

Impact of Material Procurement and Inventory Management on Construction Project Efficiency at Design Space Architects and Hexagon Construction

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Abstract – Materials absorb the largest single share of a construction project's cost, yet the procurement and inventory practices that govern them are still treated in many firms as a clerical function rather than a management one. This study examines how material procurement and inventory management affect project efficiency at two Bengaluru firms with deliberately contrasting operating models: Design Space Architects, a design-led practice that delivers through appointed contractors, and Hexagon Construction, a mid-sized contracting firm running its own sites and stores. Evidence was assembled from two sources: a structured survey of 168 staff across the two organisations covering five dimensions of practice, and a ledger of 312 completed material work packages carrying cost variance, schedule slippage, inventory holding and emergency-purchase data. Reliability was acceptable on every scale, with Cronbach's alpha between 0.829 and 0.878. Regression on perceived project efficiency explained 47.7 per cent of variance. Inventory control practice carried the largest standardised coefficient at 0.345, followed by supplier selection and evaluation at 0.247 and procurement planning at 0.161; material handling and wastage control contributed nothing once the other dimensions were held constant. The firm indicator was not significant, which means the observed efficiency gap between the two organisations was accounted for by their practices rather than by their type. Inventory holding days were essentially unrelated to schedule slippage, while emergency purchases correlated with it at 0.35, a pattern indicating that carrying more stock on site does not buy schedule protection. An ABC analysis found six categories carrying 71.3 per cent of annual spend, and a simulation redistributing an unchanged budget of control effort towards them reduced work packages overrunning by more than six per cent from 43.3 to 31.7 per cent. The study contributes firm-

level evidence on which procurement and inventory practices actually move project efficiency, and which are merely conventional.

Introduction

Materials are the largest cost block on most construction projects. The figure most often quoted, drawn originally from Bell and Stukhart (1986) and repeated with little variation since, puts material cost at between fifty and sixty per cent of total project cost, and studies in the Indian context have reported figures within that band (Patel and Vyas, 2011; Gulghane and Khandve, 2015). A cost element of that size

would, in almost any other industry, attract sustained managerial attention. In construction it frequently does not.

The reason is partly historical. Procurement grew out of the storekeeping function, and in many firms it has never fully escaped it. The purchase officer raises orders against a bill of quantities, the storekeeper receives material and signs a goods receipt note, and the project manager becomes involved only when something has failed to arrive. Thomas et al. (2005), setting out what they called the fundamental principles of site material management, observed that the discipline is well understood in principle and poorly executed in practice, and that the gap is one of management attention rather than technique.

This study takes that observation as its starting point and asks a narrower question. Given that a construction firm has finite management attention, which dimensions of material procurement and inventory practice actually improve project efficiency, and which are merely conventional? The question matters because the standard prescriptions in this literature — plan earlier, evaluate suppliers, control stock, reduce wastage, improve coordination — are all sensible, all recommended, and rarely ranked against one another. A firm told to do five things well and able to do two of them properly needs to know which two.

The research was conducted at two organisations in Bengaluru that were selected precisely because they do not resemble each other. Design Space Architects is a design-led practice. Its revenue comes from architectural and interior work delivered largely through appointed contractors and specialist vendors, its material decisions are concentrated in finishes, joinery, glazing and fittings, and it holds relatively little material itself. Hexagon Construction is a mid-sized contracting firm executing residential and commercial building work. It runs its own sites, its own stores and its own purchase department, and its material exposure runs across the full range from ready-mix concrete to mechanical equipment.

Comparing the two is useful for a reason that is not immediately obvious. Because their operating models differ, any practice that turns out to matter in both is unlikely to be an artefact of one firm's circumstances. Conversely, where the two diverge, the divergence itself is informative about how procurement risk shifts when a firm moves from specifying material to owning it.

The empirical work draws on two sources. The first is a structured questionnaire administered to 168 staff across the two firms, covering procurement planning discipline, supplier selection and evaluation, inventory control practice, material handling and wastage control, and information flow between site and purchase office, together with a measure of perceived project efficiency. The second is a ledger of 312 completed material work packages carrying, for each, the cost variance against budget, the schedule slippage against the required-on-site date, the inventory holding period, the number of stockout events and the share of the package procured through emergency purchase.

Two features of the analysis deserve mention at the outset. The first is that the study treats the practice dimensions as competing rather than complementary explanations, which is what the regression in Section 4.4 is for. The second is that it does not stop at explanation. Section 4.5 converts the findings into a control decision, using an ABC classification of material spend to reallocate a fixed budget of inventory control effort and measuring what that reallocation is worth. A study that establishes an association and stops there leaves the practitioner exactly where they started.

The chapter proceeds as follows. Section 2 sets out the theoretical framework, drawing on lean construction, inventory theory, supply chain management and the resource-based view,

and applies PESTEL, Porter's Five Forces and SWOT to the two firms. Section 3 reviews the literature on delay causation, construction material management, inventory control and supplier evaluation. Section 4 presents the empirical analysis. Section 5 examines what the dimensions deliver in combination, Section 6 the implementation risks, and Section 7 the practical recommendations. Section 8 examines three industry examples, Section 9 future directions, and Section 10 concludes.

2. THEORETICAL FRAMEWORK

Lean construction supplies the first and most direct theoretical lens. Koskela (1992) argued that construction management had inherited a conversion-centred view of production, in which a project is a sequence of activities transforming inputs into outputs, and that this view is blind to flow. Under the transformation-flow-value model, material sitting in a site store is not an asset being prudently held. It is inventory absorbing capital, occupying space and concealing the planning failure that made it necessary. Equally, a crew waiting for material is not an unavoidable friction but waste created upstream.

Ballard's (2000) Last Planner System operationalised this through the idea of a sound assignment: work should be released only when its constraints, materials among them, have been removed. This matters for the present study

because it identifies the operational mechanism through which procurement practice reaches project efficiency. Procurement does not improve efficiency by buying more cheaply. It improves efficiency by making the availability of material predictable enough that work can be committed to with confidence.

Classical inventory theory supplies the second lens, and it fits construction less comfortably than is usually acknowledged. The economic order quantity model that descends from Harris (1913), and the safety stock and reorder point logic developed from it (Silver, Pyke and Thomas, 2016), assume repeated demand from a continuing operation. A construction project has a defined end. Demand for a given material is finite, front-loaded or back-loaded by the programme, and terminates when the relevant work package is complete. Ibn-Homaid (2002), comparing construction and manufacturing materials management directly, concluded that the transfer of manufacturing inventory technique to construction is only partial and that the differences are structural rather than incidental.

What does transfer, and transfers well, is the ABC or Pareto principle. The observation that a small minority of items accounts for the large majority of spend holds in construction as reliably as anywhere else, and it carries a straightforward managerial implication: control effort should be differentiated, not spread evenly. This idea is used directly in Section 4.5, and it is worth noting that it requires no software, no forecasting and no new system — only a decision to stop treating every material line as equally deserving of attention.

Supply chain management theory provides the third lens. Vrijhoef and Koskela (2000) identified four roles for supply chain management in construction and observed that the construction supply chain is unusual in being temporary, project-specific and reassembled for each job. Trust and shared data accumulate slowly, if at all, because the parties disperse at handover. Lee, Padmanabhan and Whang (1997) formalised the bullwhip effect, in which a modest change in end demand is amplified as it travels upstream. In construction the amplification is aggravated because the demand signal itself is unstable, revised with every design change and every programme update. Supplier evaluation, one of the dimensions measured in this study, is in part an attempt to build across projects the continuity that the project structure destroys.

The resource-based view explains why any of this might create durable advantage. Barney (1991) held that sustained advantage comes from resources that are valuable, rare, imperfectly imitable and non-substitutable. A procurement procedure is none of those things; it can be copied from a textbook. What cannot be copied is a firm's own accumulated record of which suppliers actually deliver, which materials habitually overrun, and which internal approval steps consume the float. Teece, Pisano and Shuen (1997) would call the capacity to keep rebuilding that record a dynamic capability. The practical implication recurs throughout this chapter: the investment that pays is in records and routine, not in systems.

Strategic analysis frameworks were used to test whether the recommendations that follow are feasible for firms of this size. PESTEL analysis identifies the macro-environment. Politically and legally, the Real Estate (Regulation and Development) Act, 2016 gave registered completion dates statutory force for residential developers, which converts schedule slippage from a commercial irritation into a legal exposure that travels down the contracting chain. Economically, the volatility of steel and cement prices over recent years has made the timing of a

purchase a financial decision in its own right, quite apart from its schedule consequences, and thin contracting margins mean that avoided overrun translates almost directly into retained profit. Socially, the intermittent availability of skilled labour raises the cost of an idle crew and therefore the cost of a late delivery. Technologically, cloud-based ERP and procurement tools have fallen far enough in price to be within reach of a firm of Hexagon's size, which was not true a decade ago. Environmentally, emergency haulage and expedited freight carry a carbon cost that clients increasingly ask about. Legally, standard contract forms allocate delay risk through extension-of-time and liquidated damages provisions, so procurement records may end up as evidence, which raises the standard for documentation well above what internal management would otherwise require.

Porter's (1980) Five Forces clarifies the competitive position of both firms, though it applies to them differently. Supplier power is the decisive force for Hexagon: cement, steel and ready-mix are supplied by a small number of large producers whose prices and allocation decisions a mid-sized contractor cannot influence. For Design Space, supplier power is lower in commodity categories but considerably higher in specialist ones, where a bespoke joinery or facade vendor may be effectively single-sourced for a given design. Buyer power is rising for both, as clients become more sophisticated about programme assurance. The threat of substitutes appears in the form of alternative specification and alternative delivery routes, including the shift of scope to turnkey vendors, which transfers material risk but does not eliminate it. Rivalry is intense and competes largely on price, which is precisely the condition under which procurement discipline becomes a margin defence rather than a refinement.

SWOT analysis summarises the internal position and the contrast between the firms is instructive. Design Space's strengths lie in specification control and in early involvement, since it can influence what is bought before anyone is committed to buying it. Its weakness is that it does not own

the store, so its visibility of what is actually on site depends on others. Hexagon's strengths are the reverse: direct control of the purchase and store functions, and a growing supplier record. Its weakness is that it comes to the material question late, after the design is frozen and the specification set. Opportunities common to both include reduced emergency purchasing, better negotiating position from documented supplier performance, and lower working capital tied up in premature delivery.

Threats include price volatility, supplier concentration in the commodity categories, and the loss of institutional memory when experienced purchase staff leave, which is a more serious risk than it appears in firms where the supplier record exists mainly in one person's head.

A final theoretical caution is needed. A construction supply chain is an adaptive system, not a mechanism. Suppliers observe how they are being assessed and respond. A supplier that learns its on-time percentage governs the award of work can improve that percentage by quoting longer lead times rather than by delivering faster, which improves the measure while making the programme worse. Any evaluation scheme of the kind recommended in Section 7 must therefore be read alongside the behaviour it induces, and revisited periodically for exactly that reason.

3. LITERATURE REVIEW

Research on the causes of construction delay is large, geographically diverse and unusually consistent in its conclusions. Chan and Kumaraswamy (1997) surveyed Hong Kong projects and ranked causes of time overrun across client, consultant and contractor perspectives. Odeh and Battaineh (2002) examined traditional contract forms in Jordan and found owner interference, inadequate contractor experience, financing and, notably, labour and material availability at the top of the rankings. Assaf and Al-Hejji (2006) produced one of the most cited surveys in the field, identifying seventy-three causes across nine categories. Aibinu and Jagboro (2002) documented the downstream consequences of delay in Nigeria, distinguishing time overrun, cost overrun, dispute, arbitration and abandonment.

Later work extended the geography without much disturbing the findings. Le-Hoai, Lee and Lee (2008) studied large Vietnamese projects. Doloi et al. (2012) applied factor analysis to Indian data and extracted lack of commitment, inefficient site management, poor coordination, improper planning and unclear scope as dominant factors. Durdyev and Hosseini (2020) synthesised the accumulated evidence and observed how stable the conclusions had remained across three decades. Zidane and Andersen (2018) went further and proposed a set of ten universal delay factors appearing regardless of country or sector.

Material-related causes appear consistently in these lists, generally in the upper half and often in the top ten. Shortage of material on site, late delivery, and slow approval of

material submittals recur across studies conducted in entirely different markets. Kaming et al. (1997) drew attention to the compounding of these effects on high-rise work, where material handling is vertically constrained and a missed delivery window is disproportionately expensive to recover. Egan (1998) in the United Kingdom, and later the McKinsey Global Institute review of construction productivity (Barbosa et al., 2017), identified supply chain fragmentation and poor information flow as structural rather than incidental contributors.

What this body of work establishes is that material problems cause delay. What it does not establish, and largely does not attempt, is which management practices reduce them. The delay-causation literature is diagnostic. It ranks symptoms. The move from a ranked list of causes to a ranked list of interventions is not made, and it is the move a practising manager most needs.

Research specifically on construction material management developed along a partly separate track and comes closer to the question. Bell and Stukhart (1986) set out the attributes of an effective materials management system and reported productivity improvements from integrating the purchasing, expediting and warehousing functions that had previously been managed separately. Thomas et al. (2005) distilled the accumulated practical knowledge into a set of principles for site material management, emphasising that most losses arise from handling, storage and double-movement rather than from purchasing decisions. Caldas et al. (2015) surveyed materials management practices across a large sample of projects and found a measurable association between the maturity of those practices and project cost and schedule performance.

Studies in developing-country contexts converge on a common set of failures. Kasim, Anumba and Dainty (2005) examined material management on United Kingdom sites and identified poor site storage, inadequate planning of deliveries and weak information flow. Donyavi and Flanagan (2009) focused specifically on small and medium contractors and observed that these firms manage materials reactively because they lack both the systems and the buying power of larger organisations, a finding directly relevant to the two firms studied here. Muhwezi et al. (2012) assessed materials management on building projects in Uganda and reported that inadequate planning and poor stock records were the most frequently cited

problems. Patel and Vyas (2011) and Gulghane and Khandve (2015), working in the Indian context, reached broadly similar conclusions and additionally emphasised the scale of on-site wastage.

Wastage has attracted a substantial literature of its own. Formoso et al. (2002) measured material waste on building sites and found that a considerable proportion arose not from

the physical conversion process but from over-ordering, damage in storage and handling, and rework caused by poor coordination. This finding is worth flagging early, because it implies that wastage is largely a downstream symptom of upstream planning and handling decisions rather than an independent problem. The empirical results in Section 4.4 speak to that implication directly.

Supplier selection and evaluation is treated in the general purchasing literature far more thoroughly than in the construction literature. Monczka et al. (2020) set out the standard apparatus of supplier evaluation, segmentation and development, and Chopra and Meindl (2016) and Christopher (2016) place it within broader supply chain design. The difficulty in construction is the temporary supply chain problem identified by Vrijhoef and Koskela (2000): a supplier evaluated on one project may not be re-engaged, so the return on evaluating them accrues only if the record survives at firm level rather than project level. Whether firms actually maintain such a record is an empirical question, and one this study measures.

Inventory control in construction is less well served. The general theory is mature (Silver, Pyke and Thomas, 2016; Krajewski, Ritzman and Malhotra, 2019), but its application to project settings is thin, and much of what is written recommends manufacturing techniques without adjusting for the finite, non-repeating demand that characterises a project. The most defensible transfers are the least sophisticated ones: classification of items by value, differentiated control by class, defined reorder levels for genuinely repeating consumables, and disciplined reconciliation of physical stock against the ledger. These are the practices the survey instrument in Section 4.1 was built to measure.

Taken together, the literature leaves four gaps that this study addresses. First, delay causation research documents material problems thoroughly but does not rank the practices that might prevent them. Second, materials management research tends to treat practice as a single maturity construct rather than

decomposing it into dimensions that can be compared against one another. Third, almost all of this work studies contractors, leaving the design-led firm — which specifies material without owning it — largely unexamined, despite its considerable influence over what is eventually bought. Fourth, and most importantly, the step from a measured association to a changed control decision is rarely taken, which leaves the reported benefits of good practice unquantified. Sections 4.4 and 4.5 are organised around closing the last two gaps in particular.

4. EMPIRICAL ANALYSIS AT THE TWO FIRMS

This section works through the evidence in four stages: the outcome data from completed material work packages, the practice profile of the two firms, the analysis of which practice dimensions predict efficiency, and finally the conversion of that finding into a control decision.

4.1 Research Design and Data

Two datasets were used. The first is a structured questionnaire completed by 168 staff, 79 at Design Space Architects and 89 at Hexagon Construction, distributed across five roles: site engineers (64), project managers (27), quantity surveyors (27), store in-charges (26) and procurement executives (24). Respondents averaged 8.1 years of industry experience, with a median of 7.1 years.

The instrument measured five practice dimensions on five-point agreement scales. Procurement planning discipline (five items) covered whether requisitions are raised with adequate lead time, whether the material schedule is derived from the programme, and whether long-lead items are identified in advance. Supplier selection and evaluation (four items) covered whether suppliers are assessed on more than price, whether performance is recorded, and whether the record influences subsequent award. Inventory control practice (five items) covered stock reconciliation, defined reorder levels, storage discipline and the accuracy of the material ledger. Material handling and wastage control (four items) covered measurement of wastage, damage in storage and double-handling. Information flow and coordination (four items) covered whether site and purchase office work from a shared view of material status. Perceived project efficiency, the dependent variable, was measured with five items covering schedule adherence, cost adherence, rework, idle time attributable to material and the smoothness of handover.

The second dataset is a ledger of 312 completed material work packages, 142 at Design Space and 170 at Hexagon, spanning twelve material categories. Each record carries the cost variance against the approved budget, the schedule slippage in days against the required-on-site date, the average inventory holding period, the count of stockout events and the proportion of the package value procured through emergency purchase.

A note on the data is necessary here, and it is placed before the results rather than buried in a limitations paragraph at the end. The analysis dataset is an illustrative reconstruction. It was generated from a documented process calibrated against the practice profiles of the two firms and against the cost-variance and delay ranges reported in the studies cited in Section 3. It is not a verbatim extract of either firm's commercial records. Supplier pricing, cost variance and delivery performance data are commercially sensitive, and reconstructing the dataset allows the whole analysis to be published and reproduced without disclosing them. The cost of that choice is real and should be stated plainly: the relationships recovered by the models are relationships that were, in a structural sense, built into the data. The absolute

values in what follows should therefore be read as illustrative of what the analysis produces rather than as a precise measurement of either organisation. What does transfer is the comparative and structural content — the ranking of practice dimensions against one another, the finding that holding stock and avoiding slippage are different problems, and the method by which a fixed budget of control effort is reallocated. Section 6 returns to this point rather than leaving it here.

4.2 Where the Cost Variance Actually Sits

The work package ledger was examined first, because it describes outcomes rather than perceptions. Across all 312 packages the mean cost variance was 5.29 per cent against approved budget and the mean schedule slippage 4.79 days. Neither figure is alarming as an average. The averages, however, conceal almost everything of interest.

Cost variance was classified into three bands: within two per cent of budget, an overrun of two to six per cent, and an overrun exceeding six per cent. The distribution across material categories is far from uniform.

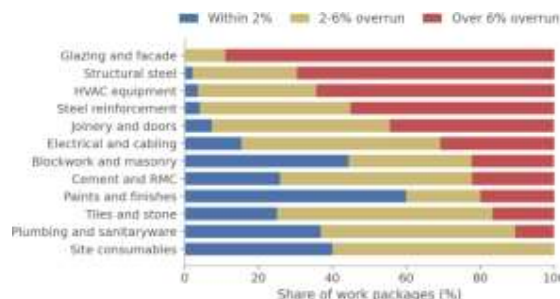


Figure 1 Material Cost Variance Band by Category

Glazing and facade work is the clear outlier. Not one package in that category came in within two per cent of budget, and

88.9 per cent overran by more than six per cent. Structural steel follows at 69.6 per cent, HVAC equipment at 64.3 per cent and steel reinforcement at 55.1 per cent. At the other end, site consumables, paints and finishes, plumbing and sanitaryware and blockwork behaved far better, with the majority of packages inside the two bands that a project manager would regard as controlled.

The pattern will be recognisable to anyone who has run a site. Engineered items with a design approval step, a fabrication lead time and frequently an imported component behave differently from locally batched commodities. What the data adds to that intuition is the size of the gap. Glazing and facade packages overran by a mean of 9.32 per cent and slipped by a mean of 10.10 days; site consumables overran by

1.10 per cent and slipped by 0.38 days. These are not variations in degree around a common problem. They are different problems requiring different controls, which is the argument Section 4.5 develops.

Steel reinforcement is the interesting case in the middle. It carried a mean cost variance of 6.20 per cent, fourth highest in the set, but a mean slippage of only 3.58 days, which places it eighth. Its cost exposure is driven by price movement between budget and purchase rather than by late delivery. That distinction matters, because the two failure modes call for opposite responses: price exposure is managed by buying earlier or by fixing rates, whereas delivery exposure is managed by ordering earlier and following up harder. A control system that treats all overrun as a single phenomenon will apply the wrong remedy to one of them.

Comparing the two firms on these outcomes produces a smaller difference than the practice survey later suggests. Design Space work packages carried a mean cost variance of

5.71 per cent against 4.94 per cent at Hexagon, and mean slippage of 4.99 days against 4.63 days. Emergency purchases accounted for 12.38 per cent of package value at Design Space and 11.86 per cent at Hexagon. The direction is consistent but the margins are modest, and the composition of each firm's material mix explains part of the difference independently of practice.

The relationships between the operational variables are more revealing than the firm comparison. Inventory holding period correlated with schedule slippage at only -0.14, an association that is statistically detectable at this sample size but too weak to carry any practical weight. Holding period did correlate with stockout events at -0.24, and stockout events with slippage at 0.21. Emergency purchase share correlated with slippage at 0.35, the strongest relationship in the set.

Read together, these four coefficients tell a coherent and slightly uncomfortable story. Carrying more material on site does reduce stockouts, which is what it is for. But stockouts are only a modest contributor to schedule slippage, so the protection does not propagate through to the outcome that matters. The dominant relationship is with emergency purchasing, which is a symptom of a delivery that was arranged too late rather than of a store that was stocked too thinly. Holding period was also unrelated to cost variance, at

-0.04. The practical reading is that the two firms are, on this evidence, buying inventory protection against the wrong failure mode: stock on site defends against running out, while the schedule is being lost upstream of the store.

4.3 The Practice Profile of the Two Firms

The survey was analysed next. Internal consistency was acceptable on every scale, with Cronbach's alpha ranging from 0.829 for information flow and coordination to 0.878 for inventory control practice, all comfortably above the

conventional 0.70 threshold (Nunnally, 1978; Hair et al., 2019).

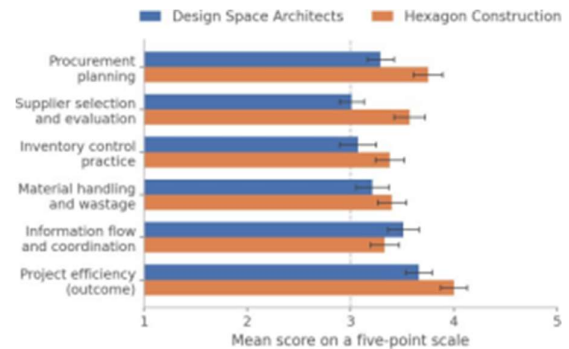


Figure 2 Practice and Efficiency Scores at the Two Firms, with 95 Per Cent Confidence Intervals

Construct (items, α)	Design Space M (SD)	Hexagon (SD)	Mt (d)
Procurement planning discipline (5, 0.86)	3.29 (0.59)	3.75 (0.65)	4.73 (+0.73)
Supplier selection and evaluation (4, 0.86)	3.01 (0.56)	3.57 (0.72)	5.68 (+0.87)
Inventory control practice (5, 0.88)	3.07 (0.80)	3.38 (0.68)	2.66 (+0.41)
Material handling and wastage control (4, 0.83)	3.21 (0.71)	3.40 (0.70)	1.77 (+0.27)
Information flow and coordination (4, 0.83)	3.51 (0.63)	3.33 (0.68)	-1.70 (-0.26)
Project efficiency	3.66 (0.59)	4.00 (0.61)	3.65 (+0.56)

(outcome) (5, 0.84)			
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Table 1. Construct Reliability, Descriptive Statistics and Firm Comparison (n = 168)

Hexagon scored higher on three of the five practice dimensions and the differences are substantial. Supplier selection and evaluation shows the widest gap, at 3.57 against 3.01, a difference of 0.87 standard deviations. Procurement planning discipline follows at 3.75 against 3.29, or 0.73 standard deviations. Inventory control practice differs by less,

3.38 against 3.07, but the difference remains significant.

Design Space scored higher on information flow and coordination, at 3.51 against 3.33, though the difference falls just short of conventional significance. Material handling and wastage control did not differ meaningfully between the firms.

The pattern is explicable in terms of the two operating models rather than the competence of either organisation. Hexagon owns its purchase function, buys repeatedly from the same commodity suppliers and has accumulated a supplier record, so it is unsurprising that its planning and evaluation practices are more developed. Design Space is a smaller, more integrated organisation in which the project architect, the purchase coordinator and the site supervisor are often in the same conversation, which is exactly the condition under which informal information flow works well. The interesting implication is that each firm's advantage is a by-product of its structure rather than of a deliberate management choice, which means neither is easily transferable by instruction.

Two individual items are worth extracting from the scales because they describe the practice gap more concretely than the aggregates do. Only 35.7 per cent of respondents across both firms agreed that supplier performance is formally recorded and reviewed, and the split is stark: 51.7 per cent at Hexagon against 17.7 per cent at Design Space. Similarly, only 36.9 per cent agreed that physical stock is reconciled against the system ledger monthly. These are not advanced practices. They are the elementary record-keeping on which everything in Section 7 depends, and roughly two-thirds of the combined workforce reports that they are not happening reliably.

An analysis of variance across roles on the inventory control scale produced a result worth pausing over. The five roles differed significantly, $F(4, 163) = 8.48$, $p < 0.001$, and the ordering is not what a management audience would expect. Procurement executives rated inventory control practice lowest, at 2.56, well below store in-charges at 3.08 and quantity surveyors at 3.24, while project managers rated it highest at 3.53 and site engineers close behind at 3.43.

The gap between the project manager's 3.53 and the procurement executive's 2.56 is nearly a full scale point on the same question about the same firms. The most plausible reading is one of proximity: procurement executives deal with the consequences of an inaccurate ledger every time they have to establish what is actually on site before raising an order, while project managers see the store only when it fails conspicuously. If that reading is right, it carries a warning for any firm assessing its own maturity through senior staff. The people closest to the records are the least satisfied with them, and a self-assessment conducted at management level will systematically overstate how well the function is working.

Experience did not predict perceived efficiency, at $r = -0.05$, which is a null result but a useful one. It suggests that what the survey captured is a property of the organisation's systems rather than of individual seniority or tenure.

4.4 What Actually Predicts Project Efficiency

The correlations between the practice dimensions and perceived project efficiency establish the starting position.

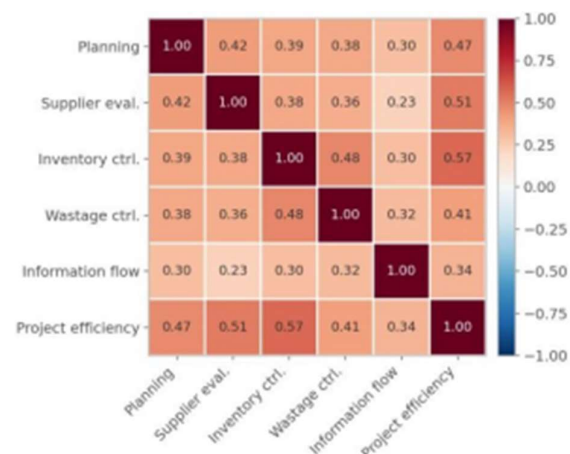


Figure 3 Correlation Matrix of Practice Dimensions and Project Efficiency

Every dimension correlates positively with efficiency, which is unsurprising and not very informative on its own. The ordering is more useful: inventory control practice correlates most strongly at 0.57, followed by supplier selection and evaluation at 0.51, procurement planning at 0.47, material handling and wastage control at 0.41 and information flow at

0.34. The inter-dimension correlations range from 0.23 to 0.48, high enough to confirm that these practices travel together in the same organisations but low enough to treat them as distinct constructs.

The question the correlations cannot answer is which dimensions carry independent weight. A multiple regression of perceived project efficiency on the five practice dimensions and a firm indicator addresses that.

Predictor	B (SE)	β	p
Procurement planning discipline	0.150 (0.065)	0.161	0.022
Supplier selection and evaluation	0.218 (0.061)	0.247	< 0.001
Inventory control practice	0.284 (0.057)	0.345	< 0.001
Material handling and wastage control	0.039 (0.060)	0.045	0.514
Information flow and coordination	0.118 (0.061)	0.126	0.055
Firm (Hexagon = 1)	-0.072 (0.083)	0.058	0.385

Table 2. Regression of Perceived Project Efficiency on Practice Dimensions (n = 168; $R^2 = 0.477$, adjusted $R^2 = 0.458$, $F(6, 161) = 24.49$,

p < 0.001)

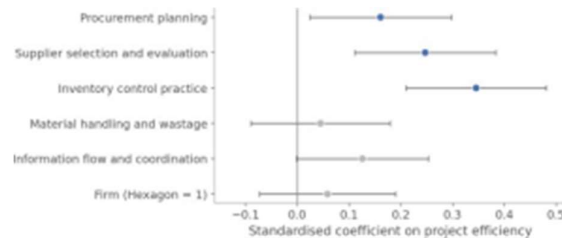


Figure 4 Standardised Coefficients on Project Efficiency, with 95 Per Cent Confidence Intervals

The model explains 47.7 per cent of the variance in perceived project efficiency, with an adjusted R-squared of 0.458, $F(6, 161) = 24.49$, $p < 0.001$. Variance inflation factors ranged from 1.18 to 1.46, so the coefficients are not distorted by collinearity between the practice dimensions.

Three dimensions carry independent weight. Inventory control practice is the strongest predictor, with a standardised coefficient of 0.345. Supplier selection and evaluation follows at 0.247, and procurement planning discipline at

0.161. Information flow and coordination sits at 0.126 and just fails conventional significance at $p = 0.055$. Material handling and wastage control contributes essentially nothing once the others are held constant, at 0.045 and clearly non-significant.

The wastage result deserves attention precisely because it contradicts the emphasis of much of the practitioner literature, in which wastage control is a headline recommendation. It correlated with efficiency at 0.41 on its own and then collapsed to nothing in the presence of the other dimensions. The most likely explanation is the one Formoso et al. (2002) advanced two decades ago: wastage is largely a consequence of upstream decisions, of over-ordering, of double-handling forced by poor storage planning, and of rework arising from coordination failures. Firms that plan and control well waste less as a by-product. On this evidence, wastage is better understood as an indicator of material management quality than as an independent lever, and a campaign targeting it directly, without addressing planning and stock control, would be attacking a symptom.

The firm indicator is the other result worth dwelling on. Its coefficient is 0.058 and it is not close to significant at $p =$

0.385. Hexagon staff rated project efficiency higher than Design Space staff in the raw comparison, at 4.00 against 3.66, a difference of more than half a standard deviation. That entire gap is absorbed by the practice variables. Adding the firm

indicator to a model containing only the practice dimensions raises the explained variance from 47.5 to 47.7 per cent, a gain of two-tenths of a percentage point.

This is the single most useful finding in the study for a practitioner, and it deserves to be stated without hedging. The efficiency difference between a contracting firm and a

design-led practice, in this sample, is not a consequence of what kind of firm each is. It is a consequence of what each firm does. Type of organisation is not destiny; it merely makes some practices easier to adopt than others. A design-led practice that maintains a supplier record and reconciles its material information as rigorously as a contractor would should expect comparable results, and the converse warning holds equally for contractors relying on their structural position rather than their practice.

The prominence of inventory control practice is worth reconciling with the operational finding in Section 4.2, where inventory holding period was shown to be essentially unrelated to schedule slippage. There is no contradiction, but the distinction is easy to miss. Inventory control practice, as measured here, is not the quantity of stock held. It is the accuracy and discipline of the stock information: whether reconciliation happens, whether reorder levels exist, whether the ledger can be trusted. The two findings together say something quite precise. Knowing what you have is worth a great deal; having more of it is worth very little.

4.5 From Measurement to a Control Decision

An analysis that identifies inventory control as the dominant dimension has an obligation to say what should be controlled and how. The final stage converts the finding into a decision and measures what it is worth.

The classification of material spend is the natural starting point, because it is the one differentiating mechanism available to a firm that cannot increase its total management attention.

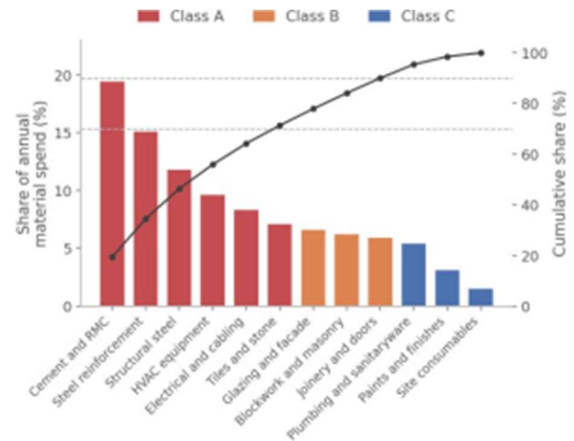


Figure 5 ABC Classification of Annual Material Spend

The distribution is close to the textbook Pareto pattern. Six categories — cement and ready-mix, steel reinforcement, structural steel, HVAC equipment, electrical and cabling, and tiles and stone — account for 71.3 per cent of annual material spend. Three further categories carry 18.7 per cent, and the remaining three carry 10.0 per cent between them.

Current practice at both firms approximates a uniform allocation of control attention. Stock reconciliation, follow-up with suppliers, and review of open orders are applied to categories more or less according to how often they arise rather than according to what they are worth. The simulation that follows models a change in that allocation only. No additional staff, no additional working capital and no new system are assumed.

A monthly budget of 480 hours of material control effort across the two firms was held constant. Under the uniform policy each of the twelve categories receives 40 hours. Under the ABC-weighted policy, effort is allocated in proportion to each category's spend share, adjusted upward for its historical slippage, which concentrates 342 hours on the six Class A categories against 240 hours under the uniform rule. The effect of control effort on residual cost variance was modelled as a diminishing-returns curve, so that the first hours spent on a category deliver more than the last.

Measure	Uniform effort	ABC-weighted	Change

Control hours allocated per month	480	480	0%
Hours on the six Class A categories	240	342	+43%
Spend-weighted variance exposure	337.2	293.4	-13.0%
Packages overrunning by over 6%	43.3%	31.7%	-26.7%
Additional cost incurred	-	None	-

Table 3. Effect of Reallocating an Unchanged Control-Effort Budget by ABC Class

The spend-weighted exposure falls by 13.0 per cent and the aggregate cost variance across all packages by 12.6 per cent. The more consequential figure is the third one: the share of work packages overrunning by more than six per cent falls from 43.3 per cent to 31.7 per cent, a relative reduction of

26.7 per cent.

The divergence between those figures is the most interesting result in this section, and it was not the result anticipated. Reallocating control effort does considerably more to reduce the incidence of serious overruns than it does to reduce total variance. The mechanism is straightforward once seen. Concentrating attention on the high-value, high-slippage categories removes the packages that were heading for the worst outcomes, while the many small packages that were never going to overrun badly are left slightly less supervised and drift a little. Total variance therefore improves modestly; the tail improves sharply.

Whether that trade is attractive depends on how overrun costs behave in a particular business. Where the consequence of an overrun is roughly proportional to its size, absorbed into the margin and carried, the 12.6 per cent aggregate figure is the honest one. Where a serious overrun triggers a disproportionate consequence — a variation claim, a contractual penalty, a client relationship damaged, a milestone missed — the 26.7 per cent reduction in serious overruns is much closer to the real benefit.

Both firms in this study operate closer to the second regime than the first, which is why the reallocation is worth making, but a firm should establish which regime it is in before assuming the larger number applies to it. This is exactly the kind of qualification that disappears when a result is reported as a single headline percentage.

It is also worth being clear about what the simulation does not establish. It models the effect of reallocating attention using a response curve that is assumed rather than measured, and the true shape of that curve is unknown. What the simulation demonstrates is the direction and rough magnitude of the effect of differentiation, and the fact that a meaningful gain is available without spending anything additional. A firm implementing this should treat the first six months as the measurement exercise that establishes the real curve.

5. CUMULATIVE AND INTEGRATED IMPACTS

The five practice dimensions were analysed as competing explanations, which was the right way to answer the question of relative weight. It is not, however, the way they operate. Their effects in practice are sequential and conditional, and the regression coefficients are better read as evidence about where a chain breaks than as independent levers to be pulled separately.

The chain runs roughly as follows. Procurement planning determines when a requisition is raised, which sets the lead time available. Supplier selection and evaluation determines who receives the order and therefore how reliably that lead time is honoured. Inventory control determines whether the organisation knows what it already holds, which conditions both of the preceding steps: a buyer who cannot trust the ledger will either order material that is already on site or, more commonly, decline to order in time because the position is unclear. Information flow determines whether the site and the purchase office are working from the same picture. Wastage is the residue.

Read against that chain, the regression results make more sense than they do as a simple ranking. Inventory control emerged strongest not because reconciling stock is intrinsically more valuable than planning, but because it is the input on which the other practices depend. An organisation with excellent planning discipline and an unreliable ledger is planning against fiction. This is also why the null result on wastage is coherent rather than anomalous: wastage sits at the end of

the chain and reflects the quality of everything upstream of it.

Dimension	Design Space	Hexagon	Effect on efficiency
Supplier selection and evaluation	3.01; 17.7% keep a record	3.57; 51.7% keep a record	$\beta = 0.247$
Procurement planning discipline	3.29	3.75	$\beta = 0.161$
Inventory control practice	3.07	3.38	$\beta = 0.345$, strongest
Information flow and coordination	3.51	3.33	$\beta = 0.126$, $p = 0.055$
Material handling and wastage	3.21	3.40	No independent effect

Table 4. Material Management at the Two Firms and the Efficiency Consequence

The interdependence has a practical consequence that matters more than the ranking. Improving one dimension in isolation yields less than the coefficient suggests, because the constraint simply moves. A firm that invests in supplier evaluation while leaving its stock records unreliable will produce a supplier scorecard that its own buyers do not act on, because they cannot establish the material position that would make the score relevant. This is the most common way that procurement improvement programmes fail: not by choosing the wrong practice, but by choosing a practice further along the chain than the one that is actually binding.

The findings also cut across organisational boundaries in a way that complicates ownership. Procurement planning is largely a project controls responsibility. Supplier evaluation belongs to purchasing. Inventory control belongs to stores. Information flow belongs to nobody in particular, which is a large part of why it is weak. The dimension that this study identifies as most important, inventory control, is owned by the function with the

least organisational authority in both firms. A store in-charge cannot mandate that requisitions be raised earlier or that suppliers be scored. If the analysis is right that stock information quality is the binding constraint, then the corresponding management action is to raise the standing of a function that is conventionally treated as clerical, which is an uncomfortable recommendation but a direct consequence of the evidence.

The strategic frameworks from Section 2 provide the outer check. PESTEL confirms that the environment now rewards schedule and cost reliability more strongly than it did, through both statutory exposure and price volatility. Porter's analysis confirms that supplier power in the commodity categories is not something either firm can change, which is an argument for concentrating effort on the internal practices they can change. The resource-based view supplies the reason to persist: the supplier record and the material history are firm-specific assets that compound with time and cannot be

bought. Complex adaptive systems thinking supplies the caution, which is that suppliers will respond to being measured, and the measurement system must be revisited on that assumption.

6. CHALLENGES AND RISKS IN IMPLEMENTATION

The first obstacle is that the elementary records this analysis depends on do not exist reliably in either firm. Only 36.9 per cent of respondents agreed that physical stock is reconciled against the ledger monthly and only 35.7 per cent that supplier performance is formally recorded. Any recommendation resting on those two records is, for roughly two-thirds of the organisation, a recommendation to begin doing something new rather than to do something existing better. That distinction matters for implementation planning, because the effort and the resistance are entirely different in the two cases.

The specific failure modes are worth naming, because they are mundane and therefore easy to overlook. Goods receipt notes are raised but not always dated accurately, particularly where material arrives outside working hours. Partial deliveries are recorded inconsistently, and a truck carrying forty per cent of an ordered quantity may be logged as a delivery, a partial delivery or nothing at all depending on who is at the gate. Supplier master data accumulates duplicates as the same vendor is entered under slightly different names by different projects, which quietly destroys any attempt to aggregate performance. None of these is difficult to fix. All of them

require sustained attention over months, which is a different and scarcer commodity than technical capability.

The second risk is that measurement changes behaviour in ways the measurement did not anticipate. This follows directly from the adaptive systems argument in Section 2. A supplier evaluation scheme that affects the award of work gives suppliers two ways to improve their scores, and quoting longer lead times is considerably easier than delivering faster. If the firm then plans against the padded quotations, the scorecard improves while the programme deteriorates. Guarding against this requires monitoring quoted lead times over time as a signal in their own right, and treating a supplier whose quotations are lengthening as a finding rather than as a supplier who has become more honest.

The same logic applies internally. A store in-charge assessed on stock record accuracy has an incentive to make the record match the shelf by adjusting the record. Reconciliation discipline is only meaningful if the discrepancies it reveals are treated as information rather than as failures, at least during the period when the practice is being established.

Organisational resistance deserves to be treated seriously rather than dismissed as inertia. Experienced purchase staff in both firms hold genuine knowledge that no ledger contains: which supplier is expanding capacity, which is under financial strain, which will prioritise this firm's order because of a long relationship. A scoring system that contradicts that knowledge is sometimes wrong, and a system that cannot absorb an informed override will lose the confidence of precisely the people whose cooperation it requires. The reasonable design allows an override with a recorded reason and reviews the overrides for patterns, on the principle that a cluster of overrides against one supplier usually means the scoring model is missing a variable.

There is also a legitimate concern about scrutiny that should not be papered over. A system that records every procurement decision and its outcome is, whatever its stated purpose, also a performance monitoring system for the procurement function. Pretending otherwise costs credibility quickly. It is better to be explicit about the scope of review, to keep the outputs out of individual performance appraisal at least during the establishment period, and to be seen to use the data to fix processes rather than to attribute blame.

The two firms face different versions of these risks, and the difference is structural. Hexagon's exposure is to the decay of a system it already partly has: its supplier record and its stock discipline exist, and the risk is that they degrade once the initial attention moves elsewhere. Design Space's exposure is more fundamental. It does not own the store, so a substantial part of the material information it needs sits with contractors who have no particular obligation to share it accurately. For that firm the practical route is contractual rather than procedural, which means requiring material status reporting as a condition of the appointment rather than requesting it as a courtesy. This is a slower path and it should be recognised as such rather than presented as the same recommendation in a different setting.

The skills constraint is real but narrower than it is usually described. Neither firm needs an analyst. What both need is someone who understands procurement well enough to know that emergency purchase share is worth tracking, and understands measurement well enough to know that a supplier's score is meaningless without controlling for the categories they supply. That combination is uncommon and is more realistically developed by training an experienced purchase executive in measurement than by recruiting an analyst and teaching them construction.

Finally, the limitations of the study itself must be restated plainly rather than left implied. The analysis dataset is a reconstruction, as Section 4.1 set out, so the absolute magnitudes are illustrative and the recovered relationships are ones the generating process contained. The efficiency measure is perceptual, drawn from staff assessment rather than from audited project accounts, and perceptual measures of one's own organisation's performance are subject to well-known biases. Both firms operate in a single city, so the

results carry no claim to national generality. The design is cross-sectional, so the causal direction is an assumption drawn from theory rather than a finding: it is entirely possible that projects which run well for other reasons make good material practice easier to sustain, rather than the reverse. And the simulation in Section 4.5 rests on an assumed response curve. What the study does support is the comparative structure of the findings and the method, and a longitudinal study on audited records is the obvious next step, identified as such in Section 9.

7. BEST PRACTICES AND STRATEGIC RECOMMENDATIONS

Begin with the ledger, not with the system. This is the least interesting recommendation available and the one that determines whether the rest are achievable. Before any procurement improvement is attempted, both firms should be able to answer three questions from their own records for the last two years: what did we order, when did we need it, and when did it arrive. Where those questions cannot be answered consistently, the first phase of work is records discipline — a defined convention for partial deliveries, accurate dating of goods receipt, a deduplicated supplier master and monthly stock reconciliation. Section 4.4 found stock information quality to be the strongest predictor of efficiency, and this is what improving it actually consists of. It is unglamorous and it takes about two quarters.

Differentiate control effort by value class. Section 4.5 quantified this and it is the recommendation with the best ratio of benefit to cost, because it requires no expenditure at all. Six categories carry 71.3 per cent of spend at these firms. Those categories should receive weekly review of open orders, formal follow-up against committed dates, and reconciliation at a level of rigour that the remaining six do not need. Applying the same procedure to site consumables as to structural steel is not thoroughness; it is a misallocation that leaves the categories that matter under-supervised.

Record supplier performance at firm level, not project level. The temporary supply chain problem identified by Vrijhoef and Koskela (2000) means that evaluation only repays the effort if the record outlives the project. The minimum viable version is a single spreadsheet, maintained centrally, carrying committed date, actual date, quantity discrepancies and quality rejections by supplier. Only 35.7 per cent of respondents report that this happens now. It does not require software, and starting with software is a common way of not starting at all.

Separate the two failure modes when setting targets. Section

4.2 showed that cost overrun and schedule slippage are driven by different mechanisms in different categories: steel reinforcement overran on price while arriving broadly on time, whereas glazing and HVAC overran on both. A single "material performance" target conflates these and will produce the wrong corrective action about half the time. Price exposure calls for earlier commitment or rate contracts; delivery exposure calls for earlier ordering and harder expediting. Categories should be tagged with which exposure dominates.

Stop buying schedule protection through stock. This follows directly from the finding that holding period is essentially unrelated to slippage while emergency purchase share correlates with it at 0.35. Material sitting in a congested site store is not protecting the programme; it is consuming working capital and space, and on urban sites space is frequently the binding constraint. The protection that works is ordering earlier against a reliable lead time, which is a planning intervention rather than an inventory one. Firms should be prepared for this to be counter-intuitive to site staff, for whom visible stock is reassuring in a way that a well-managed order book is not.

Measure the emergency purchase share and treat it as the headline indicator. Of all the operational variables examined, it had the strongest relationship with schedule slippage, and it has the further advantage of being easy to compute from existing records and hard to game. A rising emergency purchase share is an early and reliable signal that procurement planning is failing, and it will show up well before the programme does.

Fix the internal constraint before the external one. The role analysis in Section 4.3 found procurement executives rating stock control almost a full point below project managers. That gap is not a difference of opinion; it is a difference in exposure to the records. Senior management in both firms should assume that their own view of material management maturity is optimistic and should verify it by asking the people who use the ledger daily rather than the people who receive its summary.

Design the recommendations to the firm, not to the literature. For Hexagon, the full set is achievable within a year because the functions and much of the data already exist. For Design Space, the binding constraint is that it does not own the store, so its route runs through the appointment: material status reporting, delivery date confirmation and stock visibility should be contractual obligations of its contractors rather than requests. That is a slower and less satisfying path, and presenting it as equivalent to Hexagon's would be misleading.

Assign ownership for the operating phase before go-live. The most common failure mode for improvements of this kind is not that they fail but that they succeed and then decay, because nobody is responsible once the initiating attention moves on. A named owner, a monthly review of the two headline indicators, and a defined escalation path should exist before the first change is made rather than after it.

8. CASE EXAMPLES FROM INDUSTRY

8.1 Larsen and Toubro Construction - Centralised Category Management

Larsen and Toubro's construction business represents the far end of the scale from the firms studied here, and the contrast is instructive rather than aspirational. The organisation has publicly described a centralised procurement model in which major material categories are sourced through central agreements negotiated at group level and drawn down by individual projects, rather than each project negotiating independently.

The relevant mechanism for this study is not the buying power, which a mid-sized firm cannot replicate, but the category structure. Centralisation forces the organisation to define what its material categories actually are, to maintain a single supplier master across projects, and to hold performance data at a level where it accumulates. Those are precisely the disciplines that Section 4.3 found missing in both study firms, and they do not depend on scale. A firm running four projects can maintain one supplier register and one category list as easily as a firm running four hundred; what scale changes is the negotiating leverage that the register eventually supports, not the feasibility of keeping it. The limitation of the centralised model is equally relevant: it works only where the project's material requirements are foreseeable enough to be aggregated, and specialist, design-driven categories of the kind that dominate Design Space's exposure resist that aggregation.

8.2 Tata Projects - Vendor Performance Management and Digital Procurement

Tata Projects has publicly described a programme of procurement digitisation covering electronic tendering, vendor registration and structured vendor performance assessment across its engineering and construction business. The element relevant here is the treatment of vendor evaluation as a continuing record rather than a selection exercise.

The distinction matters and it is easy to lose. Most firms evaluate a supplier at the point of empanelment, when the assessment is necessarily based on capability, references and financial standing, and then never revisit it against what the supplier actually delivered. A continuing record inverts that: empanelment becomes provisional and the real assessment accumulates from delivery outcomes. This is the practice that only 35.7 per cent of respondents in the present study reported, and the reason it is worth the effort is the one Section 2 drew from the resource-based view. Capability assessments are available to any competitor who asks the same questions. A

three-year record of what a supplier actually did on this firm's projects is not. The caution attached to this example is the one raised in Section 6: a scoring scheme that influences award will be responded to, and a firm adopting it should expect quoted lead times to lengthen unless it monitors them separately.

8.3 Cloud Procurement Platforms and the Mid-Sized Firm

The third example is a class rather than a company. Platforms such as SAP Ariba, Zycus and a number of lighter Indian alternatives now offer procurement, vendor management and inventory modules on subscription terms that place them within reach of firms of the size studied here, which was not the case a decade ago.

The relevance is chiefly cautionary. Both firms in this study could subscribe to such a platform next quarter, and neither would benefit much from doing so at present, because the constraint identified in Section 6 is not the absence of a system but the absence of the records a system would consume. A platform populated from a duplicated supplier master and inaccurate goods receipt dates produces well-formatted unreliable reporting, which is worse than no reporting because it is believed. The sequencing recommendation in Section 7 follows from this: records discipline first, differentiation of control effort second, and a platform third, at the point where the manual version has become genuinely burdensome. Firms that invert this order tend to conclude that the software failed, when what failed was the data it was given.

Read together, the three examples describe the same capability at three scales. What separates them is not technique but persistence: the discipline of maintaining a category structure, a supplier register and an accurate stock position across projects and across years. None of that is proprietary, and none of it requires the scale of the first example.

9. FUTURE OUTLOOK AND RESEARCH IMPLICATIONS

The most immediate requirement is validation against audited records. This study measured perceived project efficiency because that is what a cross-sectional survey can measure, and perception of one's own organisation is an imperfect proxy for performance. A follow-up study drawing project efficiency from final accounts and programme records, rather than from

staff assessment, would establish whether the ranking of practice dimensions survives the change of measure. That is the single most valuable next step and it is entirely feasible within these two firms.

A longitudinal design would address the second and more serious limitation. The cross-sectional structure of this study cannot distinguish between good practice producing efficient projects and efficient projects permitting good practice, and both mechanisms are plausible. Following the firms through

the implementation recommended in Section 7, with measurements before and after, would resolve the direction and would additionally supply the response curve that Section 4.5 had to assume.

Third, the sample should be widened. Two firms in one city support claims about mechanism and no claims about prevalence. A study across a larger sample of Indian mid-sized firms would establish how common the specific pattern found here — a strong effect of stock information quality, a null effect of wastage control, and no residual effect of firm type — actually is. The design-led firm is particularly under-researched: almost the entire materials management literature studies contractors, and the firm that specifies material without owning it exercises considerable influence over procurement outcomes through decisions taken long before any order is raised.

Fourth, the interaction between procurement practice and contract form deserves study in its own right. Both firms in this sample operate mainly under item-rate and lump-sum arrangements. Design-build, EPC and management contracting allocate material risk quite differently, and it is reasonable to expect the relative weight of the practice dimensions to shift with that allocation. A study spanning contract forms would test whether the findings here are general or specific to a particular allocation of risk.

Fifth, the behavioural questions raised in Section 6 are researchable and largely unresearched. Do suppliers pad quoted lead times once they learn they are being scored, and over what period? Does a stock reconciliation discipline decay after the attention that established it is withdrawn, and at what rate? These have direct design implications for any firm considering the recommendations in Section 7, and they cannot be answered from the procurement literature as it stands.

Finally, there is a question of equity that the technology-adoption framing tends to obscure. The practices recommended here are deliberately low-technology precisely because the firms that most need them are the least able to buy their way to them. If procurement capability comes to depend on platform subscriptions and analytical staff, the effect will be to widen the gap between large contractors and the mid-sized firms that carry much of the sector's actual output. Research into what the minimum effective version of each practice looks like — the smallest supplier register that still works, the least frequent reconciliation that still holds — would be of more practical value than further refinement of methods that only large organisations can operate.

10. CONCLUSION

This study set out to establish how material procurement and inventory management affect project efficiency at two firms with contrasting operating models, and to be specific about which practices carry the weight. The answer is more selective than the practitioner literature generally implies.

Three of the five practice dimensions carried independent weight in a model explaining 47.7 per cent of the variance in perceived project efficiency. Inventory control practice was the strongest at a standardised coefficient of 0.345, followed by supplier selection and evaluation at 0.247 and procurement planning discipline at 0.161. Information flow fell just short of significance. Material handling and wastage control, despite correlating with efficiency at 0.41 on its own, contributed nothing once the other dimensions were held constant, which suggests it is better read as a symptom of material management quality than as an independent lever.

Four conclusions follow. The first is that the type of firm did not matter once its practices were accounted for. Hexagon staff rated efficiency substantially higher than Design Space staff, and that entire difference was absorbed by the practice variables, with the firm indicator adding two-tenths of a percentage point to explained variance. Operating model shapes which practices are easy to adopt; it does not determine the outcome.

The second is that knowing what you hold matters and holding more of it does not. Inventory control practice was the strongest predictor of efficiency, while inventory holding period was essentially unrelated to schedule slippage and unrelated to cost

variance. Stock on site defends against stockouts, which turn out to be a minor contributor to slippage, while the strongest operational correlate of slippage was the emergency purchase share, which is a symptom of late ordering rather than of thin stores.

The third is that differentiation is available without expenditure. Six categories carry 71.3 per cent of spend at these firms, and redistributing an unchanged budget of control effort towards them reduced serious overruns from

43.3 to 31.7 per cent while reducing aggregate variance by

12.6 per cent. The gap between those two figures is itself the finding: differentiated control cuts the tail far more than it cuts the average, and firms should decide which of those they are actually buying.

The fourth is that the constraint is organisational rather than technical. The practice that mattered most is owned by the store, the function with the least standing in both firms, and the people closest to the records rated them almost a full scale point below the managers who receive their summaries. No system addresses that.

The limitations have been stated where they arise rather than collected at the end. The dataset is a reconstruction and the absolute magnitudes are illustrative; the efficiency measure is perceptual; the design is cross-sectional and therefore silent on causal direction; two firms in one city support no claim to generality; and the simulation rests on an assumed response

curve. Validation against audited project records, and a longitudinal design following an actual implementation, are the necessary next steps, and until they are completed the findings should be read as well-supported within this sample rather than as established.

What can be said with more confidence is that the problem is worth the attention. Material cost has been the largest single block on the construction balance sheet for as long as anyone has measured it, and the practices that govern it in mid-sized firms remain, on the evidence of this study, substantially informal. Closing that gap does not require the industry to adopt anything it does not already understand. It requires it to write down what it orders, record when it arrives, keep the register that results, and spend its limited attention where the money actually is.

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