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# A Model to Support IT Infrastructure Planning and the Allocation of IT Governance Authority

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**ABSTRACT**

Information technology (IT) requires a significant investment, involving up to 10.5% of revenue for some firms. Managers responsible for aligning IT investments with their firm's strategy seek to minimize technology costs, while ensuring that the IT infrastructure can accommodate increasing utilization, new software applications, and modifications to existing software applications. It becomes more challenging to align IT infrastructure and IT investments with firm strategy when firms operate in multiple geographic markets, because the firm faces different competitive positions and unique challenges in each market.

We discussed these challenges with IT executives at four *Forbes Global 2000* firms headquartered in Northern Europe. We build on interviews with these executives to develop a discrete-time, finite-horizon Markov decision model to identify the most economically-beneficial IT infrastructure configuration from a set of alternatives. While more flexibility is always better (all else equal) and lower cost is always better (all else equal), our model helps firms evaluate the tradeoff between flexibility and cost given their *business strategy* and *corporate structure*. Our model supports firms in the decision process by incorporating their data and allowing firms to include their expectations of how future business conditions may impact the need to make IT changes. Because the model is flexible enough to accept parameters across a range of business strategies and corporate structures, the model can help inform decisions and ensure that design choices are consistent with firm strategy.

*Keywords: Decision support systems, IT governance, Markov decision processes, case studies, IT infrastructure planning, global operations.*

## 1. Introduction

To compete in a global marketplace, firms are increasingly building relationships and engaging in transactions with partners and customers outside their country of origin. Firms globalize their operations to reduce costs, obtain labor and expertise, and pursue growth by accessing new markets [1, 6, 28].

As part of their global strategy and structure, many firms establish subsidiaries in other countries. While corporate headquarters (HQ) emphasizes firm-wide value creation and loss prevention, subsidiaries have a more limited scope of financial performance in their respective markets [7, 8]. The firm must define the extent to which each subsidiary is able to make decisions independently of HQ, to align subsidiary governance with firm-wide financial performance. Financial performance improves when firms allow subsidiaries to react to local market conditions rather than follow globally-standardized business processes [3, 14].

At the same time, granting decision authority to subsidiaries can create tension between subsidiaries and HQ, including decisions related to the governance of information technology (IT). Firms formulate their business strategy through their governance mechanisms, and then align their IT resources to support the business strategy [9, 20]. Prior to the 2002 Sarbanes-Oxley Act (SOX), firms tended to decentralize IT governance and delegate IT investment decisions to IT professionals closest to the problem [17]. While this decentralized approach offered the advantage for firms to better utilize their IT resources to respond to local market conditions, it also involved the risk that IT investments may not align with the overall business strategy [29]. This lack of IT-business alignment could increase the likelihood of wasted financial resources, user dissatisfaction, and security control failures, create managers who are reluctant to invest in future IT initiatives, and ultimately undermine financial performance [3].

Since SOX, many firms globally centralized IT decision-making processes to mitigate this risk, optimize resource allocations, satisfy users, strengthen controls, and support the firm's strategy [17, 36].

The primary argument for centralized IT governance is that influential managers are involved in making IT decisions. These managers prioritize IT projects based on their relevance to the firm's strategy, and ensure that important IT projects receive adequate funding [34]. When decision authority is decentralized, IT professionals (while close to the problem) may not understand the negative effects of their ideal "local" solution on other areas of the firm.

The opposing argument is that centralized IT decision-making may limit the influence of local managers in the IT decision-making process, when these managers may actually have a better understanding of the problem and their respective markets. IT professionals, closer to problems that are driven by local market conditions, may be in a better position to identify and define solution requirements and prioritize projects. Centralized IT infrastructure authority risks poor decisions due to a lack of knowledge and information overload in the face of multiple complex markets [18]. Based on this argument, many firms decentralize IT governance when subsidiaries offer different products/services or operate in diverse markets [16]. When markets are more diverse and dynamic, the firm may receive more requests for new IT systems and changes to existing IT systems. In diverse and dynamic markets where change requests are frequent and HQ has a limited understanding of the problem, better IT investment decisions can be made more quickly if subsidiaries have decision authority to apply their knowledge of the local market, and these IT investments will lead to superior financial performance [16].

We develop a model that enables firms with multiple subsidiaries and varying market conditions to determine the economic consequences of centralization/decentralization of IT decision authority. Our decision framework enables firms to evaluate costs and benefits associated with various IT infrastructure designs, under varying degrees of centralized and decentralized IT control, and to evaluate IT investment risks due to uncertain future conditions. Firms can use our model to identify whether the dynamism in different markets is sufficiently large to justify the higher cost and divergent systems/processes associated with decentralization. Our model supports managers and IT decision-makers in their efforts to align IT investments with the firm's strategic objectives. We base the model on interviews with senior managers involved in IT governance at four *Forbes Global 2000* firms headquartered in Northern Europe. While the firms operate in different industries, they indicate that a better understanding of the short- and long-term economic impact of various governance and control arrangements would be helpful in making future decisions.

The remainder of the paper is organized as follows. In Section 2, we review prior research on IT governance and IT investment decisions. In Section 3, we describe the problem setting. In Section 4, we develop a model to frame the decision of whether to centralize or decentralize IT decision authority as a discrete time, finite horizon, Markov decision problem (MDP). In Section 5, we present simulation results to illustrate application of our model to IT infrastructure and governance decisions for a global firm under a range of business environment conditions. In Section 6, we conclude with managerial implications and directions for future research.

## 2. Literature review

Prior research has identified five areas of IT governance – strategic alignment, risk management, resource management, value delivery, and performance measurement [39]. This paper focuses on the *strategic alignment* area of IT governance, and identifies the near-term and long-term costs and benefits associated with centralized/decentralized IT investment decisions. Strategic alignment requires senior managers to align IT strategies with overall business strategy as the focal point of their IT infrastructure. We offer a decision support model to ensure that IT investments are aligned with firm strategy in terms of centralization/decentralization, and we incorporate knowledge about future costs/benefits more formally into the IT decision-making process.

Prior research has studied the IT investment decisions of managers as a form of strategic alignment, and found that managers achieved better organizational performance when they had a strategic intent for IT investments [24]. While managers provide oversight for IT investment decisions [30], prior research has not reached a consensus on the extent of their involvement [39]. One study suggests that senior management needs to be involved, but does not go so far as to say that all decision rights should rest entirely with senior management [36]. Another study concludes that the strategic alignment decisions of IT reside on a continuum, and based on the context could be decentralized, centralized or mixed [15]. A third study surveyed 500 managers responsible for IT governance and conducted follow-up interviews with 30 CIOs [35], and finds that strategic alignment provides revenue growth when the environment ties accountability to business results and applications are effective, otherwise strategic alignment can lead to counterproductive IT investments.

Aligning IT investments based on business needs impacts the outcome of IT initiatives, such as ERP implementation [37]. Consistent with the arguments described above, some research supports centralization and other research supports decentralization. For example, one study found that productivity increased and loss ratios decreased as insurance firms used centralized IT planning and control [26], suggesting that centralized IT planning and control can improve financial performance. Another study found that the distinctive characteristics of CRM data processing and localized nature of CRM efforts are best supported when CRM technologies are loosely coupled to the broader infrastructure and governed locally [33].

This study contributes to the literature on the effects of oversight on IT investment decisions and the allocation of decision authority. Our model provides a basis for firms to evaluate the impact of market-specific factors on the need for subsidiaries to maintain decision authority and control over local IT investment decisions. While prior research focused on process and controls, this paper incorporates the *economic considerations* of IT decision authority and IT investment decisions with the *strategic alignment* considerations of IT governance. This is an important contribution, because decision makers are not merely focused on reducing IT costs, but with ensuring that IT investments are in the economic and strategic best interests of the firm. This study continues research into how decision support techniques can facilitate IT decisions, building on prior work in a knowledge warehouse setting [27], electronic market setting [29], and Internet server-based setting [5]. Our use of a Markov decision problem model is consistent with recent research that uses MDP for other IT governance issues such as workforce and data management [12, 21]. While these studies support improved performance of specific IT infrastructure, this study broadens and extends prior research by offering a decision support model to ensure that overall IT investments are aligned with firm strategy.

## 3. Problem Setting

For this study, we collaborated with four *Forbes Global 2000* firms with headquarters in Northern Europe and subsidiaries on several continents. All four firms have revenue over US$1 billion, with equities publicly traded on U.S. and European exchanges. Table 1 provides an overview of our case study firms and interviewees, including the industry, nature of product (durable vs. non-durable), and nature of customer (industrial vs. consumer) for each firm. To protect the confidentiality of our case study firms, we assign an anonymous name based on the firm's industry. For each firm, we collected data from European HQ and U.S. subsidiaries.

**Table 1**
Case study firms and executive interviewees

| **Firm** | **Product** | **Customer** | **Executive Interviewees** | |
|---|---|---|---|---|
| | | | **Europe** | **U.S.** |
| Equipment Firm | Durable | Industrial | Global CIO<br>Regional CIO | Regional VP/Controller<br>Manager IT Operations |
| Parts Firm | Non-Durable | Industrial | Global CIO<br>Deputy CIO | Regional Controller<br>Sales Unit Controller |
| Household Goods Firm | Durable | Consumer | Global CIO<br>Global CTO<br>Global IT Director | Regional IT VP<br>Regional Controller |
| Consumer Products Firm | Non-Durable | Consumer | Global CIO<br>Deputy CIO | Regional CIO<br>Regional IT Director<br>Regional Sales Director |

One of our objectives in this multiple case study was to understand the perceived value and trade-offs associated with centralized/decentralized IT planning and governance. Case studies are frequently used to understand a contemporary phenomenon when the problem-boundary is unclear [10, 40]. Our use of case studies to frame and provide context to a problem is consistent with recommendations to use case studies as a foundation for theory-building [11, 40]. Case studies have been used in prior decision support research on IT governance, such as work to identify governance processes for high performance data warehouses [38].

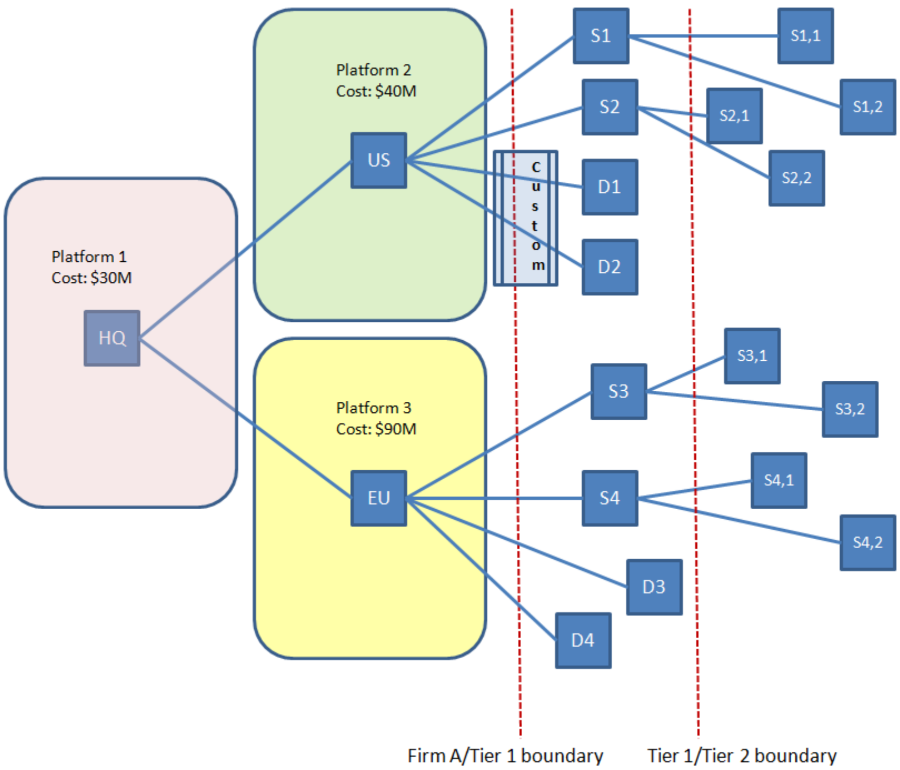
Data collection took the form of interviews that were supplemented with additional archival data including internal documentation and publicly-available information. This *data triangulation* approach enabled us to compare responses of interviewees with public data and confidential internal documents [4]. The interviews were based on semi-structured questions that asked senior managers to describe their current business challenges and IT strategies (see interview guide in Appendix A). In addition, respondents were asked to describe typical IT projects, the scope of these IT projects, and their occurrence.

Most interviews were attended by multiple members of the research team, and the data for each interview was analyzed by three members of the research team [23]. The interviews are transcribed in formal interview notes and maintained in a research database. Our data enables us to identify common high-level factors these MNCs utilize to make IT governance decisions, and these factors drove the formulation of our model. Our data confirms earlier research that found MNCs were inclined to centralized IT governance to achieve lower costs, but are concerned about the impact of centralized IT governance on agility and performance of subsidiaries [13, 19]. For example, the Global CIO of Equipment Firm stated that their efforts to adopt a common ERP system were hampered by the subsidiaries' reluctance to use common business processes, believing that each region "was fundamentally different." Similarly, subsidiaries of Parts Firm were disappointed when they were forced to migrate to a common ERP system, stating that they used to "jump over backwards for the customer" but were no longer able to do so.

### *3.1 Illustrative example*

As one example, consider the decision problem facing Consumer Products Firm, who shared specific IT infrastructure design challenges and estimates of IT costs with our research team. Consumer Products Firm has three primary business units. In addition to the corporate HQ in Northern Europe, the firm has a large subsidiary in Europe and a smaller subsidiary in the U.S. The European subsidiary sells products throughout the European Union, Scandinavia, and the United Kingdom. The U.S. subsidiary sells products throughout the U.S., Canada, and Mexico. In addition to their regional customers and distributors, both subsidiaries operate within a multi-tier supply chain environment with regional and foreign suppliers.  Figure 1 illustrates the basic operating environment.

**Figure 1**
Current operating environment of Consumer Products Firm



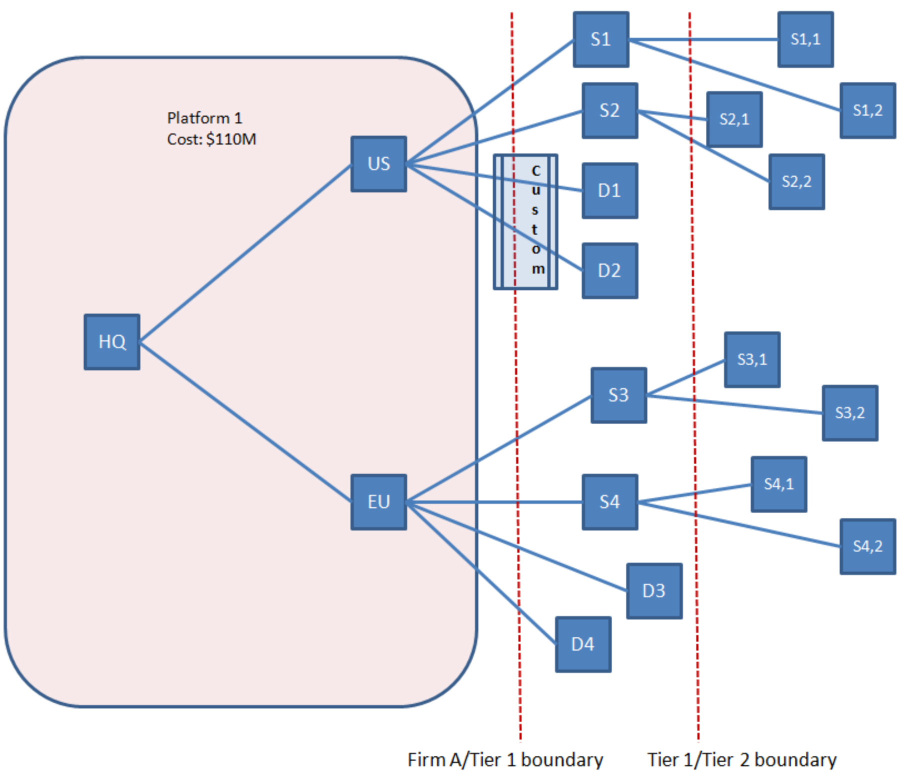

Notes:
1. In boxes, 'S' indicates supplier, and 'D' indicates distributor.
2. Amounts represent the firm's estimates of total 2009 system costs for three platforms.

As illustrated in Figure 1, the IT infrastructure of Consumer Products Firm consists of three separate but connected platforms, and each platform is associated with a corresponding annual cost.  The annual cost reflects all IT expenditures including maintenance, enhancements, modifications and integration.  Initially, the subsidiaries maintained decision authority over IT investments, and the only information required from HQ pertained to financial reporting data. Each subsidiary was free to build custom applications to improve performance.  For example, the

U.S. subsidiary invested significant resources to develop an application to obtain information from distributors for use by field sales representatives.

Consumer Products Firm identified an opportunity to achieve substantial cost reduction by consolidating the three separate platforms into a single platform. The firm would be able to reduce the number of applications and consolidate hardware, and the decrease in complexity would reduce ongoing costs associated with licenses and maintenance. The firm's goal was to move from the environment shown in Figure 1 to the environment shown in Figure 2.

**Figure 2**
Future operating environment for Consumer Products Firm




Notes:
1. In boxes, 'S' indicates supplier, and 'D' indicates distributor.
2. Amount represents the firm's estimate of total system costs for a combined platform.

While HQ was committed to ensuring that new IT infrastructure would continue to support all functionality currently in use, the subsidiaries had reservations about the plan. The overall goal, part of an "administrative excellence" initiative was to centralize the IT function to achieve greater efficiency and stability while retaining "some degree" of flexibility. The Global CIO believed the transition would benefit the overall performance of the firm, stating "If we are going to do something it needs to be under one umbrella." In contrast, the Deputy (European) CIO thought change should be gradual and that when it came to IT, the firm should strive for "good enough" rather than excellence. The U.S. Regional CIO was also skeptical, stating "The wrong IT [investments] might compromise business opportunities." The U.S. Sales Director was concerned that the ERP system and associated modules that formed the foundation of the new global platform were not well-suited to support many of the U.S. IT initiatives in place or planned for the near future. While it would still be technically possible for the U.S. subsidiary to move forward with those initiatives, the cost would be higher. The result would be a reduction in project return on investment (ROI) that would be large enough to scuttle some initiatives and reduce the attractiveness of the others.

There was additional concern that subsequent IT budgets for each subsidiary would have to be increased to accommodate requests for system enhancements, such as integration with suppliers and distributors. Absent a higher budget allocation for system enhancements, even good projects with strong ROI would begin to backlog. Further, U.S. subsidiary managers worried that their estimates regarding the need for future systems enhancements (derived from previous experience) may not reflect future needs in the new environment.

This example illustrates the fundamental challenge of determining how to allocate IT decision authority and control. On one hand, the firm must consider the potential benefits of centralization. On the other hand, the firm must also consider the potential economic and competitive impact of decisions that hinder the ability of subsidiaries to respond to local market conditions. The firm faces a decision environment where several alternative IT infrastructure plans are under consideration. Each plan specifies the substrate hardware, enterprise systems and modules the firm will support. We use the term *platform* to describe an enterprise system and its corresponding modules. The firm would like to identify the platform, or set of platforms, that maximizes expected ROI, yet is robust in the face of variability in extent to which systems enhancements are required. Our model enables firms to evaluate the short-, intermediate- and long-term financial implications of platform decisions on the costs and benefits associated with future IT initiatives. This helps to ensure that IT investment decisions are aligned with the firm's strategic goals by ensuring that the need for adaptability/local autonomy and the benefits of economies of scale/standard business processes are explicitly considered.

## 4. Valuation Model for IT Infrastructure Configuration

Our model uses available data to estimate short- and long-term costs and benefits of alternative IT infrastructure designs that use one or more different platforms under consideration. Our model assumes that IT governance should mirror the IT infrastructure design. This assumption is supported by prior research discussed in Section 2, and by our case study firms including Consumer Products Firm that serves as an example in this paper.

The model incorporates current data regarding cost and benefits of migrating to a new platform configuration (including cost of "reconnecting" to systems of business partners), future expectations of cost/benefits of IT change requests across a range of project categories, and historical data from IT project proposals to estimate the rate of change requests across project categories from each subsidiary. We model the decision problem as a discrete time, finite horizon, Markov decision process (MDP). Time is split into fixed-length intervals (periods). The process state is observed at the beginning of a period, and a decision is chosen from a finite set of possible decisions. Immediate costs and benefits are incurred depending on the state and the decision, which determines transition probabilities for the next state. That state is realized at the end of the period, the process state is updated, and the process repeats. This model seems appropriate for this setting, because IT strategic plans typically involve a finite time horizon. According to our interviews, the CIOs expect to revisit and likely replace enterprise platforms every seven to ten years. The episodic nature of IT decision-making is conducive to the discretization of time intervals where decisions can be modeled as occurring on a periodic basis.

### *4.1 Notation summary*

The essential notation for the description of the MDP is given below:

**Parameters**

*Q*: index set of subsidiaries ($Q = \{1, \dots, q\}$);

*s*: subsidiary index ($s \in Q$);

*P*: index set of IT platforms ($P = \{1, \dots, p\}$);

*j*: IT platform index ($j \in P$);

*M*: index set of time periods ($M = \{1, \dots, m\}$);

$b_t$: IT budget for new projects at time *t* (does not include ongoing maintenance).

*R*: index set of request categories ($R = \{1, \dots, l\}$);

*r*: category index for change requests ($r \in R$);

$v_{sj}$: cost of migrating subsidiary *s* to platform *j*, including all costs associated with hardware, software, integration, and implementation;

$a_{rjs}$: cost of completing a category *r* change request on platform *j* at subsidiary *s*;

$b_{rjs}$: benefit of completing a category *r* change request on platform *j* at subsidiary *s* (we allow for the fact that not all change requests will have a measureable benefit);

λ: discount rate of return (per period cost of capital).

**State Space**

$x_{rs}$: number of category *r* change requests not yet completed for subsidiary *s*;

$z_{sj}$: current platform of subsidiary *s;*

$t$: time period index ($t \in M$);

*X*: matrix of $x_{rs}$ values;

*Z*: array of $z_{sj}$ values;

*S*: process state ($S \coloneqq [X, Z, t]$).

**Random Variables**

$g_{rst}$: number of new category *r* change requests from subsidiary *s* at time *t*;

*G*: array of $g_{rst}$ variables.

**Decision Variables**

$y_{rst}$: number of category *r* change requests to complete for subsidiary *s* at time *t*;

$l_{sjt}$: whether subsidiary *s* is transitioned to platform *j* at time *t*;

*Y*: array of decision variables;

$\digamma(S)$: set of feasible decisions for a given state *S*;

*C*(*Y*): total benefit associated with decision *Y*.

**Objective Value**

$V_n(S)$: maximum expected n-stage value in state *S*.

### 4.2 *Process state*

Based on our interviews, none of the CIOs or IT Directors expected any enterprise system they selected to be in use for more than ten years. In the case of Household Goods Firm, the CIO expected the system to be in use for only five to seven years. Given that IT strategic plans and system life expectancy are finite with respect to time, we consider a decision process with a finite time horizon divided into *m* periods of constant length. The transition probability from state A to state B is constant from one period to the next. However, since the IT project budget can vary over the planning horizon, we include time in the state definition. We therefore have a stationary MDP where the process state is defined by the following:

- Current IT platform of each subsidiary
- Number of change requests for each project category for each subsidiary that have not been completed
- Time period.

### 4.3 *Constraints on decision variables*

For a state $S \coloneqq [X, Z, t]$, decision variables in $Y$ must satisfy:

- Budget:

$$\sum_s \sum_j v_{sj} l_{sjt} + \sum_r \sum_s a_{rjs} y_{rst} \leq b_t \quad (1)$$

- Project volume:

$$y_{rst} \leq x_{rs},\ \forall\, r, \forall\, s \quad (2)$$

- Platform requirements:

$$\sum_j l_{sjt} = 1, \forall\, s \quad (3)$$

- Non-negativity:

  $y_{rst} \geq 0$, integer (4)

All decisions Y that satisfy (1) – (4) for a state $S$ are denoted by $\digamma(S)$. Additional constraints can be added. For example, there may be projects that must be completed to maintain system integrity and security. While these projects may not have a direct measureable ROI, they must be completed to ensure ongoing reliability of the IT infrastructure.

### *4.4 Stage reward*

Once a feasible decision *Y* has been made at the beginning of a period, there are a number of immediate expected costs and rewards. First, there is the expected positive reward $b_{rs}$ to the firm from completing a change request of category *r* for subsidiary *s*. The firm also incurs a financial cost $a_{rs}$ associated with the completing the change request. In addition to costs and benefits associated with individual change requests, there could also be a cost $v_{sj}$ associated with migrating subsidiary *s* to platform *j*. The stage reward associated with *Y* is:

$$C(Y) = \sum_r \sum_s b_{rs} y_{rst} - \sum_s \sum_j v_{sj} l_{sjt} - \sum_r \sum_s a_{rs} y_{rst}. \quad (5)$$

$C(Y)$ can be positive or negative. If $\sum_r \sum_s b_{rs} y_{rst} > \sum_s \sum_j v_{sj} l_{sjt} + \sum_r \sum_s a_{rs} y_{rst}$, then the benefits associated with selected projects, represented by the first term in the stage reward function, outweigh the costs associated with those projects, and vice versa.

### *4.5 Transition probabilities*

Uncertainty in the problem is related to the frequency of each category of change request from each subsidiary. We assume that the entries of $G \coloneqq [g_{rst}]$ are statistically independent of each other. Let $S \coloneqq [X], [Z]$ be the current state, $Y \in \digamma(S)$ the chosen decision array, and $\hat{S} \coloneqq [\hat{X}], [\hat{Z}]$ after existing change requests are completed and new project requests arrive. State $\hat{S}$ is updated as follows:

$$\hat{x}_{rs} = x_{rs} - y_{rst} + g_{rst} \tag{6}$$

$$\hat{z}_{sj} = l_{sjt} \tag{7}$$

$$\hat{t} = t + 1 \tag{8}$$

The transition probability from $S$ to $\hat{S}$, given decision $Y$, is

$$P_{S\hat{S}(Y)} = \prod_{s \in Q} \prod_{r \in R} \mathcal{P}\{g_{rst} | z_{sj} = \hat{x}_{rs} - x_{rs} + y_{rst}\}. \tag{9}$$

### 4.6 *Objective function*

$$V_1(S) = \max_{Y \in \digamma(S)} C(Y), \tag{10}$$

$$V_n(S) = \max_{Y \in \digamma(S)} \{C(Y) + \textstyle\sum_{\hat{S}} \lambda P_{S\hat{S}}(Y) V_{n-1}(\hat{S})\}, n > 1. \tag{11}$$

The complexity of computing $V_n(S)$ for $n > 1$ depends on the size of the decision space $\digamma(S)$. For most real-world scenarios involving up to 10 subsidiaries, 50 change request categories, and a 10-year planning horizon, computing $V_n(S)$ is computationally tractable. The simulation and analysis of Consumer Products Firm in the next section included three subsidiaries, 15 project categories, and the MDP coded on a Lenovo T510 laptop with 2.53 GHz Intel Core i5 processor and 4 GB RAM, which arrived at a solution in less than one minute per problem instance.

## 5. Simulation and Analysis

The simulation is based on the decision problem facing Consumer Products Firm illustrated in Figures 1 and 2, in which Consumer Products Firm is trying to decide which business units to place on Platform 1 and which to place on Platform 2.

**Table 2**
IT configuration options for Consumer Products Firm

| Configuration | Headquarters | European subsidiary | U.S. subsidiary |
|---|---|---|---|
| 1 | Platform 1 | Platform 1 | Platform 1 |
| 2 | Platform 1 | Platform 1 | Platform 2 |
| 3 | Platform 1 | Platform 2 | Platform 1 |
| 4 | Platform 2 | Platform 1 | Platform 1 |
| 5 | Platform 1 | Platform 2 | Platform 2 |
| 6 | Platform 2 | Platform 2 | Platform 1 |
| 7 | Platform 2 | Platform 2 | Platform 2 |

Note:
1. While Consumer Products firm was seriously considering only the first two options (shaded), our simulation would enable the firm to consider all seven options.

In essence, IT decision makers were trying to decide whether to migrate all business units to the lower cost platform (Platform 1) where system modifications are more costly (where $v_{sj}$ parameter values are lower and $a_{rjs}$ parameter values are higher), or to allow the U.S. subsidiary to remain on the more expensive Platform 2 that is more flexible and less costly to modify. As suggested in Table 2, if data is available our decision support model can enable decision makers to evaluate the potential benefit of a large number of design alternatives.

Consumer Products Firm did have good estimates of the expected cost of placing each business unit on either Platform 1 or Platform 2. The impact of change requests and ongoing system enhancements were not as clear. We base the project categories on five areas shown in Table 3, identified in prior research [22] to help Consumer Products Firm better estimate the types of potential projects and the financial impact of those projects. While we found this framework to be helpful, our model allows IT decision-makers to define their own categories.

**Table 3**
Events that can motivate changes to IT platforms

| Event type | Example | Source of benefit | Source of cost |
|---|---|---|---|
| New application | Installation of new application due to business or IT changes. | Value generated by new application. | Cost of installing new application on IT infrastructure. |
| Scaling | Increase in number of transactions due to changes in business conditions or extension into new markets. | Value generated by new transactions. | Cost of scaling IT infrastructure. |
| Integration | Need to integrate applications due to mergers, supply chain management initiatives, etc. | Value generated by improved information flow. | Cost of required integration. |
| System modification | Need to combine data from multiple formats as decision aids. | Value of improved decision-making. | Cost of modifying application to produce data in required format. |
| Security | Hacker attempts necessitate more robust firewall. | Potential negative impact on transaction volume and potential loss of valuable data. | Cost of procedures required to address threat and restore the IT infrastructure. |

Note:
1. Event types based on prior research [22].

We further divided each type of event in Table 3 into categories based on the size and scope of requested changes, and estimates of corresponding cost/benefits provided by Consumer Products Firm. Table 4 illustrates the change request data structure used in the simulation.

**Table 4**
Cost/benefit data structure for Consumer Products Firm U.S. subsidiary

| Category index | Main category | Request size | Expected frequency (annually) | Platform 1 Expected cost ($k) | Platform 1 Expected benefit ($k) | Platform 2 Expected cost ($k) | Platform 2 Expected benefit ($k) |
|---|---|---|---|---|---|---|---|
| 1 | New application | Small | 160 | 20 | 25 | 15 | 25 |
| 2 | New application | Medium | 40 | 80 | 100 | 50 | 100 |
| 3 | New application | Large | 8 | 300 | 400 | 150 | 400 |
| 4 | Scaling | Small | 40 | 15 | 25 | 15 | 25 |
| 5 | Scaling | Medium | 20 | 60 | 90 | 60 | 90 |
| 6 | Scaling | Large | 8 | 200 | 400 | 200 | 400 |
| 7 | Integration | Small | 120 | 10 | 15 | 5 | 15 |
| 8 | Integration | Medium | 20 | 80 | 150 | 30 | 150 |
| 9 | Integration | Large | 4 | 400 | 650 | 200 | 650 |
| 10 | System modification | Small | 120 | 10 | 15 | 5 | 15 |
| 11 | System modification | Medium | 40 | 15 | 20 | 10 | 20 |
| 12 | System modification | Large | 12 | 100 | 200 | 50 | 200 |
| 13 | Security | Small | 200 | 5 | 10 | 5 | 10 |
| 14 | Security | Medium | 24 | 20 | 45 | 20 | 45 |
| 15 | Security | Large | 4 | 110 | 280 | 110 | 280 |

The cost parameters shown in Table 4 are expected values provided by the U.S. subsidiary of Consumer Products Firm, based on historical observations working with Platform 2 and estimates of what costs would be on Platform 1 (see Appendix B for estimates for HQ and European subsidiary). Ideally, costs would be exact rather than estimates, but in reality estimated costs often represent the best information firms have available when making decisions. Since there is uncertainty in cost estimates, we conduct simulations to test the robustness of a decision to variation in the cost, benefit and frequency of different types of change requests. Most importantly, our model is flexible to accommodate any set of parameter values or project categorization schema. This allows for sensitivity analyses to evaluate the impact of variation in parameter values on infrastructure configuration decisions.

### *5.1 Simulation details*

In this simulation we compare economic benefits derived from the recommendations provided by our comprehensive MDP model that considers costs and benefits simultaneously, with more limited recommendations that would result from a heuristic focusing primarily on IT cost (Heuristic A described below), or a heuristic focusing primarily on IT strategy (Heuristic B also described below).

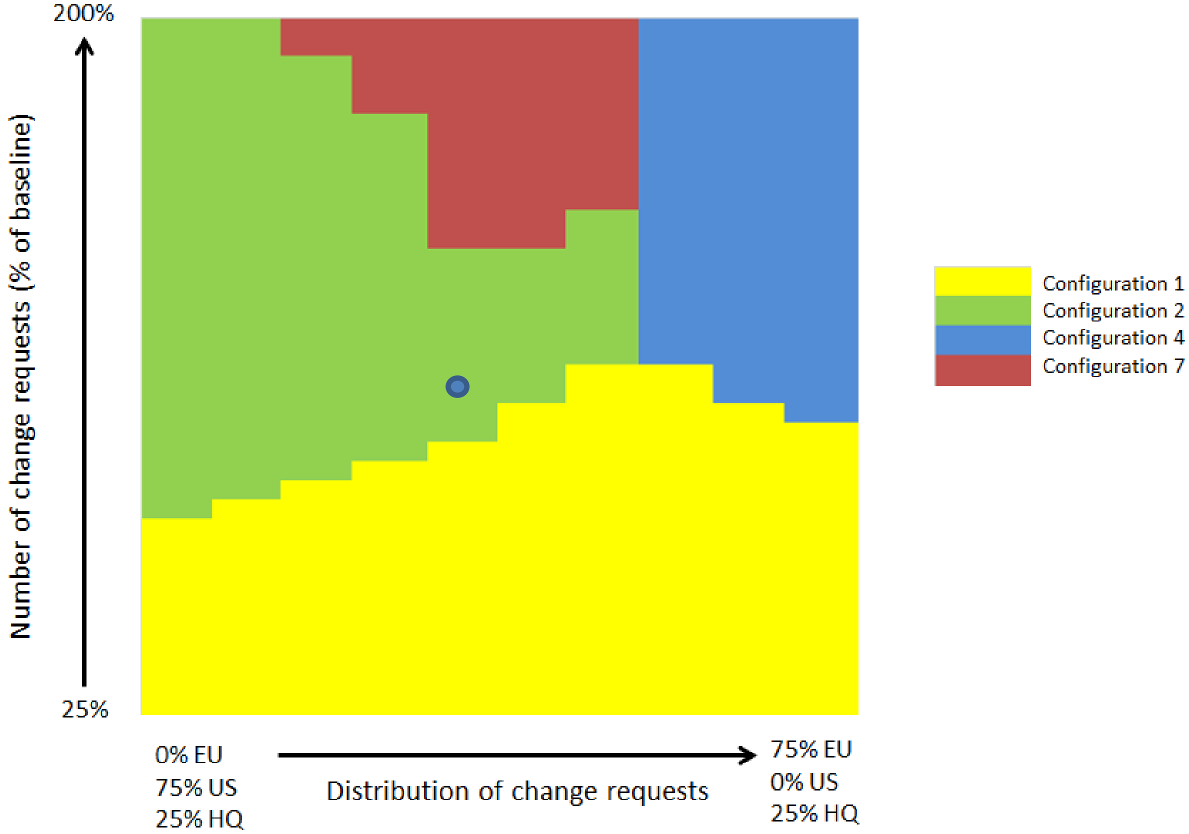
In Heuristic A, IT is a cost center [17] and the objective is to minimize expenditure by simultaneously minimizing cost and deviations from defined work flows that would require future system changes. This logic assumes that best practices have been identified and incorporated into existing systems (though the assumption was rarely tested). In our case study, we observed this heuristic at Equipment Firm and to a lesser extent at Parts Firm, where the CIOs believed that heavy investment in long-term infrastructure and tightly-integrated supply chains made frequent process changes undesirable.

In Heuristic B, IT is an enabler of value creation and the objective is to invest in systems that enable the firm to respond to rapidly evolving market conditions [32]. We observed this heuristic at the U.S. subsidiaries of Consumer Products Firm and Household Goods Firm. Firms with this mindset view IT investments as opportunities to create new processes and reconfigure existing processes. While simplistic, these decision heuristics reflect views about the future business environment of the firm. Our simulation makes significant progress by simultaneously considering cost and value [31], in the same way that the supply chain efficiency curve considers both efficiency and responsiveness [2], and financial portfolio theory considers both risk and return [25].

## *5.2 Simulation and analysis*

We compare the three decision rules described in Section 5.1 which we will refer to as minimum cost (Heuristic A), maximum responsiveness (Heuristic B), and MDP respectively. We assume the actual number of change requests for each subsidiary in a given period ($g_{rst}$) follow a Poisson distribution with parameter λ. Baseline λ is set to the expected number of change requests given by Consumer Products Firm for each business unit. The value of λ is varied from 25% to 200% of the baseline value in 5% increments (36 design points). We further analyze the impact of changes in distribution of change requests across subsidiaries on the platform recommendation. The baseline distribution of change requests is set to the actual distribution of change requests based on information provided by Consumer Products Firm (25% from HQ, 30% from the European subsidiary, and 45% from the U.S. subsidiary). For ease of exposition, we hold the proportion of change requests from HQ constant and vary distribution of the remaining 75% of change requests from 0% Europe/75% U.S. to 75% Europe/0% U.S. in 5% increments (15 design points). This yields 540 simulation design points. Assigning an expected cost and benefit to each change request was a two-stage process. First, the total number of change requests for each subsidiary is determined. Second, change requests are allocated proportionally to categories based on their relative frequency and then assigned a corresponding cost and benefit. Figure 3 shows the recommendations (from the seven possible configurations listed in Table 2) provided by the MDP for the different simulation design points.

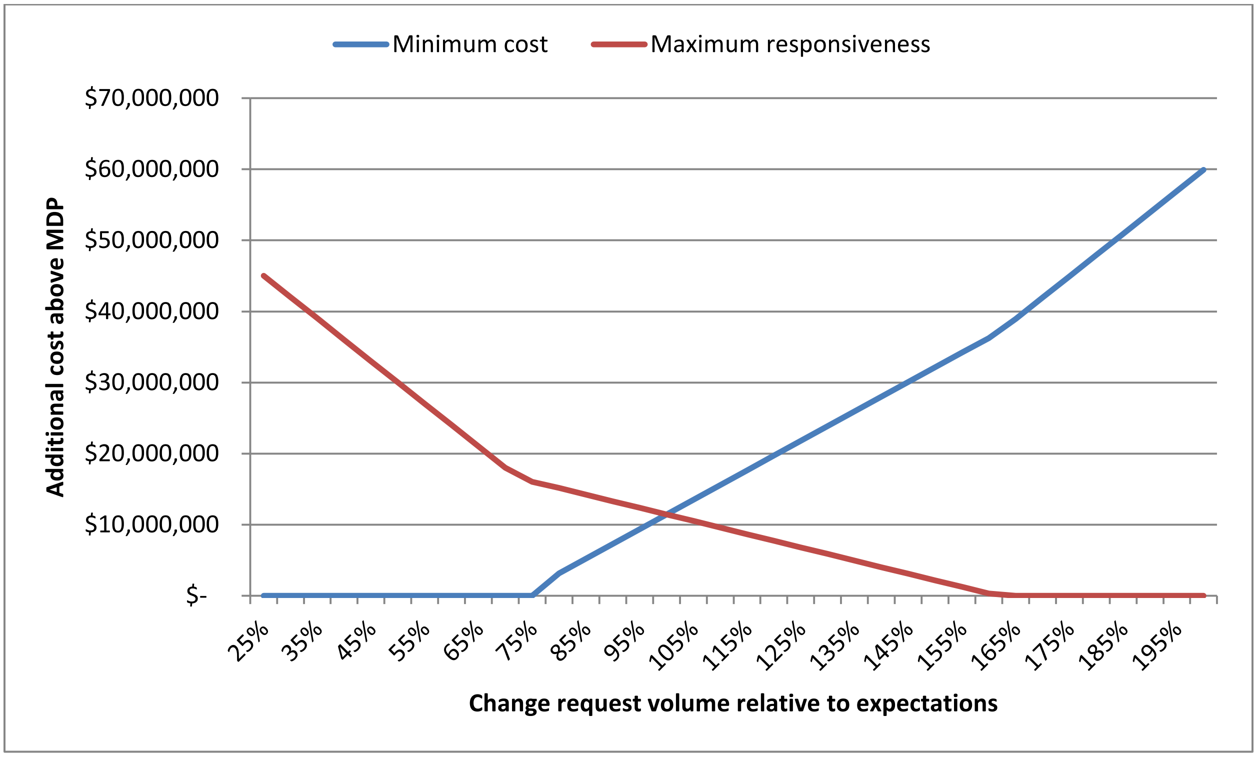
**Figure 3**
MDP recommendations




Based on the expected rate and distribution of change requests (illustrated by the 'bulls eye' on Figure 3), Consumer Products Firm is economically better off adopting Configuration 4, which allows the U.S. subsidiary to remain on Platform 2. This decision would not change without a significant decrease in either the rate of change requests or in the distribution of change requests. Figure 4 provides a more detailed look at the relative cost of following the cost minimization approach (Heuristic A) and the maximum responsiveness approach (Heuristic B), relative to recommendations provided by the MDP.

**Figure 4**

Additional seven year cost of alternate decision rules relative to MDP




The costs shown in Figure 4 represent the additional IT expense Consumer Products Firm would incur as the volume of change requests varied from the current baseline level and the proportion of requests from each business unit remained constant at the current baseline level. For the cost minimization approach (Heuristic A) to be the most effective, total expected change requests would have to fall to less than 78% of current levels. For the maximum responsiveness approach (Heuristic B) to be the most effective, total change requests would have to increase to more than 165% of current levels. These thresholds coincide with instances where the minimum cost approach and the maximum responsiveness approach yield the same recommendation as the MDP approach.

## 6. Managerial implications and future research

While senior managers are motivated to contain IT costs, they are also tasked to deploy IT to support the business in the various markets in which it competes. Our model enables firms to evaluate the financial implications of alternative IT infrastructure configuration plans. In addition to identifying the best course of action for a set of circumstances, our model enables IT decision makers to identify the breakpoints that define when an alternate course of action should be taken. This is an important contribution because while prior research has shown that firms are motivated to either centralize or decentralize IT, the cost of making the wrong decision is high. Our model supports firms in the decision process by incorporating their own data and allowing them to include their own expectations of how future business conditions may impact the need to make IT changes.

Our model can also help firms to prepare long-range budgets. By having a better understanding of the rate of change requests across subsidiaries, and matching the IT infrastructure to reflect those requests, firms will have a better understanding of how to allocate resources to each subsidiary for future projects. For example, a firm may be better off with a centralized common infrastructure across all subsidiaries. However, one subsidiary might compete in a more dynamic environment, but not sufficiently dynamic to justify a decentralized IT infrastructure. As an alternative, that subsidiary would require a change request budget that is disproportionately large compared with its overall IT budget to accommodate the level of local responsiveness and innovation it needs to succeed.

Our model is not without limitations in terms of implementation and external validation of recommendations. While an MDP approach ensures internal validity with respect to input parameters, the external validity of the model is dependent on whether future costs, benefits and frequency of various change requests are consistent with historical and/or expected values. While decision-makers can conduct sensitivity analyses, our model can only provide an optimal investment policy based on available information, and the final recommendation cannot be guaranteed optimal in the face of unknown future conditions. In addition, our MDP model assumes a stationary stochastic process over time. Even if costs, benefits and frequency of change requests are consistent with expectations, an environmental shift to a non-stationary stochastic process would violate the assumptions of our model and justify the need for alternate solution methodologies.

While our model provides useful information, there are opportunities for future research to make improvements on this model. For example, once one subsidiary is on a given platform, the incremental cost of placing another subsidiary on the same platform may decrease due to lower licensing fees, shared hardware, and shared expertise. A decision model that captures these non-linear costs would be very useful. In addition, our model assumes one-year time periods and that projects/programs are completed during each time period. In fact, many of the largest IT projects span multiple years, which can impact budget allocations and recognition of benefits. Incorporating projects spanning multiple time-periods into a framework for valuing IT infrastructure flexibility would also be a useful topic for future research.

In conclusion, executives responsible for IT governance seek to minimize technology costs, while ensuring that the infrastructure can accommodate increasing utilization, new software applications, and modifications to existing software applications. To address this challenge, we used interviews with executives from four *Fortune 200 Global* firms to develop a discrete-time, finite-horizon Markov decision model to identify the most economically-beneficial IT infrastructure configuration from a set of alternatives. Our decision model enables firms to evaluate the costs and benefits associated with alternative IT infrastructure designs, under varying degrees of centralized/decentralized IT control. Our model and findings will be useful as firms continue to expand their operations to compete in the global marketplace.

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## Appendix A: Sample Questions for Semi-Structured Interviews

*Headquarters questions*

1. What are the strategy and goals for the company as a multi-national corporation (MNC)?

2. What challenges does the company face in achieving its strategy and goals?

3. How does the company work to address these challenges [using organizational structure, IT systems, and/or business process changes]?

4. How does the company evaluate the success/failure of its initiatives [organizational, IT, business process]?

5. From the perspective of the firm, what is the desired relationship between headquarters and subsidiaries?

6. What type of information needs to be exchanged between headquarters and subsidiaries to establish and maintain this relationship?

7. Do headquarters and subsidiaries share a common view on the desired relationship and the need for information exchange?

8. Are there barriers to a common view and/or information exchange? If so, what are the barriers? How is the company working to overcome the barriers?

*Subsidiary questions*

1. Which of the functions listed below are performed at the subsidiary level? Are the associated business processes unique to the subsidiary, or are the processes based on headquarters directives?

    a. R&D/product design
    b. Procurement
    c. Production/manufacturing
    d. Marketing/advertising
    e. Sales/service
    f. IT/IS
    g. Finance/accounting
    h. HR
    i. Other

2. Please briefly describe the current IT/IS at the subsidiary level:

   a. Network/intranet
   b. Data center
   c. ERP
   d. Procurement
   e. Supply chain management
   f. Warehousing/distribution
   g. CRM
   h. Electronic commerce
   i. Major initiatives underway
   j. Other

3. What are the general strategy and goals for the subsidiary? How are these related to the firm's global strategy? How does the IT/IS function support the subsidiary's goals?

4. From the subsidiary's perspective, what is the desired relationship between the subsidiary and headquarters?

5. What type of information is exchanged with headquarters? What type of information is exchanged with other subsidiaries? Are there any barriers to information exchange, and if so, how does the subsidiary work to overcome these barriers?

6. Are there any local market aspects that have had a great impact on the current IT/IS state? Are there any corporate functions (see list under subsidiary question 1 above) that present unique requirements for the current IT/IS state?

7. Where are the major of high-level IT/IS decisions made – at the subsidiary or at headquarters? What role does your position play to define the information and application architecture? To what extent do IT/IS and executive leadership in other areas collaborate to define architecture and application strategy and implementation?

## Appendix B: Cost, benefit, and project frequency parameters

### Table B1

Cost/benefit data structure for Consumer Products Firm HQ

| Category index | Main category | Request size | Expected frequency (annually) | Platform 1 Expected cost ($k) | Platform 1 Expected benefit ($k) | Platform 2 Expected cost ($k) | Platform 2 Expected benefit ($k) |
|---|---|---|---|---|---|---|---|
| 1 | New application | Small | 80 | 20 | 25 | 15 | 25 |
| 2 | New application | Medium | 20 | 80 | 100 | 50 | 100 |
| 3 | New application | Large | 5 | 300 | 400 | 150 | 400 |
| 4 | Scaling | Small | 24 | 15 | 25 | 15 | 25 |
| 5 | Scaling | Medium | 12 | 60 | 90 | 60 | 90 |
| 6 | Scaling | Large | 4 | 200 | 400 | 200 | 400 |
| 7 | Integration | Small | 80 | 10 | 15 | 5 | 15 |
| 8 | Integration | Medium | 10 | 80 | 150 | 30 | 150 |
| 9 | Integration | Large | 4 | 400 | 650 | 200 | 650 |
| 10 | System modification | Small | 60 | 10 | 15 | 5 | 15 |
| 11 | System modification | Medium | 20 | 15 | 20 | 10 | 20 |
| 12 | System modification | Large | 5 | 100 | 200 | 50 | 200 |
| 13 | Security | Small | 200 | 5 | 10 | 5 | 10 |
| 14 | Security | Medium | 24 | 20 | 45 | 20 | 45 |
| 15 | Security | Large | 4 | 110 | 280 | 110 | 280 |

### Table B2

Cost/benefit data structure for Consumer Products Firm European subsidiary

| Category index | Main category | Request size | Expected frequency (annually) | Platform 1 Expected cost ($k) | Platform 1 Expected benefit ($k) | Platform 2 Expected cost ($k) | Platform 2 Expected benefit ($k) |
|---|---|---|---|---|---|---|---|
| 1 | New application | Small | 80 | 30 | 40 | 25 | 40 |
| 2 | New application | Medium | 20 | 125 | 150 | 125 | 150 |
| 3 | New application | Large | 4 | 450 | 600 | 225 | 600 |
| 4 | Scaling | Small | 12 | 25 | 40 | 25 | 40 |
| 5 | Scaling | Medium | 6 | 90 | 135 | 100 | 135 |
| 6 | Scaling | Large | 4 | 300 | 600 | 300 | 600 |
| 7 | Integration | Small | 50 | 15 | 25 | 5 | 25 |
| 8 | Integration | Medium | 6 | 120 | 225 | 50 | 225 |
| 9 | Integration | Large | 4 | 600 | 1000 | 300 | 1000 |
| 10 | System modification | Small | 60 | 15 | 25 | 5 | 25 |
| 11 | System modification | Medium | 40 | 25 | 30 | 25 | 30 |
| 12 | System modification | Large | 4 | 150 | 300 | 75 | 300 |
| 13 | Security | Small | 200 | 10 | 15 | 10 | 15 |
| 14 | Security | Medium | 24 | 30 | 75 | 30 | 75 |
| 15 | Security | Large | 4 | 175 | 400 | 175 | 400 |

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