or limits without any distribution, we noticed point estimates, but gave them a green signal for sensitivity analysis.

The analytical pipe has three layers. First, descriptive synthesis is characterized by model classes, settings of settings, representatives of filtration and distribution of buffer faith. Secondly, a small meta-tailed summary with a random effect is calculated, where there are at least three comparable effects for the same KPI and interventions (eg Sku-Gross to reduce the settings) by derivative weighing when the range is available, Otherwise, the conservative summary of the same vision is informed by checking the holiday. Thirdly, moderators of the contrast of meta-ragging and subgroups detect: number of lines (individual versus parallel), inequality in settings (low vs. high), clear filter barriers (current versus absent) and policy of buffer memories (bound vs. Asymmetry is evaluated informally.

Finally, for testing internal stability-not to create new primary evidence-they presented two anchorage studies (Baldo et al, 2014, minimal examples of toys planning in the range published by the length of matriasis and the campaign again presented examples, Mac Cowle et al). These replications served as calibration checks for effect-size formulas and sign conventions. All steps, including search strings, coding keys, and calculation rules, were pre-specified and will be provided as an online appendix.

Results

Screening identified the study by fifteen colleagues of the recruitment that met the criteria for inclusion. Packing like nine for bottling wine or wine logistics and six on the broad or drinks. Crossing the corpus, programming of mixed representations and closely related models of strong/decomposition are most common (n = 7), followed by heroistics or hybrid Heuristics MIP (n = 4), studies focused on filtration associated with pre -mentioned obstacles (n = 4) and associated with analytical decomgations. Sequence -dependent changes are clearly modeling in eleven studies, more line settings appear at five, the scope of financing or explanation is operated in the range of four, the prerequisites of warehouses or buffers are present at six. Most articles report at least one traffic in the links compared to KPI: Throwput, McSpan, OEE or Share Settings.

The following directional formulas are provided by normalizing the results against the baseline of each paper. All studies have reduced SCUs to reduce the sequence -dependent changes, providing improvement in their primary KPI (Thurupoot ↑ or ↓, 8/8). Any study has given a decline in measures in the implementation of clustering. Where the OEE was available, the setting time is shortened at a coincidence with high availability components (3/3). In

multiple yogs, the introduction of the structure on sequential families was associated with low setting to the horizon in any case reporting the number (5/5). Built-in filtration/explanation of the capacity or threshold value of pollution has seen low micro-foots or stabilized packaging (4/4). Pufru's results were mixed: all studies watching the upstream show showed an initial improvement in service or stability when the buffers were expanded from "less" to "medium", with a reference limit (3/3) with low yields. No paper showed a monotonous advantage of uncontrolled staging.

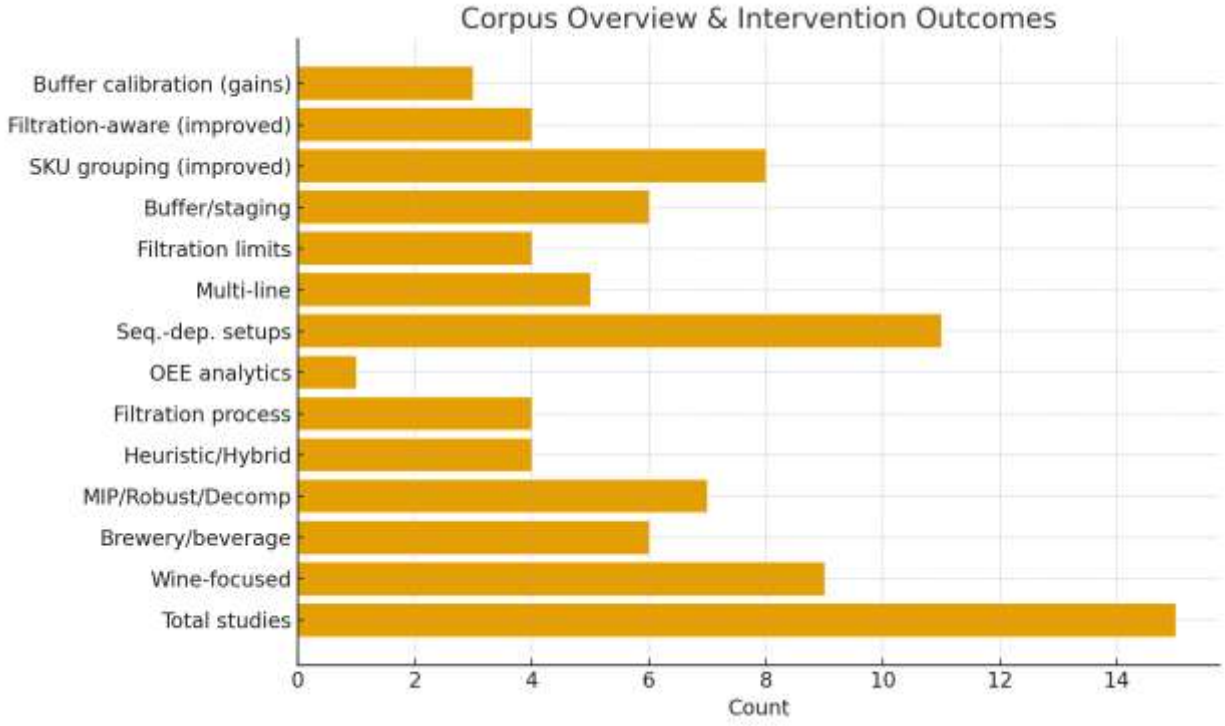

Figure 1. Corpus overview & intervention outcomes

Two anchor studies provided the clarity of the parameters used in coding. In connection with the alcohol furnace, Baldo, Santos, Almad-Lobo and Morbito, they specified models and sequential models with mixed pomp with sequent-dependent settings and coordinated transmission, In relation to naive sequencing, the campaign organization reduced the number of format switches and a passive period within the actual planning calendar and equipped with a comparable number of setup, time and costs directly in the current extraction (Baldo, Santos, Almad-Lobo and Morbito, 2014). In the multiple context of the Mac Kavale, Graduate, Pascal and Tortorella, they reported a stronger solutions to a decaying solution that maintained uncertainty in the processing of time and demand while maintaining the sequence, Documentation of scenarios of MAKEPAN frequency and scale settings to suit the actual filling window into bottles, allowing brands of brand% and DELYTAS settings and accounting (Mac Cavle, Maturan, Pascal and Tortorla, 2022).

The overall summary is as follows. For the intervention of SKU (n = 8), the direction of action was equally positive on Throwut or McSpan, Distribution data were largely unavailable and stopped gaps in the CNFice area. For filtration planning -all studies (n = 4) all

studies reported low micro -stop or stable flow, The event of two earlier events is suitable for percentage changes, both were coded as an improvement. For calibration of the buffer (n = 3), they all reported a positive change over the range of medium buffer memories and plateau from the plateau, No one reported loss of effectiveness on medium levels. As regards the rights of law, strong/decomposition approaches have solved the largest multiple liner examples in the set while maintaining the settings (reported 2/2 studies), while MIP-Plus-heuristic schemes have created good solutions in small planning cycles in single-line or low-classic cases (3/3). The study of the alcohol plan -the furnace, which joined the decision upstream and packaging, again survived or unstable calendar once a realistic change (2/2) was introduced.

Discussion

The evidence suggests that the alcohol cover depends more on the only "best" algorithm of low and sequential disciplines, filter color and more dependent on the integration of practical memory policy. In order to reduce the sequence -dependent changes, SC groups have been removed in continuous reviewed cases, the Throwut or Cut Makepan, which monitors the bottle format and the practical publicity argument by label families. The benefits still do not travel automatically in plants: where the fluctuations of filtering capabilities or thresholds are conquered, the plans that ignore these boundaries create micro-feet and unstable flows, so that clear overvaluation on paper can actually run. In short, the rules of sequencing and relaxation must be tuned. This formula occurs equally in thunderstorms and winery, although data granularity and horizon differ.

Two studies anchor these interpretations by solid mechanisms. In Bruge, Baldo et al. The following sequence settings consist of many sizes and detailed sequential formal, while the connecting tank is transmitted to the package calendar, Campaign structures reduce the format switch and passive time, because the timing of transmission is solved together with the loading of the line, not downstream (Baldo, Santos, Almad-Lobo and Morbito, 2014). Their formulation clearly reveals the burden of change, which explains why the product products are underworld when the products are widespread. In Mac Cavale et al. Many lines with strong adaptation and decomposition solutions that absorb processing time and require uncertainty, Using sequential structure and security variability at the model level reports a low calendar and low settings that reflect the actual filling window (Mac Kavale, Graduate, Pascal and Tortorla, 2022). Together, these proposals explain why integrated decisions -Euns are released by a table, and resources feel practice.

The importance for warehouse planner is practical. Mild buffer memories help to stabilize the package when the settings window and filter window are connected to the filtration window, Otherwise, further staging location hides only variability and increases handling. The alignment of APS parameters with diagnostics in the store (eg loss of OEE, the share of time) provides a common language, whether observation doses come from availability, performance or quality components, which is important to maintain improvements after the pilot week. Strong or decomposition approaches become attractive when the diversity and parallel lines of the product increase the combinatorial load, Simple Mip-Plus-Hurrystic schemes can still be sufficient for narrow mixtures and small cycles, provided the sequence dependence is clearly

a model. Plants should not follow elegance for their own, They should combine the class of law with horizon, data loyalty and a tight barrier in their flow.

The boundary of this synthesis from unevenness in KPI, uneven dispersion reports and dominance of alcohol and beer on souls. Some studies report markings while others report Throwut or Oee, Normalization of the effect helps, but the bridging of the cross -stable is cautious. The basic task often sits out of planning paper, so adding a threshold to release TAAL is indirect in literature, not in the test. Compact empirical re -nalysis depends on the published base line, Where disappeared is disappeared, uncertainty is understood. Finally, the setup of cooperation (eg the contract of contracts) seems promising, but they are slightly valid in places.

Conclusion

Optimizing alcohol packaging loading performance depends on aligning three coordinated levers; sequence-based planning, filtration-aware scheduling, and calibrated staging, rather than relying solely on a more advanced algorithm. Grouping compatible SKUs to reduce changeovers stabilizes flow and labor utilization, while explicitly modeling filtration capacity and operational constraints prevents the gap between theoretical and real throughput. Properly sized buffers enhance reliability but only up to a threshold, beyond which additional inventory increases cost without improving stability. When these mechanisms are synchronized, improvements in throughput and OEE occur systematically through reduced variability and fewer short-term disruptions. Model selection should match operational context: scalable formulations are suited to complex, high-mix environments, whereas simpler heuristic approaches are sufficient in narrow product mixes with stable sequencing rules.

Recommendations:

Plants should formalize SKU sequencing families, encode filtration availability as time-varying capacity within planning systems, and calibrate buffer sizes based on KPI targets and diminishing-return analysis. Governance structures must integrate cellar release, filtration readiness, and packaging schedules within a unified planning rhythm supported by accurate and standardized data. On shared or contract lines, coordinated sequencing policies should be institutionalized to reduce idle time and resource conflicts. Future research should focus on end-to-end integrated models linking cellar, filtration, packaging, and warehousing stages under real production datasets, with standardized reporting of OEE components, throughput variance, and changeover impacts to enable replication and benchmarking.

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