Economics of Identity and Access Management: Providing Decision Support for Investments

Marco Casassa Mont, Yolanta Beresnevichiene, David Pym, Simon Shiu
Systems Security Lab
Hewlett-Packard Laboratories
Long Down Avenue, Stoke Gifford, Bristol BS34 8QZ, England, UK
marco.casassa-mont@hp.com, yolanta.beres@hp.com, david.pym@hp.com, simon.shiu@hp.com

Abstract— **Identity and Access Management (IAM) is a key enabler of enterprise businesses: it supports automation, security enforcement, and compliance. However, most enterprises struggle with their Identity and Access Management strategy. Discussions on IAM primarily focus at the IT operational level, rather than targeting strategic decision-makers' issues, at the business level. Organizations are experiencing an increasing number of internal and external threats and risks: there is scarcity of resources and budget to address them all. Decision-makers (e.g., CIOs, CISOs) need to prioritize their choices and motivate their requests for investments. This applies for investments in IAM vs. other possible security or business investments that could be made by the organization. In this context, a range of possible IAM investment options has an effect on multiple strategic outcomes of interest, such as assurance, agility, security, compliance, productivity, and empowerment. We have developed a repeatable approach and methodology to help organizations work through this complex problem space and determine an appropriate strategy, by providing them with decision support capabilities. The proposed approach, validated in collaboration with security and IAM experts, couples economic modelling (which explores decision-makers' preferences between the different outcomes) with system modelling and simulations to predict the consequences (likely outcomes) associated with different investment choices and map them against decision-makers' preferences, in order to identify the most suitable investment options. We illustrate how this methodology has been applied in an IAM case study, in a business-driven context with core enterprise services. This work is in progress. We discuss current results and next steps.**

Keywords: IAM, Economics, Decision Support, Identity Analytics, Modelling, Simulation, Security, Strategic Preferences

I. INTRODUCTION

Identity and Access Management (IAM) solutions (providing provisioning, compliance and enforcement capabilities) are widely adopted by organizations to enable their businesses, support user management, access control, and compliance as well as deal with related security risks. However, most enterprises struggle with their IAM strategy. It is not just an IT matter. Enterprises are experiencing an increasing number of internal and external threats: there is scarcity of resources and budget to address them all. Decision-makers (e.g. Chief Information Officers — CIOs, Chief Information Security Officers — CISOs) are increasingly asked to prioritize and motivate their requests for investments. This applies for investments in IAM vs. other possible security or business investments that could be made.

The specific problem addressed by our work is how to enable these decision-makers to make informed decisions about their IAM strategy and related investments. It is a matter of understanding and dealing with the *Economics of IAM*. IAM strategy directly affects organizations' business in terms of agility, productivity, user experience, security risks and compliance. It is challenging because it can be very difficult to determine how different combinations of technology and process will affect these business outcomes. Choices have to be made without knowing the future business needs and threat landscape. In general this is an example of a problem with multiple attributes, choices, outcomes and stakeholders with high degrees of uncertainty. However organizations see ongoing growth and changes in applications, resources, roles and users, which mean that security teams must regularly address this problem. Moreover, given the cost constraints, a more rigorous approach is needed both to make the case for appropriate investments and to show due diligence to regulators.

Recent work and research activities — e.g., [1,2,3,4,5,6] — highlighted the limitations of techniques based on Return-of-Investment approaches, especially when adopted in security contexts, as the calculations do not adequately address the involved operational and dynamic aspects. Traditional consulting in this area is also often based either on generic risk assessment and common security practices (e.g., ISO2700x, CoBit, etc.) or driven by the agenda of selling portfolios of IAM products/solutions.

In this paper, we describe our approach to this problem, based on exploring decision-makers' preferences on strategic aspects of relevance and using system modelling and simulation to identify and predict how different portfolios of IAM investments would suit these needs. As a significant example, we discuss how this approach has been used in an enterprise IAM case study, involving core business services provided by SAP applications. This approach has been validated by security and IAM experts. Our work still requires refinement, but the initial results are encouraging and provide a starting point for further research and investigation. Current results and next steps are presented and discussed.

II. Economics of Identity and Access Management

Decision-makers operating in the IAM space (e.g., CIOs, CISOs) must cope with different tension points at the business, security, governance levels and worry about the involved trade-offs. They need to make informed IT investment decisions in a complex, ever changing world. They would love to get decision support capabilities to simplify their work.

To succeed in providing these capabilities, the *economics* that are at the base of strategic IT investment decisions need to be understood. We assume that there should be an economic framework within which the value of different investment outcomes can be explored and discussed. This involves identifying the major *business and strategic outcomes* of concern and determining the different stakeholders intuitive views for how these trade-off, and their preferences for overall outcomes. In this context *traditional IT metrics* are of relevance if they can help ground the analysis, by factoring in measures from underlying IT systems and processes.

In the IAM space, our analysis of decision-makers' concerns (leveraging interviews with CIOs and CISOs and security and IAM experts) has identified the following core strategic outcomes of relevance along with examples of related (IT) metrics: ***security risks*** (metrics: data breaches and incidents); ***productivity*** (metrics: correctly granted access rights); ***compliance to regulations*** (metrics: audit failures); ***costs*** (metrics: fixed and operational costs set by the financial controller).

Within an organization, different strategic decision-makers usually have different priorities; a CISO might be specifically worried about security risks and involved IT costs; a business and application manager might be worried about user productivity; a governance manager might give top priority to compliance to regulation. These multiple objectives trade off with each other. For example, security risks can be addressed potentially at the expense of productivity. Compliance management can reduce the risk of audit failures but it might also negatively impact productivity. All of these aspects have budget implications.

It is important to identify the overall organization (or decision-makers') preferences for achieving these objectives. Ideally the goal would be to encapsulate these preferences in a formal *utility function* (see [17] for utility theory) of the company and/or the decision-makers, so that a "comparative value" can be applied to each outcome. Utility functions take the form

$$U = \omega_1 f_1(T1 - \overline{T1}) + \omega_2 f_2(T2 - \overline{T2}) + \ldots + \omega_n f_n(Tn - \overline{Tn})$$

where Ti $(1 \le i \le n)$ represent the outcomes of interest - for example, *security risks, productivity, compliance and costs*; $\overline{Ti}$ $(1 \le i \le n)$ represent the decision-maker's targets for these outcomes. The functions f_i $(1 \le i \le n)$ represent the decision-maker's tolerance for variance from the targets. Finally, the weights ω_i $(1 \le i \le n)$ represent the decision-maker's preferences between the component outcomes.

If the decision-maker is equally tolerant for going over or under target for a specific outcome, the f_i can potentially be represented as a quadratic function. This choice, which has a well-supported theoretical basis captures diminishing marginal utility. For example, if the outcome component is cost, overspending by £500 is just as bad as under spending by the same amount. If the decision-maker's expresses asymmetry for exceeding the target for a component, then it is necessary to use functional forms such as Linex functions: $f(x)=(e^{\alpha x}-\alpha-1)/\alpha^2$. These functions capture this asymmetry appropriately. For example, the marginal utility of *compliance* and *productivity* might have a steeper gradient below target than above.

In the context of *IAM Economics*, one or more utility functions could be identified for the involved strategic decision-makers and/or for the organization. Let us consider the example of a decision-maker that (a) is concerned about *security risks, productivity, compliance, and costs*, with different priorities, expressed with weights ω_i, and that (b) is equally tolerant for going over or under target for each outcome. A related utility function could be the following:

$$U = \omega_1 (SR - \overline{SR})^2 + \omega_2 (P - \overline{P})^2 + \omega_3 (CO - \overline{CO})^2 + \omega_4 (C - \overline{C})^2$$

where the variables identify the decision-maker's strategic aspects of relevance (**SR**: security risks, **P**: productivity, **CO**: compliance, **C**: costs) against the desired related stakeholders' targets.

In practice it is hard to identify and instantiate this utility function, purely from an abstract analytic approach, without taking into account the implications that potential IAM investments have on the organization i.e. the impact on operational and business processes, people behaviour, the underlying IT systems, existing and foreseeable security threats (e.g. internal and external threats perpetrated by employees, attackers).

We believe that it is possible to tackle this issue and provide strategic decision support to decision-makers by (a) *explicitly eliciting their preference* on strategic outcomes of interest and (b) adopting *system modelling and simulation techniques* to explore and predict (estimate) the impact of investment choices for the organization and map these outcomes against the decision-makers' preferences in order to identify suitable investment options. We believe this creates awareness of available strategic options and enables discussions at the business level. The next section introduces the adopted methodology.

III. Methodology for Strategic Decision Support

This methodology fundamentally integrates two main approaches: (1) executable mathematical models of the underlying systems and processes along with their dynamic threat environments [7,14,18]; (2) methods from economics — specifically, utility functions and their associated dynamic analysis — together with empirical data-collection techniques [7,8,10].

Modelling and simulation have been used in various fields (e.g., hydrology, land usage, manufacturing processes, environmental and social science) to provide decision support: surveys and data-gathering activities are also used to ground

these models. Their use in security and IT, coupled with methods from economics, is, however, new [7,8,10].

Recent work by the current authors and others — e.g., [2,3, 7,8,9,10] — has begun to develop a methodology that integrates these two approaches and demonstrates its feasibility. Figure 1 provides an overview of the methodology.

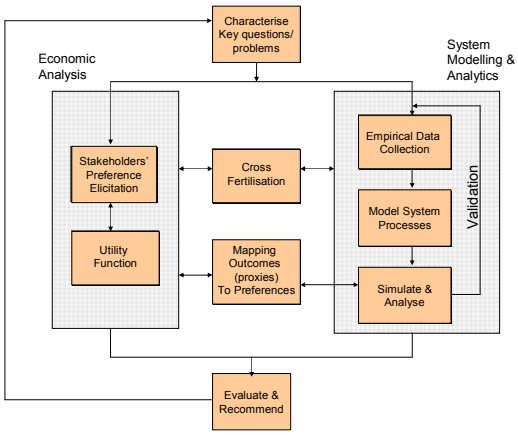


Figure 1. Overview of the Methodology

After characterizing an investment problem, an economic model is built based on strategic preference elicitation; this drives a subsequent system modelling phase that helps to ground concepts in a specific organizational context; the resulting system model(s) provides predictions of the impact of various investment choices along with estimates of the utility functions' components. This finally helps to identify the most suitable approach and investment choice. Multiple iterations and cross-fertilizations activities (between the economic and system modelling areas) might be required to refine the model and provide effective support to decision-makers.

In this context, strategic preferences are elicited from the decision-maker by using targeted questionnaires, aiming at identifying priorities and potential suitable trade-offs. Executable mathematical models not only take into account these preferences and targets but also the constraints inherent in the problem e.g. architectural, policy, business and IT processes and user behaviors - in the context of organizational dynamic threat environments.

The behavior of the model can be simulated in the presence of a (stochastic) representation of the dynamic threat environments and across different investment choices. Its predictions can then be validated against the targets and preferences of the decision-maker. These predictions can be thought as *proxies* (based on metrics and measures) to estimate utility function's components. The model may then be refined appropriately, as the decision-maker's understanding of the appropriate targets and preferences in response to the initial problem may itself be subject to reassessment and refinement.

In the specific context of IAM, system modelling can be used to capture the effects and implications of making different IAM investment choices — in areas such as *user provisioning, compliance monitoring and security enforcement* — as well as their impact on the business and in mitigating security threats (e.g. internal and external attacks, ex-worker attacks, etc). This requires understanding the implications and explicit cause-effect relationships that exist between these IAM investment options and the processes and IT operational levels.

IV. IAM Case Study

An IAM case study has been carried out in collaboration with three security and IAM Experts, to explore the feasibility of the outlined methodology to provide strategic decision support for IAM investments. The experts acted as strategic decision-makers. This paper discusses *the outcomes we obtained from one expert*, whom played the role of a CIO/CISO, on behalf of a major customer. Due to the space limitations we can only provide an overview of the findings of this case study. The details are going to be provided in [16].

This case study focuses on a large organization and considered the significant case where the decision-maker has to make strategic IAM investment decisions to support core enterprise business services, underpinned by SAP Applications. SAP applications [11] are widely used in the industry to provide: Customer Relationship Management, Supply Chain Management, Human Resources, Product Lifecycle Management and Supplier Relationship Management.

New users can join the organization and require access rights for these services; they can leave or change their roles. At the stake it is not only the accurate management of user accounts and rights, but also ensuring compliance to laws, mitigating security risks, enhancing productivity and coping with a limited budget. As discussed in Section II, investment choices are determined by the priorities and strategic issues of relevance to the decision-makers. Various trade-offs are possible, each requiring a different mix of IAM investments.

In general, investments in the IAM space can be classified in terms of: *provisioning, compliance and enforcement* [4,9]. Investments in *provisioning* (e.g., user account management) have a direct impact on productivity. For SAP applications, this ranges from ad-hoc processes to automated solutions such as SAP Netweaver IAM and APPROVA products. Investments in *IAM compliance* (e.g., monitoring and checking solutions) have a direct impact on governance and compliance aspects (e.g., SOX compliance) but only marginally affect productivity. For SAP applications, this ranges from ad-hoc manual compliance checking to automated tools such as SAP KPI, APPROVA and VIRSA remediation. Investments in *IAM enforcement, provisioning and compliance* have an impact on mitigating security threats.

For each of these IAM investment areas we identified ***5 classes of investment levels***, in the [1-5] range, with an increasing impact in terms of effectiveness of the involved control points, policies, and costs. The lowest investment levels usually involve *ad hoc processes and manual approaches*. The intermediate levels involve *hybrid approaches, with degrees of automation and policy definitions*. The highest investment levels involve *strong automation and integration with security and business policies*.

The interviewed security and IAM experts highlighted the fact that (*IAM*) ***enforcement*** (e.g. authentication and IT system security controls for patching, anti-viruses, etc.) i*s currently not*

a major concern, at least for medium-large organizations; this is a relatively mature area, where the implications are reasonably understood and various investments have already been made. Based on our classification of investment levels, we estimated that the organization under analysis already made *enforcement investments* comparable to *level 4*; that is, corresponding to the presence of general security policies, deployment of suitable control points and IT security technologies as well as processes for the reassessment of policies and control points.

The case study focused on the problem where the decision-maker is primarily interested in *exploring investment options and trade-offs* in the space of *compliance* and *provisioning* to achieve strategic outcomes of relevance. Sections V, VI and VII describe how the methodology has been applied to provide decision support.

V. ELICITATION OF STRATEGIC PREFERENCES

The approach we adopted to elicit strategic preferences from the decision-maker consists of three phases.

Phase 1 involved engaging, discussing and eliciting the set of *strategic aspects/outcomes* of relevance for the decision-maker. The decision-maker confirmed that ***Security Risks***, ***Productivity***, ***Compliance and Costs*** are at the top of their concerns**.** As discussed in Section II, this determines the utility function components of the decision-maker. A clear semantic has been agreed with the decision-maker for each of these strategic outcomes, along with meaningful (IT) metrics to measure and estimate them; see Table I.

TABLE I. DEFINITION OF OUTCOMES OF RELEVANCE AND METRICS

Security Risks	Predicted ***number of breaches/incidents*** (e.g. exploitations of credentials, unauthorized accesses, etc. due to internal/external attacks) that happens in 1 year timeframe. We looked for the max number of incidents the decision-maker accepts happening and the min number of incidents they would be reasonably comfortable with
Productivity	Predicted ***ratio (percentage) of all user accounts (and related access rights) that the organization would have liked to have been provisioned*** in 1 year. A productivity of 70% means that only 70% of all the accounts that should have been correctly provisioned actually have been provisioned.
Compliance	Predicted ***number of audit findings/violations*** (e.g. # SOX compliance audit violations) in 1 year. The lower the number, the higher is compliance.
Costs	Approximated costs in terms of ***budget ($) to be invested in IAM initiatives in 1 year timeframe***.

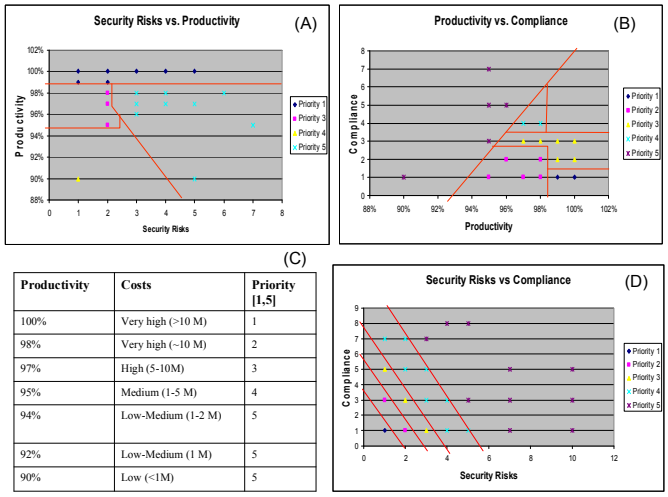
In **Phase 2**, for each of the above strategic outcomes, we asked the decision-maker to tell us which values were "good enough" (min value, i.e. where they would not be interested in spending more money to achieve more) and which ones were "just acceptable" (max value; i.e., the level below which they became extremely concerned to address the issue). This helped us to identify ***value ranges***. The decision-maker expressed the following preferences: **Security risks**: *min: 1, max: 3*; **Productivity**: *min 100%, max 100%*; **Compliance** (violations): *min: 1, max: 3*; **Costs**: *min: 500K $, max: 10M $*. We deduced that for this decision-maker ***productivity*** is a key priority whilst the ***cost*** factor is not a major issue. The decision-maker showed some degrees of tolerance in terms of ***security risks*** and ***compliance violations***.

Finally, in **Phase 3** we asked the decision-maker for their relative preferences between values of (paired) outcomes (e.g., productivity vs. compliance), to highlight tension points and quantify/qualify trade-offs. We created four questionnaires populated with values in the ranges chosen in *phase 2***:** some "outlier" values were introduced, to further check for preferences. The explored trade-offs are shown in Table II.

TABLE II. PREFERENCE TRADE-OFFS FOR STRATEGIC OUTCOMES

Security Risks vs. Productivity	Exploring how much the decision-maker is willing to compromise security in order to improve productivity (or the way around)
Productivity vs. Compliance	Lack of compliance can sometime be acceptable to increase productivity and the way around (due to stronger controls and bureaucratic processes)
Productivity vs. Costs	Exploring how much the decision-maker is willing to compromise in terms of productivity, based on the involved costs
Security Risks vs. Compliance	Exploring the relative preferences between security risks and compliance. Strong preferences in the compliance area indicate the attitude at accepting low security risks especially the ones causing audit failures

We asked the decision-maker to state their priorities, in the [1-5] range, ***where 1 meant the highest priority and 5 meant the lowest priority***. Figure 2 shows the results.



Productivity	Costs	Priority [1,5]
100%	Very high (>10 M)	1
98%	Very high (~10 M)	2
97%	High (5-10M)	3
95%	Medium (1-5 M)	4
94%	Low-Medium (1-2 M)	5
92%	Low-Medium (1 M)	5
90%	Low (<1M)	5

Figure 2. Results of Elicitation of Decision-maker's Relative Preferences

Each point in the graphs (A), (B), and (D) graphs represents a pair of values (in the questionnaire) prioritized by the decision-maker, based on their relative preferences. Various *sub-areas* of the graph have been identified based on these priorities.

Figure 2(A) shows that the decision-maker is willing to accept security risks as long as high productivity (99%-100%) is achieved — *no priority 2 preferences were expressed*. The graph (B) in Figure 2 also confirms the decision-maker's bias towards productivity. The graphs (B) and (D) show that compliance has a high priority too and the acceptable trade-offs against productivity and security risks. Finally, the table (C), in

Figure 2 confirms that the decision-maker willingness to make high IAM investments to achieve productivity.

Despite the current crude approach, and the difficulties mentioned in [10], the results show that it is possible to explicitly capture decision-maker's strategic preferences and reason on them. These outcomes have been discussed and validated with the decision-maker. The next steps of the methodology explored which IAM investments are most suitable to achieve these strategic outcomes.

VI. Exploring the Impact of IAM Investment Options by Means of Modelling and Simulation

We used modelling and simulation techniques to make predictions about the impact of possible IAM investment options on the outcomes of interest and map them against decision-makers' preferences, to identify suitable investments.

Predictive mathematical approaches are suitable to carry out modelling and simulations. The approach is based on "predictive system modelling", specifically discrete-event modelling [12,14,18]. Our approach, the mathematical basis of which is presented in [3,7,13,14,15,18], views a system as having the following key components: **Environment**: treated as a source of events that are incident upon the system of interest according to given probability distributions; **Location:** the components of a system of interest are distributed around a collection of places, which may correspond to geographical or more abstract notions of location; **Resource**: this captures the components of the system that are manipulated by its processes; e.g., devices, people, etc.; **Process**: this captures the (operational) dynamics of the system. Processes manipulate resources in order to deliver the system's intended services.

The adopted approach provides advantages over analytical approaches as it explicitly represents the dynamic dependencies and interactions among the involved entities, processes and decisions. This is of relevance for the IAM scenario where a wide variety of events, business processes, systems and human interactions are involved. We used the Gnosis modelling toolset [6,18], which implements this framework and supports Monte Carlo-style simulations.

As result of the analysis of various enterprise environments and the IAM processes impacting business services, we built a *general model*, re-usable in different enterprise contexts with minor changes and the instantiation of a few parameters. The modelled aspects have been discussed and validated with the security and IAM experts. Figure 3 shows the high-level view of the model.

This model is characterized by the following aspects: ***Status*** of the system, including *measures*, number of managed business services/SAP applications, security status of these applications (i.e., weak, medium, strong), number of users, overall status of access rights; ***Set of processes*** that can modify the status; ***Events*** that trigger processes.

The *model tracks the users' access rights for the managed SAP applications* to explicitly characterize the *access posture* of the organization and determine the impact on strategic outcomes of interest. Wrongly provisioned access rights tend to encourage threats and attacks and/or have a negative impact on productivity and compliance (e.g., because of audit failures). Four categories of access were identified: ***BizAccess*** (legitimate access rights correctly granted), ***NoBizAccess*** (legitimate access rights not granted), ***BadAccess*** (illegitimate access rights, granted) and ***NoAccess*** (illegitimate access rights, not granted). ***"Hanging Accounts"***, i.e. those access rights that are still allocated to a user, despite the user has left the organization or changed role, are also tracked.

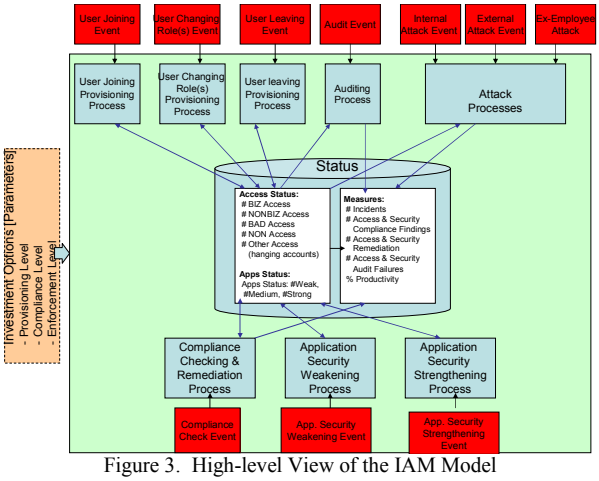


Figure 3. High-level View of the IAM Model

The impact of different *IAM provisioning* and *compliance checking* investments, for investment levels in the [1-5] range, have been factored in the modeled processes by representing the cause-effect relationships that are at the base of failures, mistakes and successes, driven by probability distributions which depend on these investments. As anticipated, the *enforcement* investment level =4.

The IAM model captures these key *processes*: *Provisioning of users' accounts and access rights* (user joining, changing roles and leaving); *Compliance Checking and Remediation activities*; *Auditing activities*; *Impact of attacks*; *Weakening of SAP applications' security*; *Strengthening of SAP applications' security*; *Threats and attacks*. Processes are triggered by related ***events***, some of them *exogenous* (i.e. not under the control of the IT management teams, such as frequency of attacks, frequency of people joining or leaving the organization, audit checks), some of them *endogenous* (i.e. that can be affected by the organization, e.g. frequency of compliance checking, security upgrades of applications). These events are characterized by probability distributions.

It is beyond the scope of this paper (due to space limits) to provide the details of all the modeled processes and probability distributions. This will be available in [16]. Two examples of modeled processes are shown in Figures 4 and 5.

Figure 4 illustrates the modeled process for *user joining the organizations*. The user provisioning steps of *approval* and *deployment of user accounts* are represented, along with potential failures that can happen, such as misconfiguration, mistakes and attempts to bypass the system, which have impact on access (*BadAccesses* and *NoBizAccesses)*. The higher the provisioning investments the lower is the probability that these mistakes can occur. Similar processes have been modelled for user leaving the company or changing their role.

Figure 5 shows the process for *compliance checking and remediation*. Depending on the level of investment made on compliance, a specific number of SAP applications is checked against their current security level — modelled as *weak, medium, strong* — and the status of user accounts checked to identify bad accesses and hanging account. When violations are spotted, remediation activities take place, whose durations depend on these investments. The higher the investment in compliance, the higher the number of violations that can detected and fixed, hence reducing the security threats and the likelihood of audit failures. Investments in provisioning compete against the ones in compliance, as they reduce the number of potential violations. Compliance investments do not address productivity issues, as compliance checks do not usually detect *NoBizAccess*.

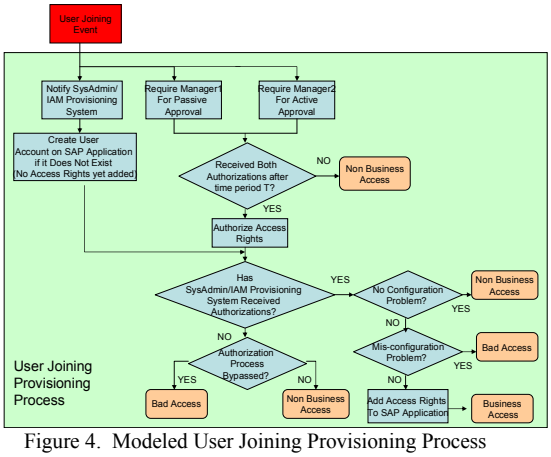


Figure 4. Modeled User Joining Provisioning Process

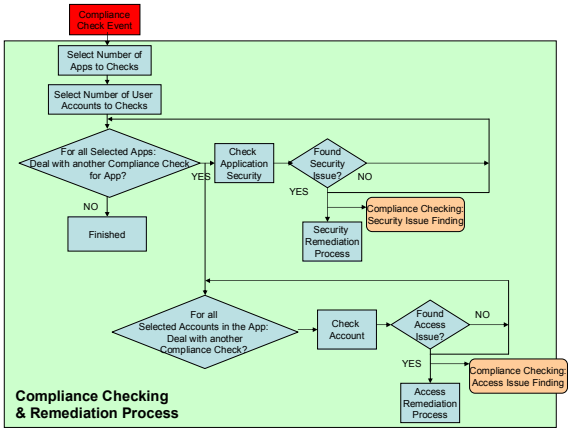


Figure 5. Modeled Compliance Checking and Remediation Process

The auditing process has been modeled in a similar way, but with the aim of spotting violations that count as failures. Another example of modeled process (not shown), is about *ex-worker attacks*. In this context skills of employees are taken into account as well as the current intranet protection level and the presence of hanging accounts. These aspects determine the likelihood of successful attacks to the organizations. The number of successful incidents is measured. Assumptions are made on the external threat environment, such as the frequency of attacks and determination of attackers.

The overall processes impact the status of model, by modifying the values of various *measures*, which include: *number of occurred incidents; number of access and security compliance findings and remediation; number of access and security audit failures; productivity*. Some of these measures (metrics) are *proxies* of the utility function's components which reflect the priorities and preferences of the decision-maker, as discussed in Section V, Table I. The *productivity* measure, defined as the ratio/percentage of all user accounts that the organization would have liked to have been provisioned, is calculated as: *(bizaccess + badaccess) / (bizaccess + nobizaccess + badaccess)*.

The cost element has not been directly represented in the model, as it is mainly a function of the provisioning and compliance investment levels.

A. Assumptions and Parameters

The model is driven by a set of parameters which determine the following aspects: *Provisioning, Compliance and Enforcement Investment Levels*; *Status Initialization; Threat Environment; Events; Processes.* Probability distributions associated to these parameters have been derived from empirical data obtained from audit logs of the organization and discussions with the decision-makers and IT teams. Probabilities related to events have been modeled with *negative exponential* (negexp) distributions. Probabilities such as likelihood of mistakes, faults, etc. vary depending on the investment levels in the [1-5] range. Table III shows examples of these parameters. Full details will be available in [16].

TABLE III. EXAMPLES OF PARAMETERS

User Events - Frequency	**New user**: negexp (3.5 days), **Leaving user**: negexp(7 days), **User change**: negexp(30 days)
Attack Events - Frequency	**Internal attack**: negexp (10days), **External attack**: negexp (10days), **Ex-worker attack**: negexp (25days)
Provisioning Process	**sysAdminFailureRate**[1,5]=[1/50,1/150,1/250, 1/800,1/1000] **bypassProvisioningApprovalRate**[1,5]=[1/50,1/100, 1/500,1/1000,1/1200]
Audit Freq.	**Audit activity**: negexp (180*days)

We considered a population of 60 SAP applications. The model was initialized with a small set of users, 10 (and related access rights) to explicitly explore the impact of handling new users, users changing roles or leaving the organization.

B. Predicting the Impact of Investment Choices

Monte Carlo simulations have been carried out for a simulated time period of 1 year. All the potential combinations of IAM investment options in the space of ***provisioning*** and ***compliance*** (with a constant ***enforcement*** investment level = 4) have been explored. As the investment levels in these two areas could vary in the [1-5] range, this has identified 25 different options**.** For each of these combinations, the model has been run 100 times to get statistically relevant results.

Average values have been generated for all the *measures*. Figures 6 and 7 illustrate how the average values of the *proxy measures* for *productivity, security risks* (i.e., total security incidents) *and compliance* (i.e., audit access failures) vary, depending of the different investment choices.

Figure 6 shows that *productivity* increases almost 30% for each *provisioning* investment level in the [2-4] range and saturates to almost 100% with the *provisioning investment level = 5*. This reflects the fact that the number of *"NoBizAccesses"* substantially drops with the increase of this investment. Compliance investments have little impact on productivity as they do not affect this factor.

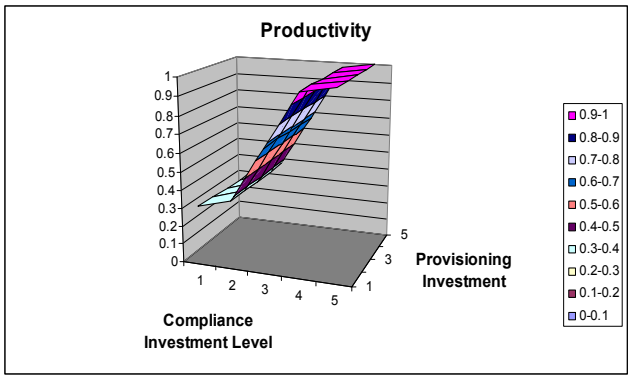


Figure 6. Simulation: Outcomes for Productivity

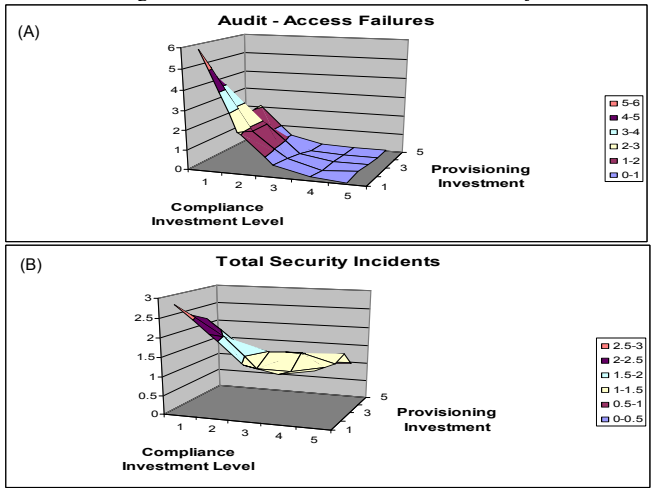


Figure 7. Simulation: Outcomes for Audit Access Failures and Total Security Incidents

Figure 7(A) shows that by increasing the investments in compliance or provisioning the number of *audit failures* (due to access issues) decreases. By increasing the investments in *provisioning*, the number of *bad accesses* and *hanging account* are reduced, because of better practices and automation; by increasing the investments in compliance, audit failures are reduced too, because of the increased effort in compliance checking. So, multiple investment trade-offs are potentially possible to deal with *audit failures*, depending on the decision-maker's preferences in this space. Figure 7(B) shows a relatively low number of yearly security incidents: this reflects the fact the enforcement investment level is 4. Additional investments in *provisioning* and *compliance* have, in general, a positive effect in further reducing the number of these incidents.

The model that produced these outcomes is the results of various refinement steps driven by reality checks and discussions with the decision-maker and the other involved security and IAM experts. The predictions we obtained have been validated as feasible and realistic.

VII. Mapping Predicted Outcomes Against Decision-Makers' Preferences

This step aims at identifying the most suitable IAM investment options - that is, the most suitable *provisioning and compliance* investment levels - by mapping the predicted outcomes against the decision-maker's preferences.

The data (predicted outcomes) shown in Figures 6 and 7 can be displayed in the same way as for the preference elicitation results, shown in Figure 2. Figures 8 and 9 show the result of mapping these predicted outcomes against *the decision-makers' top priority preferences (i.e., priorities 1, 2/3) in Figure 2*. Each point that represents a predicted outcome has been labeled with the associated compliance and provisioning levels.

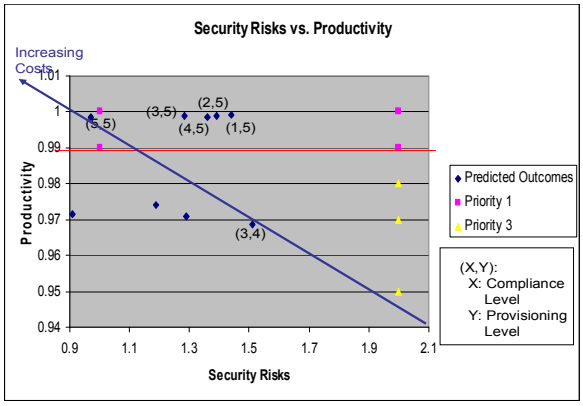


Figure 8. Mapping of Outcomes against Top Priority Decision-makers' Preferences – Security Risks vs Productivity

Figure 8 shows that, in order to achieve the decision-makers' Priority 1 preferences, it is necessary to have a *Provisioning Investment Level* = 5. In this context, any *Compliance Investment Level*, in the [1-5] range is suitable, to achieve these results. Instead, the most likely combination of investments to achieve the decision-makers' preferences labelled as Priority 3, is the following: *Provisioning Investment Level* = 4 and *Compliance Investment Level* = 3.

Figure 9, graph (A) shows that to achieve Priority 1's preferences, it is required to have a *Provisioning Investment Level = 5*. Also in this context, very little difference makes the compliance investment level because the high level of provisioning investment already minimize the occurrence of potential failures and faults. Again, this is achieved with high investment costs. Instead, Priority 2's preferences can be achieved with a *Provisioning Investment Level = 4*. Finally Figure 9, graph (B) shows that Priority 1's preferences can be achieved with a wide range of investment possibilities: the *Provisioning Investment Level* can be any value in the [2-5] range; the *Compliance Investment Level* can be any value in the [4-5] range. Priority 2's preferences can be achieved with even a wider range of investment possibilities.

By keeping into account these outcomes and various constraints, in order to achieve the decision-makers' *Priority 1* preferences, the required investments are: ***Provisioning Investment Level = 5; Compliance Investment Level = 4.***

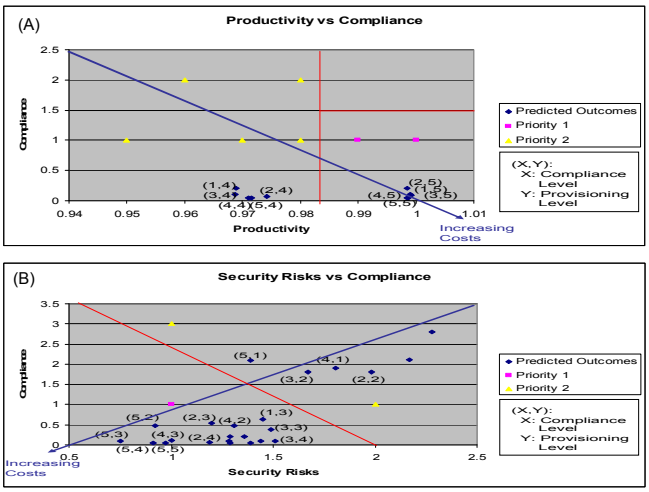


Figure 9. Mapping of Outcomes against Top Priority Decision-makers' Preferences – Productivity vs. Compliance and Security Risks vs. Compliance

This result did not come as a surprise. The decision-maker was biased towards achieving high productivity: the predicted outcomes indicate that this can happen only with the highest provisioning investment level and reasonably high compliance investment level, at high costs. This conclusion has been presented to the decision-maker to illustrate the consequences of their preferences. These predictions and conclusions have been validated as feasible and realistic. This enabled the decision-maker to reassess their preferences and priorities and explore other options. A follow-up refinement process is currently in place. We believe this is an encouraging result as it provided the decision-maker with new ground for analysis and decisions at the business level to act on.

VIII. DISCUSSION AND CONCLUSIONS

In this case study, the decision-maker had a clear idea of their priorities and a large IAM budget. In general this is not the case, as decision-makers' priorities might not be obvious, the budget might be limited and more stringent trade-offs might need to be taken into account. In addition, different decision-makers within the organization are usually involved in the decision making process: they might have different foci (e.g., on compliance or on security) and priorities, reflected by different preferences. In this context, our approach can be used to explore these viewpoints, starting from common assumptions, and provide help to decision-makers to explore trade-offs and reach compromises. Additional work is required to refine our approach, in particular to instantiate the decision-makers' utility functions. At the moment our work only provides an empirical estimate. Ideally, the targets (preferences) identified by the decision-makers and the selected predicted outcomes could also be used to mathematically instantiate these utility functions and fully represent the space of preferences of the decision-maker. This is work in progress.

This paper presented an approach to support decision-makers in defining their Identity and Access Management strategy. We illustrated a methodology that helps decision-makers work through this complex problem by explicitly exploring their preferences between different strategic outcomes; using system modelling and simulation to predict and analyze the consequences (likely outcomes) associated with different IAM investment choices, for a number of assumed future threats and business scenarios; mapping these predicted outcomes against preferences, to identify the most suitable investment options. This methodology has been applied in an IAM case study involving enterprise business services underpinned by SAP applications. Our results have been validated by a senior security and IAM expert, acting as a CIO/CISO decision-maker, on behalf of a major customer. This enabled discussions and further reassessment of preferences. This work is in progress.

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