



Risk-Based Privatization of Maintenance Activities for High-Rise Buildings Using MCDM

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Abstract : High-rise buildings depend on the reliable operation of lifts, electrical installations, heating, ventilation and air-conditioning (HVAC), fire protection, plumbing, water supply, pumps and generators. Building owners can manage these services internally or engage private contractors for selected activities. Outsourcing can provide specialist capability and flexible access to resources, but it can also expose the building to concerns about safety, workmanship, response time, contract control and cost. This study compares six maintenance activities to support a more reasoned, risk-aware privatization decision. A structured questionnaire was distributed through online and offline channels to professionals connected with construction, maintenance, facility management and contracting. The analysis used 130 complete responses from 200 distributed questionnaires, giving a 65.0% response rate. The study first examined respondents' ratings of six broad decision criteria and then assessed six maintenance activities against four activity-level dimensions: potential cost advantage, perceived safety risk, benefit from specialized private expertise and expected service quality. Criterion weights were derived by normalizing the relevant mean importance ratings, and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was used to rank the activities. Plumbing and water supply maintenance ranked first ($C_i = 0.5862$), followed by pump and generator maintenance (0.5242), lift and escalator maintenance (0.5166), HVAC maintenance (0.5143), fire protection maintenance (0.4882) and electrical maintenance (0.4554). Plumbing and water supply remained first under the tested $\pm 10\%$ changes to individual weights, although an equal-weight model placed pump and generator maintenance first. The results therefore support activity-specific screening rather than a uniform outsourcing policy. The paper also states a key methodological boundary: the questionnaire did not collect pairwise comparisons, so classical AHP weights and consistency ratios were not calculated.

IndexTerms - High-rise buildings; maintenance management; privatization; outsourcing; risk assessment; multi-criteria decision-making; TOPSIS

I. INTRODUCTION

High-rise buildings have become a familiar part of urban development, providing residential, commercial, institutional and mixed-use space within limited land areas. Their daily operation depends on several connected services rather than on the building structure alone. A problem in the electrical system may affect lifts, pumps, HVAC and access-control equipment; a water-supply failure can disrupt basic building use; and a poorly maintained fire-protection system can create serious consequences in an emergency. Maintenance is therefore a continuing management responsibility that includes inspection, preventive servicing, fault repair, testing, records, replacement planning and coordination between staff and contractors.

The choice of how to deliver maintenance is not straightforward. Keeping every service in-house requires staff, tools, training, supervision and access to specialist knowledge. A private contractor may already have technicians and equipment for a particular system, and can sometimes provide service flexibility that would be difficult to maintain internally. However, outsourcing also changes the way accountability works. The owner must set service requirements, monitor work quality, manage interfaces with other building services and ensure that urgent faults are handled within the required time. The apparent financial benefit of a contract can be reduced if the contractor has insufficient capability, poor safety practices or unclear responsibilities. Martin (1997) described the managerial and contractual issues that accompany maintenance contracting, while Hassanain et al. (2015) showed that outsourcing considerations differ according to the service under review.

For high-rise buildings, the decision should be made for individual activities rather than by adopting a single rule for every service. Lift maintenance, electrical maintenance, HVAC servicing, fire protection, plumbing and standby power differ in technical requirements and in the consequences of interruption. Maintenance outsourcing research has already used structured decision methods to compare service arrangements and contractors (Bertolini et al., 2004; Zavadskas et al., 2009). The broader multi-criteria literature also demonstrates that cost, quality, safety and capability may need to be considered together where no single measure captures the full decision (Kassab et al., 2007; Mathew et al., 2020).

In this paper, the term "privatization" is used in the practical sense adopted by the dissertation: assigning selected maintenance activities to private agencies through a contractual arrangement. It does not refer to transferring ownership of the whole building. The aim is to develop a transparent comparison of six maintenance activities using professional survey responses and TOPSIS. The work is a decision-support exercise; it does not claim that a survey ranking can replace a building-specific technical inspection, review of statutory duties or assessment of actual contractor availability.

1.1 Aim and objectives

The aim is to assess the relative suitability of selected high-rise building maintenance activities for privatization by considering respondents' views on cost advantage, safety risk, specialist capability and service quality. The study has four practical objectives:

- To summarize the importance assigned by respondents to major criteria that influence maintenance privatization.
- To compare six maintenance activities using a common set of activity-level ratings.
- To apply a transparent, survey-derived weighting procedure and TOPSIS to rank the alternatives, with sensitivity checks to test how the order responds to changes in weights.
- To interpret the ranking as a starting point for procurement and management decisions, including the controls that should accompany any outsourced arrangement.

II. LITERATURE REVIEW AND RESEARCH GAPS

2.1 Maintenance of high-rise buildings

Research on high-rise maintenance has linked maintenance policy, preventive practice and service performance. Yahya and Ibrahim (2010, 2011) discussed strategic and operational issues in high-rise office and commercial buildings, while Chua et al. (2018) considered maintenance practices in high-rise residential properties. Au-Yong et al. (2019) examined differences between maintenance priorities expressed by practitioners and the priorities observed in actual practice. These studies are relevant because maintenance priorities are shaped by building use, the service affected and the resources available to the management team. A system that supports daily necessities or safety can deserve closer attention than a less critical service, even if the latter is easier to outsource.

Maintainability is also affected by technical and management conditions. De Silva et al. (2016) examined maintainability risks in high-rise buildings and showed that several factors associated with design, construction, environment and management can influence future maintenance performance. Lantaca (2024) applied a risk-based approach to maintenance of a sewage-treatment facility in a high-rise residential property. The practical message is that building services should not be treated as interchangeable alternatives: the likely consequences of poor maintenance and the controls needed for safe work differ by system.

2.2 Outsourcing and contractor selection

Maintenance outsourcing research has treated the decision as more than a comparison of in-house costs and contractor prices. Bertolini et al. (2004) used the Analytic Hierarchy Process to help select maintenance outsourcing arrangements in an industrial case. Hassanain et al. (2015) developed a multi-criteria model for outsourcing maintenance services and grouped 38 factors into strategic, management, technological, quality, economic and functional categories. Zavadskas et al. (2009) compared apartment-block maintenance contractors using multiple criteria, reinforcing the point that a low price does not necessarily indicate the best service provider.

More recent research continues to emphasize contractor capability and the practical requirements of service delivery. Zubair et al. (2024) proposed a strategic framework for maintenance contractor selection that emphasizes best value rather than cost alone. Hosseini et al. (2023) examined real-time contractor selection for facility maintenance, including resource and response constraints. Together, these studies indicate that a privatization decision should consider what a contractor can deliver, how performance will be monitored and what happens when a system fails—not only the initial commercial offer.

2.3 Risk assessment and multi-criteria methods

Risk assessment has been applied to construction and infrastructure projects using professional judgments and structured ranking. Subramanyan et al. (2012) developed a construction risk assessment model using opinions from Indian construction experts, and Sharma and Gupta (2020) examined risk identification and management in building and infrastructure projects. In high-rise settings, Ansari et al. (2022) developed a safety-risk assessment approach using fuzzy set theory and decision methods. These studies provide a basis for identifying risk areas systematically, although their alternatives and assessment scales are not identical to those used in the present research.

MCDM has also been used for maintenance planning and strategy selection. Benítez et al. (2020) developed a dynamic multi-criteria model for maintenance planning of reinforced-concrete structures. Mathew et al. (2020) used an interval type-2 fuzzy AHP-TOPSIS approach for maintenance strategy selection under uncertainty, while Hemmati et al. (2020) combined fuzzy AHP and TOPSIS for maintenance policy selection. These applications show the value of separating the importance of criteria from the performance of alternatives. They also make clear that the method must match the data available: classical AHP requires pairwise-comparison judgments, whereas rating-based weights can be calculated from ordinary survey scales when that is what the questionnaire collected.

Table 1.1 Selected literature and its relevance to the present study

Study	Main focus	Relevance to this research
Yahya and Ibrahim (2010, 2011)	Maintenance policy and operation in high-rise buildings	Establishes the management context for building maintenance.
Chua et al. (2018); Au-Yong et al. (2019)	Preventive practice and maintenance prioritization	Supports prioritizing services according to their needs and consequences.
De Silva et al. (2016); Lantaca (2024)	Maintainability and risk-based service maintenance	Shows that risk assessment is relevant to high-rise building services.
Martin (1997)	Maintenance contracting	Highlights contract management and responsibility issues.
Bertolini et al. (2004); Hassanain et al. (2015)	Multi-criteria outsourcing decisions	Directly supports comparing maintenance alternatives across multiple factors.
Zavadskas et al. (2009); Zubair et al. (2024)	Maintenance contractor evaluation	Supports considering capability and performance alongside price.
Kassab et al. (2007)	Multi-criteria infrastructure privatization	Shows that privatization decisions can be structured as MCDM problems.

Mathew et al. (2020); Hemmati et al. (2020)	AHP-TOPSIS for maintenance strategy/policy	Provides methodological context for weighting and ranking alternatives.
Ansari et al. (2022); Sharma and Gupta (2020)	Safety and construction risk assessment	Supports structured treatment of safety and broader risk factors.

2.4 Research gap and contribution

The literature offers useful approaches for high-rise maintenance planning, contractor selection, risk assessment and outsourcing. However, these are related but distinct decisions. A contractor-selection model may compare providers for a service already chosen for outsourcing, while a maintenance-strategy model may compare preventive or corrective options. The practical question addressed here is earlier in the decision process: which of several building-service maintenance activities should be examined first for possible privatization, given professionals' views about potential benefits and safety risk?

The paper addresses this gap through a comparable survey-based assessment of six activities and a TOPSIS ranking based on four dimensions available in the final questionnaire. Its contribution is an application of existing decision methods to a specific maintenance-management question, with the inputs, weighting assumptions and limitations made explicit. The study does not claim to introduce a new MCDM algorithm or to establish universal outsourcing rules.

III. RESEARCH METHODOLOGY

3.1 Research design and sample

A quantitative, descriptive survey design was used, supported by a review of research on high-rise maintenance, outsourcing, contractor selection and risk assessment. Purposive sampling was adopted because the questionnaire sought the views of people professionally connected with construction, maintenance, facility management, contracting or engineering. The questionnaire was shared through online and offline modes. Of 200 questionnaires distributed, 130 complete responses were retained for analysis, giving a response rate of 65.0%. The response sheet used for this analysis contains 130 records with responses to the questionnaire items used in the paper.

3.2 Questionnaire and rating scales

The questionnaire had three substantive parts. First, it collected the respondent's professional designation, years of professional experience, organization type and experience in building maintenance or facility management. Second, respondents rated the importance of six broad decision criteria. This importance scale was coded from 1 to 5: 1 = Not Important, 2 = Slightly Important, 3 = Moderately Important, 4 = Very Important and 5 = Extremely Important. Third, respondents rated each of six maintenance activities on four activity-level dimensions. For these questions, 1 = Very Low, 2 = Low, 3 = Moderate, 4 = High and 5 = Very High. The final two statements used an agreement scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree and 5 = Strongly Agree.

The four activity-level dimensions were (i) potential cost advantage from outsourcing, (ii) perceived safety risk associated with outsourcing, (iii) benefit from specialized private expertise and (iv) expected service quality from a qualified private contractor. The direction of the safety dimension differs from the other three: a high cost-advantage, expertise-benefit or service-quality rating is favourable, whereas a high safety-risk rating is unfavourable. This distinction was incorporated when the TOPSIS ideal solutions were defined.

3.3 Alternatives and decision criteria

Six activities were treated as the alternatives: lift and escalator maintenance; electrical system maintenance; HVAC maintenance; fire protection system maintenance; plumbing and water supply maintenance; and pump and generator maintenance. They were selected because they represent core services on which high-rise building operations depend. The broad importance questions covered maintenance cost, safety, technical complexity, service quality, contractor experience and technical capability, and operational criticality with response time. The activity-level TOPSIS matrix, however, used the four dimensions that were rated for every activity in the final questionnaire.

3.4 Survey-derived criterion weights

Classical AHP was not applied in the final calculations. Although AHP was discussed as a possible approach during project development, the final questionnaire did not ask respondents to compare criteria in pairs. A pairwise-comparison matrix and its consistency ratio therefore cannot be derived from the collected data. Instead, the mean importance ratings for four related criteria were normalized to produce rating-based weights. The weight for maintenance cost was used as a proxy for the cost-advantage dimension; the safety importance mean was used for safety risk; the broad contractor-experience and technical-capability item was used as a proxy for the activity-level specialist-expertise dimension; and the service-quality importance mean was used for expected service quality. The proxy for specialist expertise is not an exact measurement match and is treated as a limitation.

$$w_j = m_j / \sum_k m_k$$

Here, m_j is the mean importance rating for the relevant broad criterion, and w_j is its normalized weight. After normalization, the four weights sum to 1.00. Technical complexity had the highest broad mean rating, but it was not included as a separate TOPSIS criterion because the final questionnaire did not collect a technical-complexity score for each individual maintenance activity. This is a material boundary on how the ranking should be interpreted.

3.5 TOPSIS calculation

TOPSIS ranks alternatives by comparing their weighted profiles with a positive ideal solution and a negative ideal solution. The decision matrix was formed from the mean activity-level ratings across the 130 responses. Each column was normalized using its Euclidean length, and each normalized value was multiplied by the corresponding criterion weight. The ideal best was defined as the maximum value for benefit criteria and the minimum value for the safety-risk criterion. The ideal worst was defined in the opposite way.

$$r_{ij} = x_{ij} / \sqrt{(\sum_i x_{ij}^2)}$$

$$v_{ij} = w_j \times r_{ij}$$

$$S_i^+ = \sqrt{[\sum_j (v_{ij} - v_j^+)^2]} \quad ; \quad S_i^- = \sqrt{[\sum_j (v_{ij} - v_j^-)^2]}$$

$$C_i = S_i^- / (S_i^+ + S_i^-)$$

In these expressions, x_{ij} is the mean rating of activity i for criterion j ; r_{ij} is the normalized value; v_{ij} is the weighted normalized value; v_j^+ and v_j^- are the ideal-best and ideal-worst values; S_i^+ and S_i^- are the distances from those ideals; and C_i is the relative closeness coefficient. A higher C_i indicates a higher relative position under the chosen model and criterion directions. It should not be read as a probability or as a direct percentage of suitability for outsourcing.

3.6 Sensitivity analysis and ethical considerations

The stability of the ranking was explored by changing each of the four weights by -10% and $+10\%$ in turn and rescaling the remaining weights to preserve a total of 1.00. The weighted ranking was also compared with an equal-weight TOPSIS model. These checks test sensitivity to the weighting assumptions; they do not test all possible criteria or all respondent subgroups. Participation was voluntary, and the dissertation reports that individual responses were kept confidential and results were reported in aggregate. No respondent-level identifying information is presented in this paper.

IV. RESULTS

4.1 Response and respondent profile

The analysis included 130 complete responses from 200 distributed questionnaires, corresponding to a 65.0% response rate. Maintenance Engineers made up 33.85% of the sample and Project Managers 33.08%. Together, these two groups represented approximately two-thirds of respondents. Construction-company employees formed the largest organizational group (26.92%), followed by consultancy/engineering respondents (22.31%). Professional experience varied, but 41.54% reported less than three years of direct experience in maintenance or facility management. The sample should therefore be understood as a mixed construction and maintenance-related professional sample, rather than a group consisting exclusively of senior facilities specialists.

Table 4.1. Respondent profile ($n = 130$)

Profile characteristic	Category	Frequency (n)	(%)
Professional designation	Maintenance Engineer	44	33.85
	Project Manager	43	33.08
	Civil Engineer	13	10.00
	Site Engineer	11	8.46
	Other	11	8.46
	Contractor	8	6.15
Professional experience	5–10 years	43	33.08
	11–15 years	37	28.46
	More than 20 years	19	14.62
	Less than 5 years	17	13.08
	16–20 years	14	10.77
Organization type	Construction company	35	26.92
	Consultancy/engineering	29	22.31
	Maintenance/contracting company	25	19.23
	Government/public sector	25	19.23
	Real estate/building management	16	12.31
Maintenance/FM experience	Less than 3 years	54	41.54
	3–5 years	28	21.54
	6–10 years	27	20.77
	No direct experience	14	10.77
	More than 10 years	7	5.38

4.2 Importance of broad decision criteria

Technical complexity received the highest mean importance score (3.892, SD = 1.247), followed by safety (3.792, SD = 1.054) and maintenance cost (3.769, SD = 1.242). Service quality also received a relatively high mean score of 3.615. Operational criticality and response time ranked fifth at 3.446, while contractor experience and technical capability had the lowest mean score at 2.954. These are importance ratings, not measurements of actual failure or risk incidence. Their ordering suggests that respondents considered the nature of the maintenance task and its consequences to be at least as relevant as commercial considerations.

Table 4.2 Mean importance ratings for broad decision criteria

Decision criterion	Mean rating (1–5)	Standard deviation (SD)	Rank
Technical complexity	3.892	1.247	1
Safety	3.792	1.054	2
Maintenance cost	3.769	1.242	3
Service quality	3.615	1.241	4
Operational criticality and response time	3.446	1.175	5
Contractor experience and technical capability	2.954	0.931	6

Note. Importance scale: 1 = Not Important; 2 = Slightly Important; 3 = Moderately Important; 4 = Very Important; 5 = Extremely Important. Mean is the average of 130 ratings. SD describes the spread of responses; a higher SD indicates greater variation in respondents' views.

4.3 Activity-level ratings: mean and standard deviation

Respondents did not view the six activities in the same way. Fire protection maintenance had the highest perceived cost advantage from outsourcing (mean 3.408) and the highest perceived safety-risk rating (3.392). Pump and generator maintenance had the highest mean for the benefit of specialist private expertise (3.723). Electrical maintenance recorded the highest expected service-quality rating (3.885) but the lowest perceived cost advantage (3.008). These results illustrate why an activity cannot be judged by one favourable rating alone.

Table 4.3 Activity-level mean ratings and standard deviations by maintenance activity (n = 130)

Maintenance activity	Potential cost advantage of outsourcing Mean rating / SD	Perceived safety risk Mean rating / SD	Benefit from specialized private expertise Mean rating / SD	Expected service quality Mean rating / SD
Lift and escalator maintenance	Mean: 3.300 SD: 1.268	Mean: 3.069 SD: 1.376	Mean: 3.231 SD: 1.315	Mean: 3.700 SD: 1.298
Electrical system maintenance	Mean: 3.008 SD: 1.223	Mean: 3.038 SD: 1.366	Mean: 3.285 SD: 1.215	Mean: 3.885 SD: 1.061
HVAC maintenance	Mean: 3.208 SD: 1.112	Mean: 2.985 SD: 1.220	Mean: 3.292 SD: 1.417	Mean: 3.608 SD: 1.279
Fire protection system maintenance	Mean: 3.408 SD: 1.173	Mean: 3.392 SD: 1.344	Mean: 3.531 SD: 1.404	Mean: 3.662 SD: 1.152
Plumbing and water supply maintenance	Mean: 3.354 SD: 1.244	Mean: 3.115 SD: 1.345	Mean: 3.338 SD: 1.460	Mean: 3.769 SD: 1.185
Pump and generator maintenance	Mean: 3.162 SD: 1.293	Mean: 3.285 SD: 1.354	Mean: 3.723 SD: 1.300	Mean: 3.800 SD: 1.197

Note. Activity rating scale: 1 = Very Low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very High. Every cell explicitly labels the average as "Mean" and the response spread as "SD" (standard deviation); values are not percentages. For safety risk, a higher mean indicates a higher perceived risk and is less favourable. For cost advantage, specialist expertise and service quality, a higher mean is more favourable.

4.4 Criterion weights used in TOPSIS

The four normalized weights were similar in size, with safety having the largest weight (0.2684), followed closely by cost advantage (0.2667) and service quality (0.2559). Specialist expertise had a weight of 0.2090. This distribution reduces the likelihood that the result is driven almost entirely by a single criterion, although the construct mapping described below still matters for interpretation.

Table 4.4 Survey-derived criterion weights used in TOPSIS

TOPSIS criterion	Questionnaire item used for weighting	Mean importance score	Normalized weight	Direction in TOPSIS
Cost advantage of outsourcing	Q5: importance of maintenance cost	3.769	0.2667	Benefit
Perceived safety risk	Q6: importance of safety	3.792	0.2684	Cost
Benefit from specialist expertise	Q9: contractor experience and technical capability	2.954	0.2090	Benefit
Expected service quality	Q8: importance of service quality	3.615	0.2559	Benefit
Total	—	14.131	1.0000	—

4.5 Normalized and weighted decision matrices

The mean activity ratings were normalized by dividing each value by the Euclidean norm of its criterion column. The normalized values were then multiplied by the survey-derived weights. Tables 6 and 7 report these two calculation stages so that the path from observed ratings to the final ranking can be followed. The safety-risk column is not converted into a benefit score; rather, it is handled as a cost criterion when the ideal best and ideal worst solutions are selected.

Table 4.5 Normalized decision matrix

Maintenance activity	Cost advantage	Safety risk	Specialist expertise	Service quality
Lift and escalator maintenance	0.4155	0.3977	0.3874	0.4041
Electrical system maintenance	0.3787	0.3937	0.3939	0.4242
HVAC maintenance	0.4039	0.3867	0.3948	0.3940
Fire protection system maintenance	0.4291	0.4396	0.4234	0.3999
Plumbing and water supply maintenance	0.4223	0.4037	0.4003	0.4116
Pump and generator maintenance	0.3981	0.4256	0.4465	0.4150

Note. Normalized values are dimensionless. Values are rounded to four decimal places; calculations used unrounded activity means and unrounded normalized weights wherever available.

Table 4.6 Weighted normalized decision matrix

Maintenance activity	Weighted cost	Weighted safety risk	Weighted specialist expertise	Weighted service quality
Lift and escalator maintenance	0.1108	0.1067	0.0810	0.1034
Electrical system maintenance	0.1010	0.1057	0.0823	0.1085
HVAC maintenance	0.1077	0.1038	0.0825	0.1008
Fire protection system maintenance	0.1144	0.1180	0.0885	0.1023
Plumbing and water supply maintenance	0.1126	0.1083	0.0837	0.1053
Pump and generator maintenance	0.1062	0.1142	0.0933	0.1062

4.6 TOPSIS ranking of the maintenance activities

Plumbing and water supply maintenance achieved the highest closeness coefficient, 0.5862, followed by pump and generator maintenance at 0.5242. Lift and escalator maintenance (0.5166) and HVAC maintenance (0.5143) were close to one another; their score difference was only 0.0023 and should not be treated as a meaningful practical separation without further evidence. Fire protection maintenance ranked fifth at 0.4882, while electrical system maintenance ranked sixth at 0.4554. The ordering is the result of the chosen criteria, direction of preference and respondent-derived weights; it is not a direct measure of an activity's absolute safety, quality or outsourceability.

Table 4.7 TOPSIS separation measures and final ranking

Rank	Maintenance activity	Distance from ideal best (S_i^+)	Distance from ideal worst (S_i^-)	Closeness coefficient (C_i)
1	Plumbing and water supply maintenance	0.0113	0.0160	0.5862
2	Pump and generator maintenance	0.0135	0.0149	0.5242
3	Lift and escalator maintenance	0.0142	0.0151	0.5166
4	HVAC maintenance	0.0149	0.0158	0.5143
5	Fire protection system maintenance	0.0162	0.0155	0.4882
6	Electrical system maintenance	0.0175	0.0146	0.4554

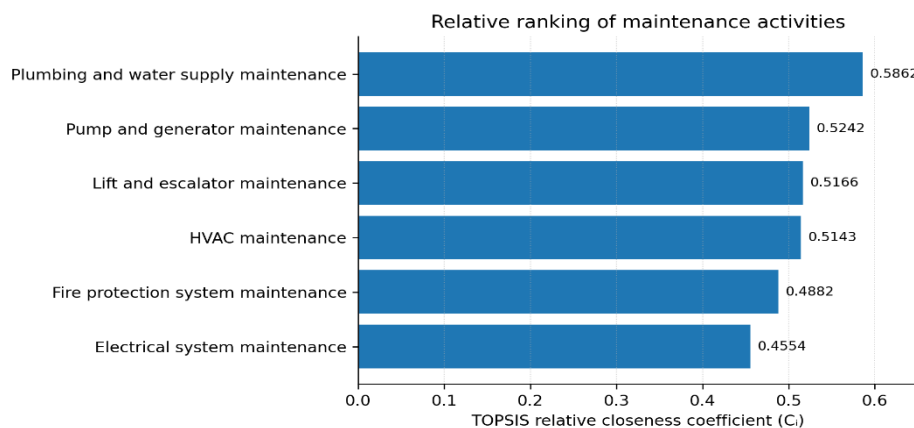


Figure 1. TOPSIS relative closeness coefficients for the six maintenance activities

4.7 General views on risk-based decision-making

The two general-opinion statements support evaluating maintenance activities individually. A total of 102 respondents (78.46%) agreed or strongly agreed that activities should be evaluated individually rather than using the same privatization decision for all building services. Eighty-nine respondents (68.46%) agreed or strongly agreed that risk assessment should be carried out before any major maintenance activity is privatized. These results align with the idea that an outsourcing decision should be documented and based on the characteristics of the service rather than applied as a uniform policy.

Table 4.8 General opinion on risk-based maintenance privatization

Statement	Mean rating	SD	Agree or strongly agree, n (%)	Rank by mean
Risk assessment should be carried out before any major maintenance activity is privatized.	3.923	1.061	89 (68.46%)	2
Maintenance activities should be evaluated individually rather than using the same privatization decision for all building services.	4.023	0.936	102 (78.46%)	1

Note. Agreement scale: 1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree. The agree/strongly agree percentage combines responses coded 4 and 5.

V. DISCUSSION

5.1 Interpreting the highest-ranked alternatives

Plumbing and water supply maintenance ranked first because it produced the strongest combined profile under the four selected activity-level dimensions. Its cost-advantage mean was relatively high (3.354), the perceived safety-risk mean was moderate compared with fire protection and pump/generator maintenance (3.115), and the expected service-quality mean was 3.769. The result supports putting this service near the top of a shortlist for detailed outsourcing appraisal. It does not show that all plumbing work should be contracted out: a real decision should consider system condition, leakage history, equipment arrangement, response requirements, water quality responsibilities, available vendors and the owner's current skills.

Pump and generator maintenance ranked second and recorded the highest perceived benefit from specialist private expertise (3.723). Specialist providers may be attractive where equipment testing, manufacturer-related knowledge or standby-power experience is needed. At the same time, its safety-risk rating was relatively high (3.285). If outsourced, this service would therefore need clear rules for safe isolation, testing, emergency availability, documentation and owner-side acceptance. The contractor-selection literature similarly emphasizes technical capability and past performance alongside commercial terms (Padhi & Mohapatra, 2009; Zubair et al., 2024).

5.2 Close rankings and high-risk activities

Lift and escalator maintenance and HVAC maintenance had closeness coefficients of 0.5166 and 0.5143. This small difference means the model does not support a strong practical distinction between them. For lifts, the service agreement should define response time, availability, inspection routines, emergency rescue procedures and escalation contacts. For HVAC, performance requirements may include planned servicing, fault response, records and checks on whether the system continues to meet the building's requirements. The suitability of either service for outsourcing will depend on the quality and availability of qualified contractors and on the building's demand for continuous operation.

Fire protection maintenance illustrates the need to interpret all the criteria together. It received the highest potential cost-advantage mean (3.408), but it also had the highest perceived safety-risk mean (3.392). Since safety risk is treated as a cost criterion in TOPSIS, this risk offsets some of the activity's favourable scores and contributes to its fifth-place rank. The result must not be read as saying that fire protection is unimportant or that it should remain unmaintained. Instead, the ranking points to the need for strict qualification requirements, independent checking, complete testing records, clear defect escalation and continued owner oversight for any outsourced arrangement. This is consistent with the broader emphasis on systematic safety-risk evaluation in high-rise environments (Ansari et al., 2022).

Electrical maintenance ranked sixth despite having the highest expected service-quality mean (3.885). Its perceived cost-advantage mean was the lowest (3.008), so the favourable service-quality score did not dominate the combined result. This is a useful example of the trade-off the model is intended to expose. A low ranking does not mean that external electrical specialists should never be used. It suggests that full privatization was less favourable under this specific weighting and scoring model, while selective contracting for specialist tasks may still be appropriate where internal operational control is important.

5.3 Broad criteria and the interpretation of contractor capability

The broad importance question placed technical complexity first, followed by safety, cost and service quality. That pattern supports the view that privatization decisions are not purely financial. However, technical complexity was not entered into the final TOPSIS matrix because the final questionnaire did not ask respondents to rate each activity separately on that dimension. The final ranking therefore uses four activity-level ratings rather than all six broad criteria. This difference between the general-importance scale and the activity-level performance ratings should remain visible whenever the ranking is used. It is also why the model is better viewed as a comparative screening tool than as a fully validated decision rule.

Contractor experience and technical capability had the lowest broad importance mean (2.954), but specialist expertise received a comparatively high activity-level rating for pump and generator maintenance. These findings are not necessarily contradictory: a general rating of a criterion and a service-specific judgment answer different questions. Still, the weighting method used the general contractor-capability mean as the proxy weight for specialist expertise. Future versions should measure the importance of specialist expertise directly or apply criterion-weighting questions that exactly match the activity-level criteria.

5.4 Sensitivity and the role of weighting

Plumbing and water supply maintenance retained first place across the tested $\pm 10\%$ changes to individual weights. This suggests that its position was not dependent on a small adjustment to any one of the four respondent-derived weights. The equal-weight comparison produced a different outcome: pump and generator maintenance ranked first, with plumbing and water supply second. The top position is therefore stable under the specified local perturbations but not under every alternative weighting assumption. Pump and generator maintenance benefits more from its strong specialist-expertise rating when the criteria are weighted equally, whereas the respondent-derived weights give more importance to safety and cost-related ratings.

Table 5.1 Leading three activities under sensitivity and alternative-weight scenarios

Scenario	Rank 1	Rank 2	Rank 3
Base respondent-derived weights	Plumbing and water supply	Pump and generator	Lift and escalator
Cost weight -10%	Plumbing and water supply	Pump and generator	HVAC
Cost weight +10%	Plumbing and water supply	Lift and escalator	Pump and generator
Safety weight -10%	Plumbing and water supply	Pump and generator	Fire protection
Safety weight +10%	Plumbing and water supply	HVAC	Lift and escalator
Expertise weight -10%	Plumbing and water supply	Lift and escalator	HVAC
Expertise weight +10%	Plumbing and water supply	Pump and generator	HVAC
Service quality weight -10%	Plumbing and water supply	Pump and generator	HVAC
Service quality weight +10%	Plumbing and water supply	Pump and generator	Lift and escalator

Equal-weight TOPSIS	Pump and generator	Plumbing and water supply	Fire protection
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Note. For each $\pm 10\%$ scenario, one weight was varied and the other weights rescaled so that the total remained 1.00. The table reports the three leading alternatives only. The equal-weight scenario is a separate comparison rather than a $\pm 10\%$ perturbation.

5.5 Connection with previous research

The findings are consistent with previous work in one central respect: maintenance outsourcing needs a structured assessment of the service under consideration. Hassanain et al. (2015) found that maintenance-outsource decisions can involve strategic, technical, quality, economic and functional factors, while Bertolini et al. (2004) used a multi-criteria method to select outsourcing arrangements. High-rise maintenance studies have similarly emphasized prioritization, preventive practice and service performance (Chua et al., 2018; Au-Yong et al., 2019). The current paper adds a common comparison of six activities using one set of survey-derived ratings and a transparent ranking method. The precise ranking is specific to the present sample and should not be expected to reproduce the order found in other buildings or contexts.

VI. PRACTICAL IMPLICATIONS FOR BUILDING OWNERS AND FACILITY MANAGERS

The ranking should be used as an initial screening step, not as an instruction to outsource automatically. Table 11 links each activity's result to practical controls that owners should examine during procurement review.

Table 6.1 Suggested management response to the activity-level ranking

Maintenance activity	Interpretation from this study	Practical control if outsourcing is considered
Plumbing and water supply	Highest score; prioritize for detailed outsourcing appraisal.	Set preventive schedules and leak-response targets; check workmanship, reporting and provider capacity.
Pump and generator	Second; highest specialist-expertise rating.	Require qualified technicians, planned testing, safe isolation and emergency cover; review test records.
Lift and escalator	Third; ranking close to HVAC.	Set availability and response targets; define rescue, inspection and escalation procedures.
HVAC	Fourth; ranking close to lift maintenance.	Specify preventive servicing, fault-response windows and performance records.
Fire protection	Fifth; highest perceived safety risk.	Require qualified providers, documented testing, independent checks and clear emergency control.
Electrical system	Sixth; highest quality rating but lowest cost advantage.	Use specialists selectively; retain owner control over shutdown and safe restart.

Before tendering, the owner should convert these broad suggestions into a service specification that identifies the precise tasks to be outsourced, response requirements, service standards, safety responsibilities, reporting format, defect escalation, liability and acceptance procedures. Evaluation should cover technical capability, past performance, trained manpower, tools, spare-parts access and emergency coverage alongside the commercial bid. After award, performance records should be reviewed periodically; repeated missed response targets or unresolved defects should trigger corrective action and, where necessary, reconsideration of the outsourcing arrangement.

VII. LIMITATIONS AND FURTHER RESEARCH

Several limitations should be considered when interpreting the results. First, purposive sampling was used and a probability-based sampling frame covering buildings and professional groups was not available. The 130 responses should therefore not be treated as statistically representative of every high-rise building or maintenance professional. Second, the results are based on professional perceptions. The questionnaire did not measure actual contract costs, breakdown histories, accident rates, service outages or performance after privatization. The ratings summarize judgments about likely cost advantage, safety risk, specialist expertise and service quality; they are not observed outcomes.

Third, the final questionnaire did not collect AHP pairwise comparisons. Consequently, classical AHP weights and a consistency ratio could not be calculated. The paper uses normalized mean-importance ratings as criterion weights and TOPSIS for ranking. In addition, the specialist-expertise weight is derived from a related but not identical item on contractor experience and technical capability. The weighting approach is transparent but would be improved by a questionnaire in which the weighting constructs match the alternative-level criteria exactly. Technical complexity was the most highly rated broad criterion but was not available as an activity-specific score, and it was therefore not entered in the TOPSIS matrix.

Fourth, only four activity-level dimensions were included in the ranking. Other factors—such as statutory obligations, current asset condition, contract duration, life-cycle cost, the availability of local vendors, spare-parts lead time, owner staffing capacity, insurance and the quality of existing maintenance records—can change the preferred arrangement for a particular building. The current ranking is accordingly a first-stage comparison, not a comprehensive procurement evaluation.

Further research could collect a broader and more geographically diverse sample and analyse owners, facility managers, contractors and technical specialists separately. A redesigned questionnaire could use pairwise comparisons if classical AHP is required and should measure each activity against the same complete set of criteria. A building-level case study could then compare the survey-based ranking with actual contract prices, response times, downtime, defects, compliance records and safety performance over time. Such evidence would help determine whether the preference scores are associated with better maintenance outcomes in practice.

VIII. CONCLUSION

This study examined the relative suitability of six high-rise building maintenance activities for privatization using professional survey responses and TOPSIS. From 200 distributed questionnaires, 130 complete responses were analysed. Technical complexity had the highest broad importance rating, followed by safety, maintenance cost and service quality. At the activity level, fire protection maintenance received the highest perceived cost-advantage and safety-risk ratings; pump and generator maintenance

received the highest specialist-expertise rating; and electrical maintenance received the highest expected service-quality rating but the lowest cost-advantage rating.

Using the normalized survey-derived weights, plumbing and water supply maintenance ranked first, followed by pump and generator, lift and escalator, HVAC, fire protection and electrical maintenance. Plumbing remained first under the tested $\pm 10\%$ changes to individual weights, although the equal-weight model placed pump and generator first. This difference shows that the weighting method influences the result and should be reported openly. The ranking is best used to prioritize further appraisal, not as a fixed rule for every high-rise building.

The main practical conclusion is that maintenance privatization should be selective and risk-aware. Cost advantage must be considered together with safety, specialist capability, service quality and the building's operating needs. If an activity is outsourced, the decision should be supported by qualified contractor selection, clear contract terms, measurable service standards, documented safety responsibilities and continuing owner-side monitoring. The value of the present approach lies in making these trade-offs visible and providing a transparent starting point for a more detailed building-specific decision.

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