International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue:01 | Jan-2022 SJIF Rating: 7.185 ISSN: 2582-3930

Optimizing Workplace Layout to Reduce Material Handling Time: A Review

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Abstract

Material handling can consume a substantial share of shop-floor labour even when processing methods remain unchanged. This study develops a reproducible comparison of existing and improved workplace layouts for a xyz small manufacturing unit. A deterministic route-and-time model represents seven work areas, six sequential transfers, and a reference output of 240 units in twelve batches. Handling time is decomposed into loaded travel, empty return, loading and unloading, and route waiting. All numerical inputs are synthetic assumptions, not observed industrial measurements. Reducing the cumulative loaded route from 114 to 50 m per batch lowers travel time from 237.50 to 104.17 s per batch. With unchanged transfer work and a separately assumed reduction in waiting, total handling labour falls from 597.50 to 392.17 s per batch, equivalent to 34.37%. Geometry alone accounts for 26.67 of the 41.07 labour minutes saved per reference shift. A sensitivity analysis identifies the conditions under which congestion or slower movement would erode this benefit. The study contributes an auditable accounting framework that separates physical layout effects from operating-policy assumptions. The findings establish conditional engineering potential rather than an empirically verified treatment effect.

Keywords: workplace layout; material handling time; systematic layout planning; empty return; small manufacturing; sensitivity analysis

1 Introduction

The movement of material between successive operations is an essential part of manufacturing, yet it does not directly transform the product. A component may undergo a short machining operation and then remain dependent on collection, transfer, unloading, and repositioning before the next operation can begin. Workplace layout influences this supporting work by determining the physical relationships between machines, storage locations, inspection points, and dispatch areas. Consequently, a manufacturing process can contain efficient individual workstations while its overall material-handling arrangement continues to consume avoidable labour time. The engineering problem is to identify that avoidable component without confusing transport time with processing time or production lead time.

For small manufacturing units, rearrangement offers a potentially accessible improvement route because it can use existing equipment and floor space. Its value, however, depends on the process being served. A shorter connection between two workstations is beneficial only when the connection carries sufficient flow and remains usable for the selected handling method. Machine access, service connections, turning space, and temporary storage can prevent the visually shortest route from becoming the most effective operating route. Layout evaluation therefore requires a description of actual or specified movement paths rather than a comparison of station positions alone. Pourvaziri et al. (2021) address this relationship by integrating aisle structure with facility placement.

The facility-layout literature provides a substantial foundation for arranging production resources. Mathematical approaches formalize relationships among locations, flows, and constraints, whereas planning approaches generate alternatives from process sequence and proximity requirements. Anjos and Vieira (2017) examine optimization formulations across several layout classes. The wider review by Pérez-Gosende et al. (2021) connects alternative generation with the manufacturing and handling system being designed. For a time-focused

investigation, these perspectives establish the spatial decision but leave an additional accounting question: which elements of handling labour change when a route is shortened?

A complete handling cycle contains more than loaded travel. The handler may return without material, prepare the next container, unload at the destination, and wait for access or a dispatch instruction. These activities respond differently to layout improvement. Route shortening affects travel directly, while container transfer can remain unchanged. Waiting may improve when access becomes clearer, but it may also persist because of release rules or workstation occupancy. An evaluation that applies the percentage distance reduction to the entire handling cycle would therefore exaggerate the time benefit whenever fixed transfer work remains substantial.

This distinction matters when a layout project is assessed against competing improvement options. Repositioning a workstation, changing a container, and altering a dispatch rule can all reduce handling time, but they do so through different mechanisms. Combining them in one before-and-after total makes it difficult to identify the source of the improvement. A component-based analysis allows the geometric effect to be compared with the additional effect of lower waiting. It also identifies the residual work that becomes dominant after travel has been reduced, thereby informing the next improvement priority.

The present study examines a seven-area manufacturing process in which storage, cutting, drilling, deburring, assembly, inspection, and finished staging are linked by six sequential transfers. The comparison retains process sequence, output, batch size, travel speeds, and transfer work while changing route lengths and, in a separate scenario, waiting time. The primary outcome is handling

labour per batch and per reference shift. Worker-distance and production output are treated as related measures with different boundaries; they are not used as substitutes for the time outcome.

The research objective is to determine how much handling time the improved arrangement releases and which components account for that release. Three questions organize the analysis: how the total changes at equal workload, what proportion is explained by geometry alone, and under which travel or waiting conditions the advantage disappears. The contribution is a reproducible decomposition supported by controlled alternatives and break-even analysis. It provides an engineering explanation of the result rather than relying on an isolated improvement percentage. The following sections establish the literature position, define the process and calculation model, present the component results, and discuss their operational implications.

2 Literature and Analytical Position

Facility layout research encompasses different spatial representations, objective functions, and operational constraints. Anjos and Vieira (2017) review optimization approaches across layout classes; their work cautions against treating an improved feasible arrangement as a proven global optimum. Hosseini-Nasab et al. (2018) organize the wider problem family around its characteristics and constraints. These studies support explicit definition of the layout problem before numerical comparison.

Pérez-Gosende et al. (2021) connect layout generation and assessment with manufacturing-system characteristics. Anjos and Vieira (2021) demonstrate the importance of a specified row structure in mathematical layout formulation. The present analysis uses an aisle-route representation instead of solving a continuous placement problem. Distances are therefore model inputs, not values inferred from an unreported optimization algorithm.

Performance evaluation also requires operational context. Jayachitra and Prasad (2010) compare alternative layouts using simulation and experimental design. De Carlo et al. (2013) evaluate a low-capacity production line with layout and lean alternatives. These contributions motivate examination of time and flow together, without borrowing their numerical results for the present case.

The contribution here is deliberately narrower than a new layout algorithm. It is an explicit decomposition of the handling-time difference into route shortening, unchanged transfer work, and a separate waiting-time assumption. This prevents the whole calculated gain from being attributed to geometry. The analysis also retains empty return movements, which otherwise make the apparent handling requirement too small.

The research questions are whether the route change reduces handling labour at fixed output, how much of the reduction is geometrically determined, and what operating conditions could reverse the advantage. These questions are answered by arithmetic and sensitivity tests.

Two further research strands sharpen the present evaluation. Kikolski and Ko (2018) discuss workstation arrangement and the use of simulation in layout assessment. Dombrowski and Ernst (2013) evaluate layout variants through scenarios. Together they motivate comparison across operating conditions rather than reliance on one nominal route-and-speed combination. Here, speed, waiting, and route detours are varied independently to identify which mechanism controls the handling-time result.

The inclusion of empty returns represents worker activity that a loaded-material route alone would omit. These strands support the study's focus on a complete handling cycle and on the separation of direct geometric savings from operating-policy effects.

3 Study Design and System Boundary

The case represents a hypothetical bracket-manufacturing process with raw-material storage (R), cutting (C), drilling (D), deburring (B), assembly (A), inspection (I), and finished-goods staging (F). The process order remains R–C–D–B–A–I–F. Twelve twenty-unit batches complete all six transfers during the reference shift. This common workload allows the layout comparison to isolate handling intensity rather than differences in production volume.

One handler undertakes each loaded movement and returns empty along an equal-length route. The return convention closes each transfer cycle and accounts for repositioning. It is an explicit operating assumption; a continuous milk run would require a different return model. Loading and unloading together require 40 s per transfer. Processing time, breaks, and unrelated supply walks are outside the handling-time boundary.

Table 1. Synthetic operating assumptions for both layout scenarios

Variable	Existing	Improved
Units per reference shift	240	240
Batch size and number	20 units; 12 batches	20 units; 12 batches
Transfers per batch	6	6
Loaded travel speed	0.80 m/s	0.80 m/s
Empty return speed	1.20 m/s	1.20 m/s
Load plus unload per transfer	40 s	40 s
Waiting per transfer	20 s	8 s

Study design and data provenance. This deterministic numerical study uses a synthetic dataset representing a small manufacturing process. Route lengths, transfer times, and waiting allowances are specified model inputs. The numerical results describe the modelled system rather than an observed factory intervention. Waiting is evaluated independently of geometry through controlled scenarios.

4 Layout Intervention and Time Model

The improved scenario places consecutive operations nearer along accessible material routes and locates receiving and finished staging near their respective process endpoints. It does not change the technological sequence or eliminate required operations. The distances describe feasible-path targets in a route network; without machine footprints, doors, and utility locations, they do not establish a buildable floor plan.

Table 2. Route lengths and calculated handling time per batch transfer

Route	Old m	New m	Old s	New s
R–C	18	8	97.50	64.67
C–D	24	10	110.00	68.83
D–B	16	8	93.33	64.67
B–A	22	10	105.83	68.83
A–I	20	8	101.67	64.67
I–F	14	6	89.17	60.50
Total	114	50	597.50	392.17

For route i and layout k, the complete handling cycle is $t_{ik} = d_{ik}/vL + d_{ik}/vE + h_i + w_{ik}$, where d is the one-way route length, vL and vE are loaded and empty speeds, h is combined transfer work, and w is waiting. Batch handling time is $T_k = \Sigma t_{ik}$. Shift handling labour in minutes is $H_k = N\ T_k/60$, with N = 12 batches.

The percentage reduction is $100(T_0 - T_1)/T_0$. Route lengths are in metres and speeds in metres per second, so every term in t is in seconds. The model adds one handler's sequential task time. It does not add simultaneous elapsed times across different workers or claim that this sum is production lead time.

5 Handling Time Results

Figure 1. Synthetic handling labour components for an equal workload of 240 units.

Table 3. Decomposition of handling labour at fixed output

Component	Existing min	Improved min	Saved min
Loaded travel	28.50	12.50	16.00
Empty return	19.00	8.33	10.67
Load and unload	48.00	48.00	0.00
Waiting	24.00	9.60	14.40
Total	119.50	78.43	41.07

Total handling labour declines by 34.37%, from 119.50 to 78.43 min per reference shift. The average handling requirement falls from 29.88 to 19.61 s per unit. The unit values allocate the complete batch-handling cycle over twenty components.

Loaded and empty travel together decline by 56.14%, matching the proportional route reduction because both speeds remain fixed. The smaller reduction in total handling time follows from the unchanged 48.00 min of loading and unloading. After improvement, transfer work becomes the largest component, accounting for approximately 61.20% of handling labour. Consequently, further route compression has diminishing influence on the total unless the transfer method also changes.

6 Attribution and Comparison Of Alternatives

The combined scenario contains two interventions: shorter routes and lower waiting. Their contributions can be separated because the model is additive. With the new routes but the original waiting allowance, handling time is 92.83 min per shift. This geometry-only scenario saves 26.67 min, or 22.32% of baseline handling labour.

Applying the lower waiting allowance saves another 14.40 min.

Thus, 64.94% of the combined saving is attributable to the route term within the model, while 35.06% depends on the waiting assumption. This decomposition does not establish causal attribution in a real factory. It identifies which input changes produce the numerical result, making the claim reproducible and easier to challenge.

Table 4. Controlled alternatives at 240 units

Scenario	Distance per batch m	Wait per transfer s	Handling min
Existing	114	20	119.50
Geometry only	50	20	92.83
Waiting only	114	8	105.10
Combined improvement	50	8	78.43

The comparison also shows why a single percentage can conceal different improvement mechanisms. A manager may achieve the geometric change yet retain the same dispatch delays. In that case, the appropriate estimated reduction is 22.32%, not 34.37%. Conversely, improved dispatch without relocation offers 12.05% under the assumed waiting change.

No global optimum is claimed. Only defined alternatives are compared, and relocation costs are not included in the time objective. A layout that saves fewer minutes may still be preferable when it avoids utility relocation, preserves expansion space, or reduces disruption. The present result therefore identifies an operational advantage that remains subject to feasibility and investment constraints.

7 Sensitivity and Break Even Conditions

Walking speed depends on load, surface, turning, and congestion. To examine this dependence, both layouts are recalculated with the same slower loaded speed of 0.60 m/s, holding empty speed at 1.20 m/s. Handling labour becomes 129.00 min for the existing scenario and 82.60 min for the combined improvement. The reduction is 35.97%. Route shortening retains value when transport is slower, but the assumption of equal speeds across layouts remains consequential.

Table 5. Deterministic sensitivity scenarios at 240 units

Assumption	Existing min	Improved min	Reduction
Base case	119.50	78.43	34.37%
Both loaded speeds 0.60 m/s	129.00	82.60	35.97%
No waiting improvement	119.50	92.83	22.32%
Improved wait 30 s per transfer	119.50	104.83	12.27%
Improved routes 20% longer	119.50	82.60	30.88%

A direct break-even condition is available. With the improved route sum of 50 m and unchanged speeds, travel and transfer work require 344.17 s per batch before waiting. Equating the total to the baseline 597.50 s gives a maximum average improved waiting allowance of 42.22 s per transfer. Above that value, the geometric benefit is outweighed by waiting.

A different threshold holds when waiting remains 8 s but loaded speed deteriorates only in the new layout. Solving 50/vL + 50/1.20 + 240 + 48 = 597.50 gives vL ≈ 0.187 m/s. This mathematical threshold is not a safe operating target. It illustrates that the model tolerates substantial speed deterioration before losing its time advantage, while providing no assessment of physical effort or collision risk.

The thresholds define operating limits for the selected design. Waiting and travel-speed changes are evaluated separately so that their contributions remain identifiable. This sensitivity structure makes the time advantage conditional on specific operating conditions rather than on a single nominal estimate.

8 Discussion and Operational Implications

The principal finding is that distance reduction translates into a smaller percentage reduction in total handling time when loading, unloading, and waiting remain substantial. In the constructed case, a 56.14% route reduction produces a 34.37% overall handling reduction only after waiting also improves. The gap between these percentages is not an inconsistency. It is the expected consequence of the time composition.

For this process, the cutting-to-drilling and deburring-to-assembly links contain relatively large route opportunities. However, the route with the largest length reduction is not automatically the best relocation priority. The model assigns equal frequency to every link. If replenishment, rework, or inspection sampling creates unequal flows, the relevant priority is frequency multiplied by time saved, subject to space and safety constraints.

The loading-and-unloading component is unchanged intentionally. Combining layout rearrangement with new containers, handling devices, or batch sizes would make the comparison less specific. Those changes may be valuable, but they should be represented as additional interventions. The decomposition helps retain a defensible boundary around what the layout itself is expected to accomplish.

The calculated 41.07 min saving is released handling labour. It is not necessarily a payroll saving, nor does it equal 41.07 min of added machine uptime. A handler may have idle gaps that cannot be combined into a productive task, while a bottleneck may continue to wait for reasons unrelated to

transport. These distinctions explain why the productivity question requires a separate capacity model.

The most relevant operational implication is therefore the need to preserve the accounting boundary when comparing alternatives. A complete cycle includes loaded travel, empty repositioning, and transfer work. Counting only the visible loaded movement overstates the percentage importance of layout geometry. Conversely, excluding a long empty return understates total labour consumption.

The numerical framework can support early engineering appraisal because its assumptions are inspectable. Its usefulness is strongest when a site has an established process route and a manageable number of transfer links. It is weaker when routing is stochastic, workers combine tasks, or queues depend strongly on release patterns. In those circumstances, a discrete-event representation would be needed to resolve interactions that this additive model deliberately leaves outside its scope.

9 Limitations and Conclusion

The study is limited by the synthetic origin of its data. Its arithmetic is reproducible, but its numerical magnitudes are not estimates for a named factory or a population of small enterprises. The route assumptions have not been checked against a physical building, and the lower waiting allowance is imposed rather than predicted. No claim is made about successful installation, worker acceptance, injury reduction, or sustained operational performance.

The constant-speed model also omits acceleration, turning penalties, trolley availability, and load-dependent fatigue. A route with several constrained corners can take longer than a straighter route of equal length. The assumed return to origin may be conservative for a coordinated delivery system and inaccurate for a worker who continues directly to another assignment. These features can alter both absolute labour requirements and the ranking of alternatives.

Within these boundaries, the study answers all three research questions. The improved route arrangement reduces handling labour at equal workload. Geometry alone saves 26.67 min per shift, while the combined scenario saves 41.07 min. The total benefit disappears if average waiting on the improved routes exceeds approximately 42.22 s per transfer under the other base assumptions.

The central conclusion is that layout evaluation should report a time decomposition rather than infer handling savings directly from distance savings. An accessible route model can make the calculation auditable and expose the contribution of operating assumptions. In this illustrative case, unchanged loading and unloading limit the achievable percentage reduction and become the dominant residual activity after improvement.

Data availability. The model inputs and calculation rules are reported in the methods and tables. All results can be reproduced from the disclosed dataset.

References

Anjos, M. F., & Vieira, M. V. C. (2017). Mathematical optimization approaches for facility layout problems: The state-of-the-art and future research directions. *European Journal of Operational Research, 261*(1), 1–16. https://doi.org/10.1016/j.ejor.2017.01.049

Anjos, M. F., & Vieira, M. V. C. (2021). Mathematical optimization approach for facility layout on several rows. *Optimization Letters, 15*, 9–23. https://doi.org/10.1007/s11590-020-01621-z

De Carlo, F., Arleo, M. A., Borgia, O., & Tucci, M. (2013). Layout design for a low capacity manufacturing line: A case study. *International Journal of Engineering Business Management, 5*, 1–10. https://doi.org/10.5772/56883

Dombrowski, U., & Ernst, S. (2013). Scenario-based simulation approach for layout planning. *Procedia CIRP, 12*, 354–359. https://doi.org/10.1016/j.procir.2013.09.061

Hosseini-Nasab, H., Fereidouni, S., Fatemi Ghomi, S. M. T., & Fakhrzad, M. B. (2018). Classification of facility layout problems: A review study. *The International Journal of Advanced Manufacturing Technology, 94*, 957–977. https://doi.org/10.1007/s00170-017-0895-8

Jayachitra, R., & Prasad, P. S. S. (2010). Design and selection of facility layout using simulation and design of experiments. *Indian Journal of Science and Technology, 3*(4), 437–446. https://doi.org/10.17485/ijst/2010/v3i4.20

Kikolski, M., & Ko, C.-H. (2018). Facility layout design—Review of current research directions. *Engineering Management in Production and Services, 10*(3), 70–79. https://doi.org/10.2478/emj-2018-0018

Pérez-Gosende, P., Mula, J., & Díaz-Madroñero, M. (2021). Facility layout planning. An extended literature review. *International Journal of Production Research, 59*(12), 3777–3816. https://doi.org/10.1080/00207543.2021.1897176

Pourvaziri, H., Pierreval, H., & Marian, H. (2021). Integrating facility layout design and aisle structure in manufacturing systems: Formulation and exact solution. *European Journal of Operational Research, 290*(2), 499–513. https://doi.org/10.1016/j.ejor.2020.08.012