OPTIMISING OPERATING COSTS IN INDUSTRIAL ENTERPRISES BY REDUCING THE DURATION OF PRODUCTION PROCESSES

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DOI:https://doi.org/10.5281/zenodo.24181181

Abstract

The thesis examined how the duration of the production cycle in an industrial enterprise drives operating costs. Cycle time was split into processing, queue, setup and move time. Little's law, the Kingman queueing approximation and overall equipment effectiveness (OEE) were combined into a model that prices work-in-process holding, changeovers, and overtime and idle time. The Central Bank key rate of 14% served as the capital-cost reference. In an illustrative (hypothetical) plant, cutting changeover time from 90 to 30 minutes and halving lot sizes reduced cycle time from 12.17 to 3.50 days, lowered annual cycle-time-related costs from UZS 810.2 million to UZS 310.2 million and released UZS 1.56 billion of working capital. Monthly monitoring of cycle time and pricing each day of it in investment decisions were proposed.

Keywords: cycle time, Little's law, OEE, SMED, value-stream mapping, work in process, operating costs.

Annotatsiya

Tezisda sanoat korxonasida ishlab chiqarish siklining davomiyligi operatsion xarajatlarga qanday ta'sir qilishi o'rganildi. Sikl vaqti ishlov berish, navbat, qayta sozlash va tashish vaqtlariga ajratildi. Litl qonuni, Kingman navbat formulasi va uskunadan umumiy foydalanish samaradorligi (OEE) asosida tugallanmagan ishlab chiqarishni saqlash, qayta sozlash hamda ish vaqtidan tashqari ishlash va bekor turib qolish xarajatlarini birlashtiruvchi model tuzildi. Kapital qiymati uchun Markaziy bankning 14 foizli asosiy stavkasi olindi. Bitta zavod bo'yicha faraziy (shartli) misolda qayta sozlash 90 daqiqadan 30 daqiqaga qisqarganda sikl vaqti 12,17 kundan 3,50 kunga tushdi, yillik xarajat 810,2 mln so'mdan 310,2 mln so'mga kamaydi va 1,56 mlrd so'm aylanma mablag' bo'shadi. Sikl vaqtini oylik nazorat qilish va har bir kunning narxini investitsiya qarorlarida hisobga olish taklif etildi.

Kalit so'zlar: sikl vaqti, Litl qonuni, OEE, SMED, qiymat oqimi xaritasi, tugallanmagan ishlab chiqarish, operatsion xarajatlar.

Аннотация

В тезисе было изучено, как длительность производственного цикла промышленного предприятия влияет на операционные затраты. Время цикла было разложено на время обработки, ожидания в очереди, переналадки и перемещения. На основе закона Литтла, формулы очереди Кингмана и общей эффективности оборудования (OEE) была построена модель, объединяющая затраты на содержание незавершённого производства, переналадки, сверхурочную работу и простои. В качестве цены капитала была принята ключевая ставка Центрального банка 14%. В условном примере одного завода сокращение переналадки с 90 до 30 минут уменьшило время цикла с 12,17 до 3,50 дня, годовые затраты снизились с 810,2 до 310,2 млн сумов, а из оборота было высвобождено 1,56 млрд сумов. Были предложены ежемесячный контроль времени цикла и учёт стоимости одного дня цикла в инвестиционных решениях.

Ключевые слова: время цикла, закон Литтла, OEE, SMED, картирование потока создания ценности, незавершённое производство, операционные затраты.

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INTRODUCTION

In most factories a part spends far more time waiting than being worked on. If an order needs twelve days to pass through a workshop but is cut, punched, bent and painted for only about three hours, the rest of its stay is paid for in tied-up capital, in extra handling and in overtime when late orders are rushed out. Stalk described time as the next source of competitive advantage [1]. For a cost manager the same time is a cost driver, although it rarely appears as a separate line in the accounts.

The question has practical weight for Uzbekistan's industry, which is expanding quickly. In 2025 industrial output grew by 6.8% in real terms, manufacturing produced 86.0% of it, and 59.8 thousand industrial enterprises were operating at the start of 2026 [2]. Many of them finance working capital with bank loans. On 4 November 2026 the Central Bank kept its key rate at 14%, with annual inflation at 6.4% in September [3], so even in real terms money frozen in work in process costs about 7.1% a year (author's calculation). A shorter production cycle releases this money and lowers related operating costs, and the growth of the sector makes the reserve larger each year.

The thesis builds a cycle-time cost model that links process duration to three groups of operating costs: holding work in process (WIP), changeovers, and overtime and idle time. RQ1: which components of cycle time can a plant shorten, and through which levers? RQ2: how much operating cost does one day of cycle time carry? RQ3: what saving follows from a realistic value-stream improvement? The contribution is a compact model that expresses Little's law, a queueing approximation and OEE in money and that a plant economist can fill with shop-floor data.

LITERATURE REVIEW

Cycle time, work in process and variability

Little proved that the average number of items in a stable system equals the arrival rate multiplied by the average time spent in it [4]. Hopp and Spearman turned this identity into the core of factory physics: for a given throughput, WIP and cycle time move together, and queue time rises steeply as utilisation approaches one and as variability grows [5]. Karmarkar showed that lot size shapes lead time in a convex way: very large lots make parts wait for the whole batch, while very small lots consume capacity in setups [6]. Cycle time is therefore an outcome of capacity, variability and batching decisions rather than a fixed technical parameter.

Changeovers and equipment effectiveness

Shingo's single-minute exchange of die (SMED) method separates internal setup work, done while the machine stands, from external work done while it runs, and then converts and streamlines internal steps [7]. McIntosh and co-authors noted that lasting changeover gains also depend on equipment design, not only on reorganising the crew [8]. Nakajima introduced OEE within total productive maintenance as the product of availability, performance and quality [9], and Muchiri and Pintelon reviewed how OEE is applied and warned that it should be read together with cost and flow measures [10].

Value-stream mapping and lean flow

Rother and Shook proposed value-stream mapping with a current-state map, a future-state map and a timeline that sets lead time against processing time [11]. Womack and Jones placed flow and pull at the centre of lean thinking [12]. Shah and Ward found that bundles of lean practices, including setup reduction and preventive maintenance, are associated with better operating performance [13], and Seth and Gupta reported cycle-time and inventory reductions after value-stream mapping at an Indian auto-component supplier [14]. Most of this work reports gains in days and units. Their translation into sums, with a local cost of capital, is less common, and this thesis focuses on that step.

METHODOLOGY

The model describes one product family flowing through a sequence of operations with a single bottleneck. Cycle time is first decomposed:

$$CT=t_p+t_q+t_s+t_m, \qquad PCE=\frac{t_p}{CT}\cdot 100 \qquad (1)$$

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where CT is the cycle time of a lot from material release to dispatch, days; t_p is processing time, when the product is actually transformed; t_q is queue time in front of all operations; t_s is setup time, including the wait of a lot while a machine is changed over; t_m is move time; PCE is process cycle efficiency, %. In plain words, PCE shows which share of its stay in the plant a product is really worked on.

$$WIP=TH\cdot CT \qquad (2)$$

where WIP is the average number of units in process and TH is throughput, units per day [4]. Simply put, with output held constant, inventory on the floor falls in the same proportion as cycle time.

$$OEE=A\cdot P\cdot Q, \qquad A=\frac{T_a-n_s s-T_d}{T_a} \qquad (3)$$

where OEE is overall equipment effectiveness of the bottleneck; A is availability; P is the performance rate (actual to ideal speed); Q is the quality rate (share of good units); T_a is available time, min per day; n_s is the number of changeovers per day; s is changeover duration; T_d is breakdown and minor-stop time, min per day [9]. In plain words, OEE tells what share of planned time the bottleneck makes good parts at full speed.

$$t_q^b=\frac{c_a^2+c_e^2}{2}\cdot\frac{u}{1-u}\cdot t_e, \qquad u=\frac{TH\cdot t_0}{T_a\cdot OEE} \qquad (4)$$

where t_q^b is queue time at the bottleneck; c_a^2 and c_e^2 are squared coefficients of variation of arrivals and of effective process times; u is utilisation; $t_e=b\cdot t_0/OEE$ is the effective process time of a lot of b units; t_0 is ideal time per unit [5]. Simply put, the queue grows with variability, with lot size and very sharply as the bottleneck nears full load. This equation links the levers: SMED allows smaller lots, higher OEE lowers u, and both shorten t_q.

$$C=(r+h)\cdot v\cdot TH\cdot CT+D\cdot n_s s\cdot k\cdot w+c_{ot}H_{ot}+c_{id}H_{id} \qquad (5)$$

where C is annual cycle-time-related operating cost, UZS; r is the cost of capital; h is the holding rate for storage, handling and obsolescence; v is the average value of a unit in process; D is working days per year; k is changeover crew size; w is wage cost per worker-hour, with s in hours; c_{ot} and c_{id} are costs per overtime and idle hour; H_{ot} and H_{id} are those hours per year. In plain words, the three terms price frozen money, changeover labour and hours paid because flow is uneven.

$$\Delta C=(r+h)\cdot v\cdot TH\cdot \Delta CT+D\cdot k\cdot w\cdot \Delta(n_s s)+c_{ot}\Delta H_{ot}+c_{id}\Delta H_{id} \qquad (6)$$

where Δ denotes the difference between the current and the future state. Simply put, each day removed from cycle time saves $(r+h)\cdot v\cdot TH$ a year, and the plant also receives a one-off release of working capital $v\cdot TH\cdot \Delta CT$, which is a cash effect rather than an annual saving.

Macroeconomic context comes from the National Statistics Committee [2] and the Central Bank [3]. The cost of capital is set at the key rate of 14%, a lower bound because industrial borrowers pay a margin above it. The plant is an illustrative (hypothetical) example; all values were computed in Python, and the assumptions are listed under Table 1.

ANALYSIS AND RESULTS

Current and future state of the illustrative plant

The plant makes steel panels in four steps: cutting, punching, bending, and painting with assembly. It ships 400 panels per day over 250 days, the punching press is the bottleneck, and a panel in process is worth UZS 450,000 on average. Table 1 applies equations (1)–(5) to the current state and to a future state after SMED, smaller lots, basic maintenance and FIFO lanes.

Table 1

Cycle-time cost model of the illustrative plant: current and future state[1]

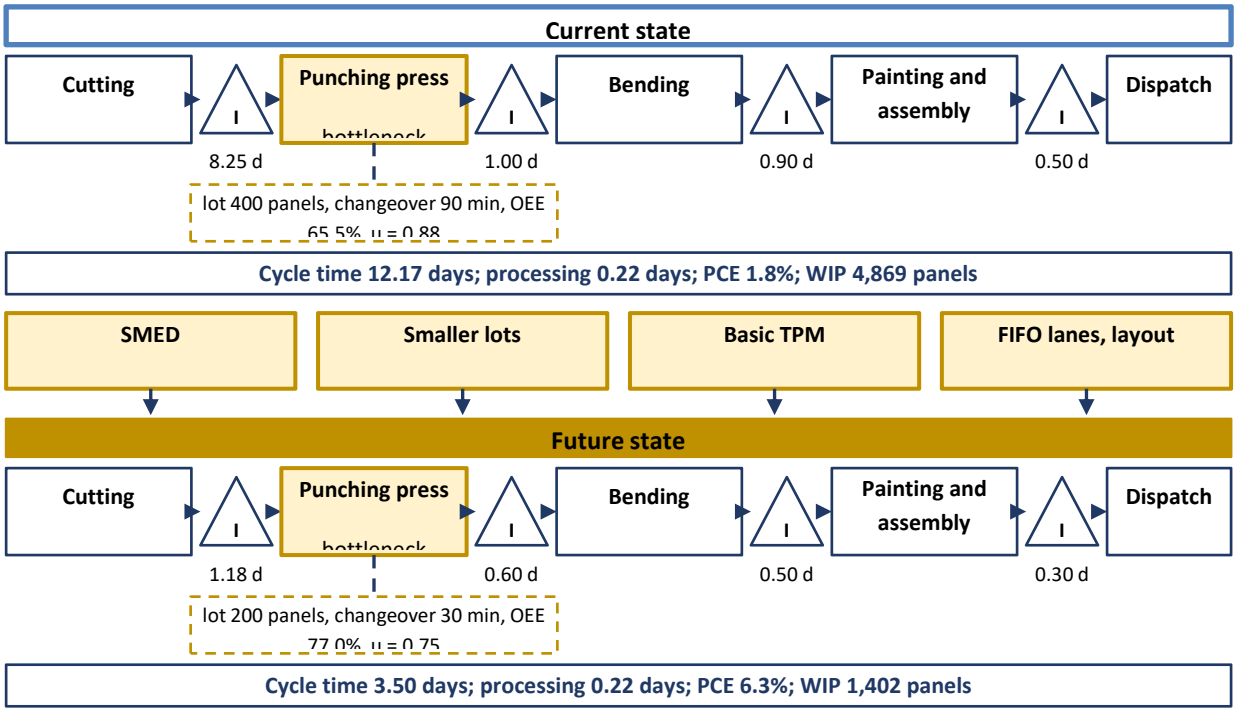
Indicator	Current state	Future state

[1] Source: Illustrative (hypothetical) example; costs per year; author's calculation in Python by equations (1)–(6). Assumptions: available press time 900 min per day, 250 working days, ideal press time 1.3 min per panel, average value of a panel in process UZS 450,000, cost of capital 14% (key rate [3]), holding rate 6%, changeover crew of 4 workers at UZS 40,000 per hour, overtime UZS 80,000 and idle time UZS 40,000 per hour.

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Indicator	Current state	Future state
Lot size, panels	400	200
Changeovers per day; duration, min	1.0; 90	2.0; 30
Breakdowns and minor stops, min per day	80	55
Availability / performance / quality, %	81.1 / 85.0 / 95.0	87.2 / 91.0 / 97.0
OEE, %	65.5	77.0
Bottleneck utilisation	0.88	0.75
Squared variation of arrivals; of process times	1.0; 1.5	0.9; 1.2
Queue at bottleneck; other queues, days	8.25; 2.40	1.18; 1.40
Setup / move / processing time, days	0.50 / 0.80 / 0.22	0.20 / 0.50 / 0.22
Cycle time, days	12.17	3.50
PCE, %	1.8	6.3
WIP, panels (UZS billion)	4,869 (2.19)	1,402 (0.63)
WIP holding cost, UZS million	438.2	126.2
Changeover cost, UZS million	60.0	40.0
Overtime and idle cost, UZS million (hours)	312.0 (2,400; 3,000)	144.0 (1,000; 1,600)
Cycle-time-related cost, UZS million (per panel)	810.2 (8,102)	310.2 (3,102)

In the current state the press runs lots of 400 panels with a 90-minute changeover and loses 80 minutes a day to stops, so its OEE is 65.5% and its utilisation reaches 0.88. At that load equation (4) gives a queue of 8.25 days in front of the press, two thirds of the whole cycle of 12.17 days. Processing takes 0.22 days, so PCE is only 1.8%. In the future state changeovers fall to 30 minutes, which allows lots of 200 with two changeovers a day and still raises availability to 87.2%. OEE climbs to 77.0%, utilisation drops to 0.75, and the press queue shrinks to 1.18 days. Cycle time falls by 71.2% to 3.50 days and WIP from 4,869 to 1,402 panels. In plain words, the plant ships the same output with less than a third of the material on the floor.



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Figure 1. Value stream of the illustrative plant: current and future state[2]

Figure 1 shows the same change as a value-stream map. Inventory triangles mark where panels wait, and the timeline under each state compares cycle time with processing time. The gold row lists the four improvements. The largest triangle, in front of the press, is the one that shrinks most, which confirms that improvement work should begin at the bottleneck.

Cost of one day of cycle time

With r+*h*=20%, v of UZS 450,000 and TH of 400 panels, each day of cycle time costs the plant UZS 36.0 million a year in holding cost alone. By equation (6) the 8.67 days removed save UZS 312.1 million in holding cost, UZS 20.0 million in changeover labour and UZS 168.0 million in overtime and idle hours, or UZS 500.1 million in total. Cycle-time-related cost falls by 61.7%, from UZS 8,102 to UZS 3,102 per panel. On top of this, UZS 1.56 billion of working capital is released once. If only the key rate is counted (r+*h*=14%) the holding saving is UZS 218.4 million, and with a 26% rate closer to commercial loan pricing it reaches UZS 405.7 million. Simply put, the conclusion holds across a realistic range of capital costs.

Two results deserve attention. First, the changeover term falls only by a third, because the plant now changes over twice as often. The main value of SMED lies in the queue time it removes by making small lots affordable, and this effect is invisible if SMED is judged by saved crew hours alone. Second, equation (4) explains why loading the bottleneck close to full capacity is costly: at u=0.88 every extra percentage point of load lengthens the queue far more than at u=0.75. A plant that buys capacity only to keep the bottleneck busy may therefore raise its operating costs.

CONCLUSION AND SUGGESTIONS

The thesis showed that the duration of production processes can be priced. Little's law turns cycle time into WIP, the queueing approximation explains where waiting comes from, OEE connects equipment losses to utilisation, and the cost model expresses all of this in sums that a plant economist can defend. In the illustrative plant, cycle time fell from 12.17 to 3.50 days, annual cycle-time-related cost fell by UZS 500.1 million and UZS 1.56 billion of working capital was released.

Four recommendations follow for Uzbekistan's industrial enterprises. First, measure cycle time and its four components monthly for the main product families and report PCE next to output and cost. Second, use the cost of one day, (r+*h*)·v·TH, when SMED, maintenance or layout projects are appraised, so that their benefits include released capital and shorter queues. Third, begin with the bottleneck: shorten changeovers, then reduce lot sizes, and keep utilisation below roughly 0.85 by lowering variability. Fourth, plan the released working capital as a funding source in the annual budget. Future research can calibrate the model with time studies in several Uzbek plants and extend it to multi-product lines with shared bottlenecks.

REFERENCES

1. Stalk, G. (1988). Time: The next source of competitive advantage. Harvard Business Review, 66(4), 41–51. https://hbr.org/1988/07/time-the-next-source-of-competitive-advantage
2. National Statistics Committee of the Republic of Uzbekistan. (2026). Industrial production in January–December 2025 [press release]. https://stat.uz/img/news/press-reliz-sanoat-19_01_2026-j_-eng_p28348.pdf
3. UzDaily. (2026, November 4). Uzbekistan Central Bank keeps key rate at 14%. https://www.uzdaily.uz/en/uzbekistan-central-bank-keeps-key-rate-at-14-04-11-2026/
4. Little, J. D. C. (1961). A proof for the queuing formula: L = λW. Operations Research, 9(3), 383–387. https://doi.org/10.1287/opre.9.3.383
5. Hopp, W. J., & Spearman, M. L. (2011). Factory physics (3rd ed.). Long Grove, IL: Waveland Press. https://books.google.com/books?vid=ISBN9781577667391

[2] Source: Author's development based on [11] and Table 1 (illustrative plant). Triangles mark inventory waiting in front of the next step; d = days; u = bottleneck utilisation.

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6. Karmarkar, U. S. (1987). Lot sizes, lead times and in-process inventories. Management Science, 33(3), 409–418. https://doi.org/10.1287/mnsc.33.3.409
7. Shingo, S. (1985). A revolution in manufacturing: The SMED system. Cambridge, MA: Productivity Press. https://books.google.com/books?vid=ISBN0915299038
8. McIntosh, R. I., Culley, S. J., Mileham, A. R., & Owen, G. W. (2000). A critical evaluation of Shingo's SMED (Single Minute Exchange of Die) methodology. International Journal of Production Research, 38(11), 2377–2395. https://doi.org/10.1080/00207540050031823
9. Nakajima, S. (1988). Introduction to TPM: Total productive maintenance. Cambridge, MA: Productivity Press. https://books.google.com/books?vid=ISBN0915299232
10. Muchiri, P., & Pintelon, L. (2008). Performance measurement using overall equipment effectiveness (OEE): Literature review and practical application discussion. International Journal of Production Research, 46(13), 3517–3535. https://doi.org/10.1080/00207540601142645
11. Rother, M., & Shook, J. (1999). Learning to see: Value stream mapping to add value and eliminate muda. Brookline, MA: Lean Enterprise Institute. https://books.google.com/books?vid=ISBN0966784308
12. Womack, J. P., & Jones, D. T. (1996). Lean thinking: Banish waste and create wealth in your corporation. New York: Simon & Schuster. https://books.google.com/books?vid=ISBN0684810352
13. Shah, R., & Ward, P. T. (2003). Lean manufacturing: Context, practice bundles, and performance. Journal of Operations Management, 21(2), 129–149. https://doi.org/10.1016/S0272-6963(02)00108-0
14. Seth, D., & Gupta, V. (2005). Application of value stream mapping for lean operations and cycle time reduction: An Indian case study. Production Planning & Control, 16(1), 44–59. https://doi.org/10.1080/09537280512331325281

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