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Article

Improving Mechanisms for Managing Production Chain Efficiency in Enterprises on The Basis of Demand Variability

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Abstract: The article examined the theoretical and methodological foundations for improving mechanisms that manage production chain efficiency in enterprises on the basis of demand variability. Drawing on industrial dynamics, bullwhip effect theory, demand-driven planning, postponement and manufacturing flexibility, the author interpreted demand fluctuation as a manageable phenomenon generated by the information and decision system linking chain partners. A bullwhip ratio, a coefficient of demand variation and a capacity-demand coordination index were proposed. Official statistics were used to assess the monthly and half-yearly unevenness of Portland cement output in Uzbekistan. As a result, a mechanism model was developed that combined point-of-demand data sharing, decoupling inventory buffers, flexible capacity and a sales and operations planning loop. Practical proposals for building materials enterprises were substantiated.

Keywords: Demand Variability, Bullwhip Effect, Production Chain, Demand-Driven Planning, Inventory Buffers, Flexibility, Building Materials

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1. Introduction

For most of the twentieth century the efficiency of a production chain was judged by criteria that implicitly assumed a stable external environment: unit cost, equipment utilisation and the turnover of working capital. Under this assumption, fluctuations in output were regarded as a reflection of fluctuations in the market, and the task of management was reduced to following demand as closely as capacity allowed. J. Forrester overturned this view by showing that an enterprise and its partners form a single system of interacting flows of information, materials, money, labour and equipment, and that delays and amplification within these flows can generate oscillations considerably larger than the external change that triggered them [1]. Industrial dynamics thus established the proposition on which the present article rests: a significant part of the variability observed by a manufacturer is produced inside the chain, by the way its links perceive, transmit and react to demand signals, and is therefore open to managerial influence.

Behavioural research gave this proposition an explanation at the level of individual decisions. In a controlled experiment with a multi-echelon distribution system, J. Sterman demonstrated that decision makers systematically underweight the supply line of orders already placed but not yet received, misperceive feedback and consequently overreact to changes in incoming orders, which produces persistent oscillation and amplification [2]. H. Lee, V. Padmanabhan and S. Whang later introduced the term “bullwhip effect” for the growth of order variance as one moves upstream and identified four structural causes:

demand signal processing, rationing and shortage gaming, order batching and price fluctuations [3]. Each of these causes arises from the rational behaviour of a separate link under incomplete information, so the variability faced by an upstream producer becomes an attribute of chain governance rather than an exogenous characteristic of the market.

The design of an efficient chain also depends on the nature of the product and its demand. M. Fisher distinguished functional products with predictable demand, for which a physically efficient chain minimising cost is appropriate, from innovative products with unpredictable demand, which require a market-responsive chain capable of absorbing forecast error through buffers and speed [4]. Building materials occupy an intermediate position in this typology. Their annual volume follows construction activity and is relatively predictable, yet their demand within the year is strongly seasonal and sensitive to the rhythm of investment projects. A cement or brick plant therefore has to combine the cost discipline of an efficient chain with the responsiveness of an agile one. In this article, a management mechanism is understood as a coordinated set of rules, information channels, inventory positions and planning routines through which the decisions of all links are tied to actual end demand rather than to the distorted orders of the immediate customer.

The practical significance of the problem for Uzbekistan is determined by the scale of the tasks set for the construction sector. The "Uzbekistan 2030" Strategy provides for a twofold increase in the production of building materials and for the expansion of energy-efficient materials output [5]. Rapid growth of this kind raises the value of every tonne of capacity and every day of inventory, which makes the control of internally generated variability a direct source of efficiency. The aim of the article is to develop theoretical and methodological proposals for improving mechanisms that manage production chain efficiency on the basis of demand variability. The tasks are to systematise the theories explaining the amplification of variability, to justify indicators for measuring it, to assess the unevenness of output in the building materials sector on official data and to construct a conceptual model of the management mechanism.

The quantitative theory of the bullwhip effect was consolidated by F. Chen, Z. Drezner, J. Ryan and D. Simchi-Levi, who derived a lower bound for the ratio of order variance to demand variance in a two-stage chain where the retailer forecasts demand with a moving average and follows an order-up-to policy [6]. Their result showed that amplification grows with the replenishment lead time and declines as the forecasting window lengthens, and that centralising end-demand information reduces, but does not eliminate, the effect. S. Disney and D. Towill extended the analysis to the replenishment rule itself and proved that a proportional order-up-to policy allows a manager to trade bullwhip against inventory variance: smoothing orders stabilises production at the cost of larger fluctuations in stock [7]. For a manufacturer, the latter insight is essential, because it turns the choice of ordering rule into an explicit decision about who in the chain absorbs variability, and in what form.

Empirical studies refined the scope of the theory. G. Cachon, T. Randall and G. Schmidt examined industry-level data for the United States and found that amplification is far less universal than laboratory evidence suggests: many manufacturing industries smooth production relative to demand, and seasonality plays a decisive role in whether amplification is observed at all [8]. X. Wang and S. Disney, reviewing the subsequent literature, concluded that the measurement of the effect depends on data aggregation, the time bucket and the treatment of seasonal components, and that research has shifted from demonstrating the phenomenon to designing policies and structures that contain it [9]. These findings indicate that a management mechanism should distinguish between predictable seasonal variation, which can be planned, and amplified random variation, which must be dampened through information and ordering discipline.

Structural instruments for absorbing variability form a second line of research. H. Lee and C. Tang modelled delayed product differentiation and showed that postponing the point at which a common intermediate becomes a specific product lowers inventory

and improves service, while the benefits depend on the cost of redesigning the process. W. Jordan and S. Graves demonstrated that limited process flexibility, configured as a chain in which each plant can make a few products and the products and plants are linked in a closed loop, captures most of the benefits of full flexibility at a fraction of its cost. For building materials producers, both results have direct analogues: common clinker or blended binders can be finished into different cement grades close to the order, and kilns, mills and packing lines can be assigned overlapping product ranges.

The third line concerns planning processes. N. Tuomikangas and R. Kaipia synthesised the literature on sales and operations planning and described it as a coordination framework that aligns demand, supply and financial plans through cross-functional meetings, shared data, performance metrics and organisational roles [10]. R. Miclo, M. Lauras, F. Fontanili, J. Lamothe and S. Melnyk assessed demand-driven material requirements planning in a simulation study and found that strategically positioned decoupling buffers, sized from actual consumption, provided a better balance of service level and inventory than conventional forecast-driven planning under variable demand. A. Syntetos and co-authors emphasised that supply chain forecasting yields value only when forecasts are integrated with inventory and ordering decisions and when information is shared across echelons [11].

The reviewed literature supports three generalisations. First, variability observed upstream is partly endogenous and can be reduced by improving information flows and ordering rules. Second, the residual variability must be absorbed by an explicitly chosen combination of inventory buffers, flexible capacity and postponement. Third, these instruments yield results only within a regular planning process that coordinates the links of the chain. What remains insufficiently developed is a mechanism that unites these three elements and is supported by simple indicators suited to enterprises in emerging industrial sectors, where firm-level order data are often limited. The methodology set out below addresses this gap.

2. Materials and Method

The methodological basis of the research is the systems approach, in which the production chain is treated as a set of links connected by material and information flows with delays and decision rules. Theoretical synthesis, comparative analysis and generalisation were used to integrate the theories of industrial dynamics, the bullwhip effect, postponement, flexibility and coordinated planning. The empirical part relied on official releases of the National Statistics Committee of the Republic of Uzbekistan: cumulative monthly data on Portland cement output by large enterprises for January to July 2021 half-yearly output for 2023 to 2025 annual industrial data for 2025 and data on construction works for January 2026 [12]. Monthly volumes were obtained by differencing cumulative totals, and second-half volumes as the difference between annual and first-half output. The degree to which a chain amplifies demand variability was measured by the bullwhip ratio:

$$\mathrm{BR} = \frac{\sigma_O^2}{\sigma_D^2} \quad (1)$$

where BR – the bullwhip ratio of a chain link; σ_O^2 – the variance of orders placed by the link on its supplier over the period of analysis; σ_D^2 – the variance of demand received by the link from its customers over the same period. A value above one indicates that the link transmits amplified variability upstream, a value equal to one corresponds to pass-through of demand, and a value below one means that the link smooths its orders and absorbs variability in its own inventory. Calculated for successive links, the ratio shows where in the chain amplification originates. The inherent variability of demand, against which amplification is judged, was measured by the coefficient of variation:

$$\mathrm{CV} = \frac{\sigma_D}{\mu_D} \quad (2)$$

where CV – the coefficient of variation of demand; σ_D – the standard deviation of demand per period; μ_D – the mean demand per period. Being dimensionless, the coefficient

allows products, plants and years to be compared and serves as a criterion for choosing between a level and a chase production strategy. The quality of coordination between capacity and demand was assessed with the capacity-demand coordination index:

$$K_{cd} = 1 - \frac{1}{T}\sum_{t=1}^{T}\frac{|Q_t - D_t|}{D_t} \quad (3)$$

where K_{cd} – the capacity-demand coordination index; Q_t – planned production output in period t; D_t – demand or actual shipments in period t; T – the number of periods. The index approaches one when the production plan follows demand closely and decreases as the average relative mismatch grows; the mismatch has to be covered by inventory, overtime or lost sales. Indicators (1) to (3) form a complementary system: the first diagnoses the transmission of variability, the second characterises its source and the third evaluates the response of the production plan.

3. Results and Discussion

The need for a variability-oriented mechanism in the building materials sector follows from the scale and pace of its development. In 2025, industrial enterprises of Uzbekistan produced output worth 1,101.1 trillion soums, 6.8% more than in the previous year; manufacturing accounted for 86.0% of this volume, and producers of other non-metallic mineral products made up 13.8% of the 59.8 thousand industrial enterprises operating at the beginning of 2026. Portland cement output rose from 15.4 million tonnes in 2024 to 20.2 million tonnes in 2025. On the demand side, construction works in January 2026 amounted to 13,021.0 billion soums, 9.2% more than a year earlier, with buildings and structures growing by 4.9%, civil engineering objects by 35.6% and specialised works by 4.3% [13]. Such divergent segment growth rates mean that the mix of products demanded from materials plants shifts continuously, which adds structural variability to the seasonal one. The seasonal profile of cement output is presented in Table 1.

Table 1. Monthly Portland cement output by large enterprises of Uzbekistan, January to July 2021

Month	Cumulative output, thousand t	Monthly output, thousand t	Index to the period mean, %
January	559.3	559.3	57.2
February	1,325.4	766.1	78.4
March	2,228.4	903.0	92.4
April	3,582.6	1,354.2	138.5
May	4,679.2	1,096.6	112.2
June	5,807.2	1,128.0	115.4
July	6,842.7	1,035.5	105.9

Table 1 reveals a pronounced intra-year unevenness of output. The mean monthly volume over the seven months was 977.5 thousand tonnes, while January output amounted to only 57.2% of this level and April output reached 138.5%, so that the ratio of the peak month to the weakest month was 2.42. Using formula (2), the coefficient of variation of monthly output equalled 26.7%, a value that places cement among products with moderate but clearly planned seasonal variability. For a hypothetical level strategy, in which a plant produces the period mean every month, the coordination index calculated by formula (3) was 0.760, meaning that the monthly production plan would deviate from actual shipments by 24.0% on average. This mismatch would have to be covered by building stocks in winter and drawing them down in spring, which requires storage capacity and working capital. The data therefore confirm that the choice between level, chase and mixed strategies is a matter of measurable economic consequence for the chain.

Variability also manifests itself between half-years and between years, which is directly relevant to forecasting. The National Statistics Committee reported that cement output in January to June 2025 reached 9,158.2 thousand tonnes, 18.2% more than in the same period of 2024, while first-half output in 2023 and 2024 had amounted to 5,731.9 and 7,745.3 thousand tonnes respectively [14]. Combining these figures with annual output makes it possible to reconstruct the distribution of production between the two halves of the year (Table 2).

Table 2. Distribution of Portland cement output between half-years, 2023 to 2025

Indicator	2023	2024	2025
First half-year output, thousand t	5,731.9	7,745.3	9,158.2
Growth of first half-year output, %	-	35.1	18.2
Annual output, million t	-	15.4	20.2
Second half-year output, thousand t	-	≈7,654.7	≈11,041.8
Growth of second half-year output, %	-	-	≈44.2
Share of first half-year in annual output, %	-	50.3	45.3

Table 2 shows that the growth rate of first-half output slowed from 35.1% in 2024 to 18.2% in 2025, whereas annual output grew by 31.2% and second-half output by approximately 44.2% [15]. The share of the first half-year in annual production fell from 50.3% to 45.3%, meaning that the second half of 2025 carried a noticeably larger part of the load. For chain management this pattern has two consequences. A forecast that extrapolated the first-half growth rate would have underestimated annual demand by a wide margin, and dealers who reacted to the late acceleration by enlarging their orders would have sent the amplified signal to the plant that the theory of demand signal processing predicts. Since second-half values are derived from rounded annual totals, they are treated as approximate, but the direction of the shift is unambiguous. These results justify a mechanism in which forecasts are revised on end-demand data rather than on incoming orders, as shown in Figure 1.

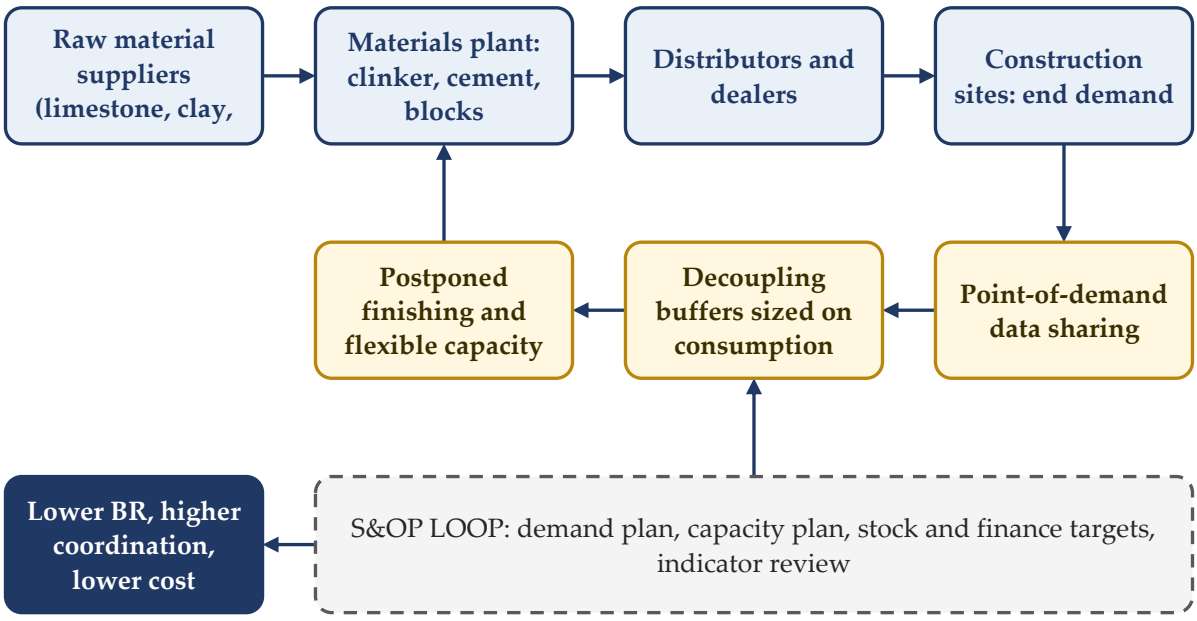


Figure 1. Demand-driven production chain management mechanism

Note: the upper row shows the forward flow of materials; the middle row shows the demand information and buffering loop; the lower row shows the sales and operations planning loop and its result. BR, CV and K_{cd} are calculated by formulas (1) to (3).[16]

The model in Figure 1 organises the mechanism around three interacting loops. The forward loop connects raw material suppliers, the materials plant, distributors and construction sites. The information and buffering loop transmits consumption data from construction sites directly to the plant, bypassing the distortion of intermediate orders, and uses these data to size decoupling buffers and to trigger postponed finishing and flexible capacity. The planning loop, implemented as a monthly sales and operations planning cycle, reconciles demand plans with capacity, stock and financial plans and assigns responsibility for absorbing seasonal and structural variability. The theoretical novelty of the model lies in the fact that the three indicators are embedded as feedback signals: the bullwhip ratio identifies the links that amplify orders, the coefficient of variation separates planned seasonality from random noise, and the coordination index evaluates whether the chosen production strategy matches the demand pattern. The outcome block reflects the expected results: a lower bullwhip ratio, a higher coordination index and a lower cost of serving variable demand.[17]

The results are consistent with the international evidence. The distinct seasonal profile in Table 1 corresponds to the conclusion of G. Cachon and co-authors that seasonality determines whether producers smooth or amplify demand [18], and the choice of a mixed strategy with planned winter stocks reflects the trade-off between order and inventory variance formalised by S. Disney and D. Towill [19]. The shift between half-years in Table 2 illustrates why F. Chen and co-authors attached such importance to the forecasting window and to centralised demand information [20]. For enterprises of Uzbekistan, the practical value of the mechanism is that it can be introduced step by step, starting with data exchange with large dealers and construction companies, and that its indicators can be calculated from the shipment and order records every plant already keeps.

4. Conclusion

The research has substantiated that the efficiency of a production chain under variable demand depends less on the magnitude of market fluctuations than on the way the chain perceives and transmits them. Industrial dynamics and bullwhip theory explain variability as a partly endogenous product of information delays and local decision rules, while the theories of postponement, process flexibility, demand-driven planning and sales and operations planning provide instruments for dampening and absorbing it. The proposed system of indicators, comprising the bullwhip ratio, the coefficient of variation of demand and the capacity-demand coordination index, links the diagnosis of variability with the evaluation of the production plan and can be applied with the data available to industrial enterprises.

The analysis of official statistics has shown that the building materials sector of Uzbekistan is developing at high rates, with cement output increasing by almost a third in 2025, and that this growth is accompanied by marked monthly and half-yearly unevenness. The coefficient of variation of monthly cement output of 26.7% and the coordination index of 0.760 for a level strategy demonstrate that deliberate management of seasonal variability offers tangible gains in inventory, capacity use and service level, supporting the objectives set by the “Uzbekistan 2030” Strategy.

The following proposals are put forward for improving production chain management mechanisms. First, building materials enterprises should include the bullwhip ratio, the coefficient of variation of demand and the capacity-demand coordination index in monthly management reports and set target ranges for them by product group. Second, plants should conclude data-sharing agreements with large distributors and construction companies to receive weekly consumption and site schedule data, which would allow forecasts to be revised on end demand rather than on incoming

orders. Third, decoupling inventory buffers of clinker and finished products should be positioned and resized each season on the basis of actual consumption, with planned winter stocks financed through seasonal working capital lines. Fourth, enterprises should apply postponement by holding common intermediates and finishing specific grades close to the order, and should configure mills and packing lines in overlapping product chains to gain flexibility at moderate cost. Fifth, a monthly sales and operations planning cycle involving sales, production, procurement and finance should be institutionalised as the central coordination body of the chain.

Implementation of these proposals would allow enterprises to meet growing construction demand with lower inventory and capacity costs and higher reliability of supply. Further research is planned to calculate the proposed indicators on firm-level order and shipment data of cement and brick producers and to estimate their relationship with enterprise financial performance.

REFERENCES

[1] G. P. Cachon, T. Randall, and G. M. Schmidt, "In search of the bullwhip effect," Manufacturing & Service Operations Management, vol. 9, no. 4, pp. 457–479, 2007, doi: 10.1287/msom.1060.0149.

[2] F. Chen, Z. Drezner, J. K. Ryan, and D. Simchi-Levi, "Quantifying the bullwhip effect in a simple supply chain: The impact of forecasting, lead times, and information," Management Science, vol. 46, no. 3, pp. 436–443, 2000, doi: 10.1287/mnsc.46.3.436.12069.

[3] S. M. Disney and D. R. Towill, "On the bullwhip and inventory variance produced by an ordering policy," Omega, vol. 31, no. 3, pp. 157–167, 2003, doi: 10.1016/S0305-0483(03)00028-X.

[4] M. L. Fisher, "What is the right supply chain for your product?" Harvard Business Review, vol. 75, no. 2, pp. 105–116, 1997. [Online]. Available: https://hbr.org/1997/03/what-is-the-right-supply-chain-for-your-product

[5] J. W. Forrester, "Industrial dynamics: A major breakthrough for decision makers," in The Roots of Logistics, P. Klaus and S. Müller, Eds. Berlin, Germany: Springer, 2012, pp. 141–172. Originally published in Harvard Business Review, vol. 36, no. 4, pp. 37–66, 1958, doi: 10.1007/978-3-642-27922-5_13.

[6] W. C. Jordan and S. C. Graves, "Principles on the benefits of manufacturing process flexibility," Management Science, vol. 41, no. 4, pp. 577–594, 1995, doi: 10.1287/mnsc.41.4.577.

[7] H. L. Lee, V. Padmanabhan, and S. Whang, "Information distortion in a supply chain: The bullwhip effect," Management Science, vol. 43, no. 4, pp. 546–558, 1997, doi: 10.1287/mnsc.43.4.546.

[8] H. L. Lee and C. S. Tang, "Modelling the costs and benefits of delayed product differentiation," Management Science, vol. 43, no. 1, pp. 40–53, 1997, doi: 10.1287/mnsc.43.1.40.

[9] R. Miclo, M. Lauras, F. Fontanili, J. Lamothe, and S. A. Melnyk, "Demand Driven MRP: Assessment of a new approach to materials management," International Journal of Production Research, vol. 57, no. 1, pp. 166–181, 2019, doi: 10.1080/00207543.2018.1464230.

[10] J. D. Sterman, "Modeling managerial behavior: Misperceptions of feedback in a dynamic decision making experiment," Management Science, vol. 35, no. 3, pp. 321–339, 1989, doi: 10.1287/mnsc.35.3.321.

[11] A. A. Syntetos, Z. Babai, J. E. Boylan, S. Kolassa, and K. Nikolopoulos, "Supply chain forecasting: Theory, practice, their gap and the future," European Journal of Operational Research, vol. 252, no. 1, pp. 1–26, 2016, doi: 10.1016/j.ejor.2015.11.010.

[12] N. Tuomikangas and R. Kaipia, "A coordination framework for sales and operations planning (S&OP): Synthesis from the literature," International Journal of Production Economics, vol. 154, pp. 243–262, 2014, doi: 10.1016/j.ijpe.2014.04.026.

[13] X. Wang and S. M. Disney, "The bullwhip effect: Progress, trends and directions," European Journal of Operational Research, vol. 250, no. 3, pp. 691–701, 2016, doi: 10.1016/j.ejor.2015.07.022.

[14] President of the Republic of Uzbekistan, "On the Strategy 'Uzbekistan–2030'," Decree No. PF-158, Sep. 11, 2023. [Online]. Available: https://lex.uz/docs/-6600413

[15] National Statistics Committee of the Republic of Uzbekistan, "Production of Portland cement in Uzbekistan (according to data from large enterprises)," Sep. 10, 2021. [Online]. Available: https://stat.uz/uz/matbuot-

markazi/qo-mita-yangiliklar/11494-o-zbekistonda-portlandsement-mahsuloti-ishlab-chiqarish-yirik-korxonalar-ma-lumotlari-bo-yicha

[16] National Statistics Committee of the Republic of Uzbekistan, "Cement production increased by 18.2%," Jul. 22, 2025. [Online]. Available: https://stat.uz/uz/matbuot-markazi/qo-mita-yangiliklar/62770-sement-ishlab-chiqarish-hajmi-18-2-ga-o-sgan

[17] National Statistics Committee of the Republic of Uzbekistan, "Industrial production in the Republic of Uzbekistan (January–December 2025)," Press Release, Jan. 21, 2026. [Online]. Available: https://stat.uz/img/news/press-reliz-sanoat-21_01_2025-j_-lotin_p43175.pdf

[18] National Statistics Committee of the Republic of Uzbekistan, "Construction work carried out in the Republic of Uzbekistan (January 2026)," Press Release, Feb. 28, 2026. [Online]. Available: https://stat.uz/img/press-relizlar/qurilish-uzb_p68123.pdf

[19] J. D. C. Little, "The state of the art in production planning and control," Management Science, vol. 38, no. 8, pp. 1101–1115, 1992.

[20] M. Christopher, Logistics & Supply Chain Management, 5th ed. Harlow, U.K.: Pearson Education, 2016.