AN EMPIRICAL MODEL TO ESTIMATE IT SERVICE OUTAGE COSTS

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DECLARATION

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ABSTRACT

Modern organizations depend on Information Technology (IT) services to generate direct revenue in addition to supporting electronic communication and internal processes. With such dependence on IT systems and services, unplanned outages are a major problem. Frequent or long outages lead to direct losses such as loss of revenue, compensations for work overtime, and fees to fix the services. Moreover, it leads to indirect losses such as loss of customer confidence and reputation. While IT service outages are a well-known problem, there is no clear and effective model to estimate the cost of outage. This is further complicated by the lack of understanding about key elements of outage cost, ways to measure them, and difficulty in capturing indirect losses. We address this gap by developing a model to estimate IT service outage costs. First, based on related work and expert judgment, we derived a set of factors that capture the cost of IT service outage. Based on those factors, we then formulated an IT service outage cost model. Third, we implemented the model as a spreadsheet and shared it with senior managers of diverse set of organizations. While a few organizations were able to quantify cost of IT service outages, most were able to provide only the qualitative insights. Consequently, we also had a set of interviews with such organizations to understand the importance of quantifying the cost of IT service outage, relevance of cost factors, and the utility of the proposed cost model. Based on the feedback, the proposed cost model was further improved. Key cost factors identified include productivity loss, revenue loss, loss due to reputation and loyalty damage, services fees, compensation for work overtime cost, new hardware, and other miscellaneous costs. The proposed cost model will enable organizations to estimate financial losses related to IT service outage, identify key contributors to those losses, identify areas of improvement, and justify investment on IT resources for better service quality and dependability.

Keywords: cost model, cost of outage, semi-empirical study, IT services, service outage

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ABBREVIATIONS

BC	Business Continuity
DR	Disaster Recovery
IT	Information Technology
MTBF	Mean Time Between Failures
MTTR	Maximum Time to Repair
RTO	Recovery Time Objective
RPO	Recovery Point Objective
ROI	Return on Investment
SEK	Swedish Kroner
DDoS	Distributed Denial of Service
WWW	World Wide Web
SLA	Service Level Agreement
ITIL	IT Infrastructure Library
CIO	Chief Information Officer
CTO	Chief Technical Officer
RBV	Resource-Based View
OT	Overtime

Chapter 1

1. INTRODUCTION

1.1 Background

With the increasing adoption and reliance on Information Technology (IT) services, their reliability becomes utmost important. With the dependency on IT services and 24/7 uptime expectation, unplanned outages in IT services are a major problem. Such outages can range from a few minutes network connectivity interruption to devastating security breaches and key device failures. Effect of outages is varying depending on the industry, e.g., some organizations feel the impact immediately while others may get impacted only after a couple of hours of outage. Some of the direct impacts include loss of revenue of a division or the entire organization, possible data loss or exposure to third-parties, compensation for work overtime, and system restoration costs. The effect of IT service outage ripple far beyond these immediate financial losses. It may lead to indirect losses such as loss business opportunities and existing customers are leaving the business to join with competitors. Moreover, organization reputation suffers as dissatisfied customers express their bad experiences through word-of-mouth and social media. While businesses invest heavily to acquire and maintain IT services with the expectation of increasing quality and reliability of the services, quality and reliability do not increase in proportion to the investment. Moreover, lack of understanding of the costs and other consequences of IT service outages results in such investment being made on areas or equipment that do not lead to best return on investment. Furthermore, it leads to the everlasting tussle between the IT team and the management, as the investment on IT cannot be justified as having direct impact to the core business.

Although several related works focus on cost of IT service outages, the are many gaps in the literature. For example, not only a few empirical studies exist but also most of those studies tried to address the problem either through simplified analytical calculations [1] or numerical simulations [2]. While these developments contributed to the literature in some extent, we believe semi-empirical model to estimate cost of IT service is a better technique to address the problem in a more transparent manner.

In this study, we aimed to contribute to cost estimation by analyzing the key cost factors of IT service outages through a methodical and transparent set of case studies from multiple organizations.

1.2 Problem Statement

In this research our primary goal is to formulate a cost model to estimate cost of IT service outages. Development of a simple tool to calculate the outage cost is also useful to understand areas in the IT infrastructure that need further developments.

Although IT service outages are common, it seems that organizations are unclear about the actual financial impact outages have on organization's revenue, productivity, and reputation. This is because organizations have inadequate knowledge about the key factors that affect the outage cost and how to measure it. Moreover, as factors do not contribute equality to the cost estimate, it is also important to understand the relative contribution of those factors to the ultimate cost. Therefore, understanding of these factors are important to IT service designers to take decisions in proactive manner to minimize future outages and associated costs. Moreover, there is no clear and effective model to estimate the IT service outage cost. Therefore, the problem to be addressed by this research can be formulated as follows:

How to derive a cost model to measure the cost of IT service outage?

1.3 Objectives

This research attempts to achieve the following objectives to address the above research problem:

- Identify key cost factors that contribute to cost of IT service outage
- Formulate an IT service outage cost model to estimate the direct, indirect, and opportunity costs associated with IT service outage
- To develop a tool to calculate and forecast cost of IT service outage while varying impact of cost factors
- Evaluate the proposed cost model and tool using industry feedback from several sectors

- Improve the proposed cost model and tool based on the feedback

Before calculating outage costs, it is necessary to understand the key cost elements/factors of IT service outage. Initial set of such factors can be derived based on related work and expert judgment. They can be categorized as tangible and intangible, as well as short and long-term costs. Once the key cost factors are identified, we formulated a cost model which calculates estimated outage cost figure of given cost figures of previous outages.

The formulated cost model was developed as a spreadsheet-based tool to calculate and forecast IT service outage costs. Several cost figures associated with different cost factors need to be entered to the tool to estimate the outage cost. If the respondent believes the estimation is not reasonable based on the entered data, respondent is allowed to refine values of cost components to adjust the total estimated cost. Refinement of values of cost components could be an iterated process until the estimation of outage cost becomes a reasonable judgment. When the respondent agrees with the produced estimation, it reflects the financial impact of the organization for the given outage incidents. Such a tool should also generate relevant graphs to forecast outage costs under varying set of parameters. This enables a user to make some adjustments in outage times and the cost components towards the savings of outage costs in future incidents. These adjustments can be compared with originally produced cost figures too.

The tool needs to be shared among senior managers of organizations from several sectors to get broader feedback and analyze the utility of the tool across different outage scenarios and organizations. The selection of organization should be based on the IT service usage on their daily business functions. Depending on the extent the participants agree with the estimation generated by the tool, effectiveness of the formulated model and the tool could be determined. If there is any improvement required according to the feedback, the model need to be refined and redistributed to gather feedback again about the improved release. This refinement would have to be done several times to improve the precision of formulated cost model and the tool.

1.4 Outline

The reminder of this thesis is structured as follows. In Chapter 2, review existing literature, the notion of IT infrastructure, interdependencies of IT infrastructure and business components, IT service outages and its impact, and the availability and its importance for business continuity are discussed. Chapter 3 explain the proposed cost model, preparation of tool for cost model validation and how data gathered for model evaluation and decision forecasting. Chapter 4 explains quantifications of various qualitative costs and formation of the cost model. Research data is collected through semi-empirical study and Excel worksheet, questionnaire results analysis is discussed in Chapter 5. Concluding remarks, limitations of the research, and future work are presented in Chapter 6.

Chapter 2

2. LITERATURE REVIEW

The role, IT plays in increasing the competitiveness of business cannot be undermined since it enables most organizations to increase productivity and profitability. "7 out of 10 organizations believe IT infrastructure enables competitive advantages and optimizes business performance" [3]. This ensures most businesses depend on IT infrastructure for most of the aspects of their daily operations. To ensure good service and tremendous quality; reliable and efficient IT infrastructure is essential. Due to more and more demand on IT service, businesses allocate large sum of money on the IT infrastructure, and therefor they expect highest level of availability of the IT services. IT service availability refers to as how often a resource is performing its tasks across all the minutes or seconds of a given year.

2.1 IT Infrastructure

Kumar et al. [4] defined *IT infrastructure* as "a collection of technologies, people, and processes that facilitates large-scale connectivity and effective interoperation of an organization's IT application." IT infrastructure allows organizations to share information across business units internally and business partners externally. Because of this motive, an efficient IT infrastructure is an important necessity for business operations which uses of distributed information and knowledge throughout the operations. Basically, IT infrastructure can be categorized into two parts; human and technical. Technical infrastructure be composed of information, user applications, technical equipment such as hardware, software, network equipment and other tangible resources. On the contrary, human infrastructure consists with knowledge and human capabilities which is required to managed IT resource efficiently and effectively. It transforms IT components into beneficial IT services through the human experience, skills, and knowledge. Therefore, IT infrastructure has been received the capabilities to ensure the continuity of the agreed performance to both internal and external business units. IT infrastructures can be improved by giving training to IT staff and investing in technology. Also, IT is helping business operations and making customers

feel satisfy with its operations and has changed the scope of modern marketing environment in recent times as well as making internet business operations more convenient and efficient than direct business operations.

IT infrastructure consist of various components. These components can be mainly categorized into seven groups as follows:

i. Hardware Platform – consists with servers and client computers, and networking components. Servers process organization data while networking components build platform to interconnect various business units for collaboration and information sharing.
ii. Operating System and Application Software Platform – offer support on doing business processes with utilization of hardware and networking components.
iii. Communication and Collaboration – with support of interconnected computers or network segments, internal and external collaboration and communication enables, e.g., email and videos conferencing.
iv. Data and Knowledge – key drivers to execute business processes
v. Facilities – support equipment which are necessary for delivery of information.
vi. Human Resources – refers to as trained employees for functioning of business activities
vii. Service – Most organizations seek external expert services for some of their business operations as maintaining in-house facilities are very expensive

IT has been incorporated in most parts of the modern businesses because these businesses have realized the need to increase efficiency and profitability. It will help to open wide range of opportunities and derive a new business model; something called virtual assistant organizations. It brings organizations to allow their employees' mobility and convenience to work from elsewhere. These organizations not only receive extended opportunity on the flexibility to work elsewhere, they also have a chance to minimize the required office space and related facilities like IT infrastructure, cabling, power, air-conditioning, support office staff, etc. Another advantage that IT has brought to businesses is "dashboard facility." Business dashboards are graphical form of runtime overview about the business activities and

their performance. Those graphs give a quick insight into financial health and system health itself. Dashboards can also give several benefits which includes;

Table 2.1 – Benefits of business dashboards.

Benefit	Description
Visibility	Business dashboards provide complete visibility into performance of business operations. Management of the organization has chances to understand functioning and not functioning components or resource and apply fixes to overcome any problems. Perhaps it helps managers to provide quick answers to their every business question.
Save Time	System managers or administrative people may not require accessing systems to analyses logs and create utilization or any other types of reports. Because dashboards give quick insight about the overall health and more binary level information about the systems operations, it will make much relief from their busy life and allow to use that time for business development and increasing sales.
Results	Critical information about systems and business performance are quickly available and it helps in making result-oriented decisions fast. Usually graphs and reports use verity of colors to show different matrices. For e.g., increasing trend figures show green while decrease in marked in red color. Managers can quickly identify factors or business areas which need their attention.
Productivity and Profit	These dashboards bring benefits to improve business performance, and it indirectly improve productivity, and business profits. It gives details about the areas which need more attentions for developments and areas where managers do not need to spend their efforts.

2.2 IT Infrastructure Availability

Uptime and availability of an IT infrastructure refers to as how often a resource is performing its tasks across all the minutes or seconds of a given year. As IT services are becoming a significant part of revenue generation of most of the organizations today, it is important to make sure that service availability and the health of network hardware and software of datacenters are performing at the expected level. Uptime and availability of an IT infrastructure refers to as how often a resource is performing its tasks across all the minutes or seconds of a given year. Effect of IT service availability measures how reliance each areas of business units interact with IT systems. Those who mostly depend on IT services can endure a much steeper curve that they are unable to do their jobs. While people who interact with IT services less, do not worry much to continue their jobs when IT services not available. Organizations those who heavily use IT services need to be aware that financial implication is high at a service outage

and must take required actions on IT resilience, third party supplier management and Business Continuity (BC)/Disaster Recovery (RD) planning. Depending on the industry, effect of downtime is varying. Though preparation for every scenario is difficult, however organizations need to prepare for situation more likely to minimize the impact to organization operations. In 2017, Delta Airlines faced four-hour system outage causing 280 flights to be cancelled [5]. Financial loss for the organization was estimated as over USD 150 million. According to the 2017 Data Health Check Survey [6], 35% of businesses are entirely unaware of the financial threat due to outages and significantly underestimate the true cost. In 1999, online auction giant, eBay experienced a three-day outage in their software system losing an estimated USD 2 million a day. Customers were disappointed with their business and posted messages to warn others that reliability of the eBay's systems is not at successful level and leave the service. In 2001, Nike was unsuccessful to meet their third-quarter earnings estimated because they had experienced some issues with their recently implemented supply chain system. In the following day its affect was 20% loss in business value [7].

According to a recent survey with 170 security professionals [8], 32% of them have responded that their IT services infected with ransomware attack and 11% of those have taken longer than a week to restore their services back online. 29% responded mentioning that if their organization affected a ransomware threat, they would experience outage losing revenue between USD 5,000 and USD 20,000 a day. 27% have responded that the amount could be over USD 20,000 a day.

2.2.1 Quantifying Availability

IT service availability is a most important factor for the business continuity. It is defined as any service is on-line and ready to access and can provide its function in a certain point-in-time. A variety of factors can affect system off-line; ranging from planned outages for maintenance to catastrophic failure. Exactly how much outage can be tolerated will dictate that comprehensiveness, complexity and cost of the solution.

Maintaining high availability is crucial in many applications. Ulrik et al. [9] mentioned that "IBM Global Services report that unavailable systems cost on American businesses USD 4.54 billion in 1996, due to loss productivity and revenues." The report also stated that cost of a one-hour outage range from airline reservation at USD

89.5 thousand to brokerage operations at USD 6.5 million (1998 exchange rates apply to USD). “A vivid reminder of the financial sector’s sensitivity occurred when the Nordic and Baltic stock markets were forced to close down for 5 hours on June 4, 2008 due to the trading system Saxess being down. This outage caused to block approximately 20 billion SEK worth transactions” (Swedish Kroner).

2.2.2 Measurements of Availability

IT services availability is vital for business continuity. Complex technical nature of IT services put the availability at a risk. It is desirable to be the system resilience and high available means that all or most of a failure conditions are well defined. It is likely that all the failures cannot be dealt with very well, but at least those situations should be identified and setup a plan to handle with such situations to recover the system operations. It is known fact that most applications can dealt with 99% uptime [10]. On average, businesses can tolerate 90 minutes of weekly outage though. However, most of the cases it depends on when the outage occurs. If it occurs between 1.00 A.M. to 2.30 A.M. on weekend, that is going to be very less business impact than if it falls between 10.00 A.M to 11.30 A.M. on weekdays [10].

All outages do not equally affect to every organizations. Organizations those who are having customers regularly interacting with the business through IT services, there may have much higher impact to revenue when an outage occurred even for a short time window. It would cause to make unhappy customers. As IT service outages can make unhappy customers, there is a higher chance to leave those customers to competitors. An outage that causes inconvenience to loyal customers is more costly than how organizations think about it.

2.3 IT Service Outages

If IT services deliver facilities to users to perform their office works more efficient, manageable and timely manner, but if unknown situations come to interrupt their works, it will be referred to as service outage. IT service outage can be caused by many factors. O'Callaghan et al. [11] distinguished outages can be mainly categorized into two parts; namely planned outages and unplanned outages. Unplanned outages can be classified into different categories, such as natural causes, human errors due to internal

or external parties, hardware faults, system overload, vandalism. Contrary, organizations frequently perform planned outages to maintenance of their IT infrastructure to avoid an unplanned outage. However, organizations believe planned outages may not cause an impact to the business operations, there are situations that those incidents would cause inevitable outages. Lei et al. [12] showed that most common outage incidents that have happened in the healthcare sector are computer virus/hacker attacks, network connectivity issues, power outages, human errors, natural causes such as thunderstorms. Some well-known outages as discussed in [11] are listed in Table 2.2.

According to a survey conducted by Gartner [10] about common causes of outages, it was found as higher contribution of outages (27%) come from software failures. Second higher (23%) was caused by hardware failures. There are other causes such as human errors, network failures, and natural disasters. A similar study conducted by CNT [10] showed hardware failures as the major cause (44%) of outages while second higher cause was human errors (32%). Other causes include software corruptions and bugs, virus attacks, and natural disasters.

However, both survey results have shown that human errors are the major cause of IT service outages. There are mainly two reasons for human error caused outages. First, sometimes people make careless mistakes. Second reason is, usually people do not have clear idea about system operations and their functions. A better way to avoid human-caused outages is through educating people through simple system design. This can be achieved by conducting or sending people to training sessions on latest technologies. By keeping good solid knowledgeable people for operating IT services and technically sound team for administering IT service, organization can reduce the amount of outage they cause.

The other highlighted result of the surveys is the variance of hardware-caused outages. With the advancement of technologies, hardware-caused outages are minimized today. With the technology matured, hardware components become more reliable over time. For example, most frequent replaceable components like disks and power supplies have been achieved the highest level of redundancy. If a disk or power supply fails on a critical component of a storage array, its workload is automatically swap over to a

secondary component with zero or very less amount of time which users feel no outage anymore.

Table 2.2 – Well-known outage causes.

Causes for Outage	Description
Natural disaster	Some natural causes which cannot be predicted have damaged the IT services, e.g., earthquakes and flood, thunderstorms.
Hardware failure	Hardware components may fail due to unknown causes or disastrous situations like fire, earth quicks, etc. Hardware components can be server motherboard, storage controller, network interface card, etc. According to Becker et al. [13], outages caused by hardware malfunctioning contributed 13% of total 117 unplanned outages occurred in 12 consecutive months.
Software failure	Application software may not perform its required operations as expected. Becker et al. [13] has revealed that outages caused by software failures accounted 87% of total 117 unplanned outages in the period of one year.
Human error	Human error consists with actions such as ignorance of events, invalid input, and mischaracterization of the metrics [13].
System overload	There are situations that IT system component runs over its capacity limit in a certain period of time [14]. Caccamo et al. [15] says, in real-time environments, tasks may have different criticality and flexible timing constraints. For example, when an vital resource runs much greater than actually it has to run, this leads to low efficiency and wastes available resources [14], [15]. So main cause of system overload outages is that there are enough resources to conduct the next step.
Computer virus and hacker attack	Attackers are endlessly trying to find vulnerabilities in systems to interrupt systems operations through various mechanisms, e.g., viruses destroy data and damage resources [16]. DDoS (Distributed Denial of Service) attack is a popular computer threat that organizations face when using WWW (World Wide Web) [17], [18].
Loss of network connectivity	When loosing Servers' access to network resources, it prevents communications from other external or internal resources or people.
Power outage	Electrical power outage cause all the network equipment stop working.
Vandalism	People damage organization's IT system components on purposely.
Unknown or not disclosed causes	All other causes those cannot be categorized into any of the above categories are included here.

2.3.1 Type of Damages

Dubendorfer et al. [19] stated that impact of IT service outage lasts not only short term, but also its impact reflects for long while even after the outage resolved. IT service damages can be divided into four categories as said by financial impact to the business [19]. Quantifying financial damage of the business operations are discussed in this work. When performing this, several factors which are described in Table 2.3 must be

considered. However, calculations of the impact of these factors are only approximations. Still these figures can provide some insight about type of investment must be deployed to improve the infrastructure and disaster recovery solutions. However, qualitative loss expectancy varies with the type of the industry. Moreover, it also changes over time.

2.3.2 Type of Costs

Quantifying financial loss caused by IT service outages is very complicated task, because IT infrastructures are complex and varies from organization to organization. There are several factors contribute to IT service outage costs, but some of them are not very clear to quantify. The first category of cost factors includes *downtime-related loss* such as productivity and revenue loss. Probably this cost can be incurred within the actual outage window itself. Another category is *DR cost* which includes cost for working staff and material to get the system again up and running. Possibly this loss can also be incurred within the actual outage window. *Liability loss* is also another category for outage cost calculations. Some parts of this cost are difficult to make clear. Liability loss describes when SLAs can be met, and the third parties demand financial compensation. The loss is incurred during $[t_1, \infty]$ where t_1 as the time at which the attack has been stopped. In case third party claim is in dispute, substantial legal cost may arise. It is hard to estimate how much the actual damage to third party without asking it from them. For example, when ISP is unable to provide service to customers, they typically must reimburse their customers for the outage time. Another hard to find loss cost is *Customer loss*. When service unavailable for some time, customers become unhappy about the service. As mentioned in Section 0, about eBay's three day outage in 1999 [7], dissatisfied eBay users posted messages to warn others that eBay service was not reliable and leave the service. So, in that incident, they might move to a competitor or band the service by no longer using it. These types of loss are incurred over a very long time $[t_2, \infty]$ where t_2 as the time shortly after the attack. This loss is also including potential new customers too.

Table 2.3 – Business financial impact of IT service outages.

Financial Impact	Description
Downtime Loss	This cost can be divided as productivity loss and revenue loss. Productivity loss refers to as idle employees are no longer working on their daily works and they may be less efficient to fulfill their duties, and they may have to do some works in later time when system service is restored. Revenue loss should also be accounted due to loss transactions as customers were unable to access a service due to the unavailability of online services.
Disaster Recovery	Quantify the time that organization must spend on system recovery.
Liability	When the service level deviate from the agreed SLA, the customer may claim compensation for the service interruption. This cost can be increased if the issue lasts several days
Customer Loss	Unhappy customers may decide to leave and terminate contracts with the organizations. The new customer joining rate may also drop if the organization reputation damaged. These costs may not reflect immediately the incident happens, but it would typically take several weeks or months.

As we reiterated throughout the literature review, IT service outages produce negative impact to the business operations and revenue generation. When an outage occurs, associated cost can include losses in revenue, stock price, staff time, reputation, customer loyalty, and customer satisfaction. So, this shows that the outages are a significant concern for organizations less for their technology impact than for their business impact. It is important to restore normal service operations as quickly as possible to minimize the adverse impact on business operations. Providing a permanent fix sometimes may take a while, but organizations must restore services to an acceptable operational level at least until providing a permanent fix for the root cause of the incident. Hourly cost of IT service outages probably be in the range of hundreds or thousands of US dollars for organizations those who heavily incorporate IT services in their businesses. Therefor it is a high necessity in present economical business society to find a way to estimate IT service outage costs.

Cost estimation of IT service outages has been studied before and those studies may have given some contribution to this research area. All these studies have identified and highlighted that a better understanding of the cost factors and other key consequences of IT service outages would important to formulate cost estimation

model to quantify IT service outage costs and amount of resources that will be required to restore services back in normal operations.

2.4 Estimating Revenue and Productivity

Patterson has stated that prior studies of estimating IT outage costs considered only for revenue loss of online based businesses, but other costs can only be calculated possibly when functions of those services stops working in outages [20]. But the study further highlighted that other than direct revenue loss, idle employees' costs, although if it does not directly affect to revenue, should also be included in the loss cost estimation. So, he/she derived an equation to capture both the cost of loss productivity of employees and the cost of loss revenue from missing sales.

$$\begin{aligned} &Estimated\ average\ cost\ of\ 1\ hour\ of\ downtime \\ &= \text{Empl. costs/hour} * \%\ \text{Empl's affected by outage} \\ &+ \text{Avg. Rev./hour} * \%\ \text{Rev. affected by outage} \end{aligned} \tag{2.1}$$

Employee costs per hour is just the total salaries of all employees per month divided by the average number of working hours per month. *Average revenue per hour* is just the total revenue of an organization per month divided by average number of hours per week an organization is operated the business. This cost parameter includes two costs: revenue associated with the business and revenue supported by the internal information technology infrastructure. Most organizations publish their revenue and other expenses annually, so those documents may have such data. Other two parameters of the equation is; fraction of employee and fraction of revenue affected by the outage. These values are an educated guess. Any big or small IT organization may suffer severe IT service interruptions at lease for minutes, hours or days, but magnitude of the revenue loss varies according to the business. The revenue term is a guess which may not be accurate, and someone can convince that it is different. Although we normally attempt to be more precision, but it may not be possible here. An expert user (e.g., CIO and CTO) could decide on their own fractions in making their decisions. For example, "in August 2013, a five minute inaccessibility of the Google services led to a 40% decrease

in Internet traffic and an estimated revenue loss was over USD 500,000 for Google alone" [21].

2.5 Ponemon Datacenter Outage Cost Study

Ponemon Institute has done a study on Cost of Datacenter Outage on 2016 [22]. This study captured cost figures on direct and indirect costs including; critical data loss, impact to the productivity, damages to assets, detection and recovery costs of core business processes, liability and litigation defense cost, loss of confidence and trust among investors, and damage of brand reputation. According to the findings of this study, the average cost of outages has increased from USD 505,502 in 2010 to USD 740,357 in 2016. These figures show that outage cost is increased by almost 50% in six years. The most organizations are now going for automated and digitized business model by abandoning long and slow manual processes. Because of this digital transformation, modern business operations are far more productive than before. At the same time higher reliant on the technologies make the more vulnerable to service failures.

Sample of 63 datacenters were nominated from 15 industry sectors in the survey [22]. It was found that IT service outage costs varies across industries. For example, while the cost of the financial services was USD 994,000, the lowest was USD 476,000 from the public sector [22]. This study discusses about nine different cost categories and they are compared for five years. Based on the findings, highest cost is associated with business disruption such as reputation damage. The next higher is revenue loss. Lowest cost is for third-party services in the recovery process. A reason for this can be, most of the organizations come to an agreement with suppliers and vendors for IT service support annually. Other cost types are equipment, ex-post activities, recovery, detection, IT productivity, and end-user productivity costs. According to the findings, detection cost is higher than the recovery costs. Equipment cost is comparatively low, because today most of the equipment are fault tolerant; hence, do not need to be replaced frequently.

Also this study has found that cost of outage is linear to the duration of the outage [22]. The highest cost of unplanned IT service outage is over USD 17,000 per minutes and average cost is nearly USD 9,000 per incident. Furthermore, UPS system failure was reported as the 25% of root causes of outages in this research. This study shows that though the cost of IT service outages continue to rise, the sources of Datacenter outages are not changed much as what they were in six years back. But it shows that a notable risen in the cyber-attack happens in past couple of years. Therefore, it is predictable that this can be a major challenge to IT services administrators in near future.

Although IT service failures abound, it is unlikely that organizations know the actual financial impact that the failures have on organizations brand name. Anandhi et al. [7] analyzed how organizations are penalized by the market against unplanned IT service outages. Authors have analyzed in which way the organizations suffer from brand name damage due to unforeseen operating failures of IT services. They have used Resource-Based View (RBV) of the firm and Event Study Methodology in their work.

2.6 Influence of IT Services to Business Operations

Probably IT service failures cause as a result of shortages in organizational capabilities. It may have a direct relation to the RBV of the organization. RBV commonly includes IT related capabilities to avoidance of IT failures. Some of these capabilities can be described as; organization's ability to manage IT related changes, their expertise and competencies to process data, interest and abilities to conduct experiments in the latest technologies, ability to integrate IT with their organizational business operations [23]. Capabilities explained as "information based tangible or intangible processes that are organization specific and developed over time through complex interactions among the organization's resources" [24]. The Resource-Based View (RBV) describes that IT operations can help to improve business performance with association of other resources [25]. For example, "an off-the-shelf supply-chain system can combine with existing supplier trust and relationship to form a mutually reinforcing and advantage-creating resource bundle". However, the strength of the resource bundle can be week at an IT services interruption. As a result of this, supply-chain system may become

malfunction and it would affect the supplier trust and relationship. These factors in turn can negatively impact the growth and revenue prospects of the organization.

Anandhi et al. [7] studied event study methodology to analyze and estimate irregular stock price changes as a result of IT service outages. This study accounted some control variables to conclude IT service reliance for different industry sectors. For example, telecom or financial services are considered as higher IT intensive industries than mining industry. Organizational size, growth rate, IT intensiveness, industry type, failure rate, failure severity, and history of failures are accounted to differentiate this concern. Researchers followed [26] recommendations to show robustness of their event study analysis results. Anandhi et al. [7] have associated sample of 213 publicly available newspaper reports about IT service failures in their study. Sample was taken for outages in last ten years. They removed the outliers from the total sample before to execute the regression. Smallest justifiable event window [26] was considered as two days including event day and the day before that. This is because information about the outage might have leaked to the market the day before to the actual report in the newspapers. To analyze the abnormal return, authors employed an estimated window of 120 trading days before to the incident and ending two days prior to the incident. They have used two estimation windows for the verification of the accuracy of the results of their work.

Findings of this study shows; an organization with 2-day outage window would result 2% average cumulative abnormal drop in stock prices and market responds more negatively to implementation related failures affecting new systems than to operating failures involved in existing systems. Further, the study demonstrates that more severe IT service failures result in a greater rejection in organizations' reputation and that organizations with history of IT services failures suffer a greater negative impact.

2.7 Summary

As IT is integrated with every aspects of the business operations today, reliable and efficient IT infrastructure is essential to ensure business customers to receive continuous and tremendous quality service. Therefore, it is the utmost responsibility of the IT team to make sure that service availability and the health of network

infrastructure is performing at the expected level. Though the great majority of service and data unavailability occur as a result of planned outages such as routine maintenance activities, unexpected nature of unplanned outages are more damaging to the organizations in terms of financially. Organizations those who heavily use IT services need to be aware that unplanned outages can have significant consequences, including loss revenue, loss productivity, and damage to reputation. Though, it is difficult to quantify indirect losses such as loss of customer confidence and irreparable damage to business reputation due to outages, it results unexpected long term damage to organizations. So, understanding of key outage cost factors is critical. While there are several related works have been done on IT outage cost estimation, there are only a little empirical studies conducted among these studies. Consequently, we believe semi-empirical model to estimate IT service costs is a better way to address this problem in more transparent manner. We aimed to conduct several case studies to evaluate the formulated cost model.

Chapter 3

3. RESEARCH METHODOLOGY

A better way of estimating financial damage caused by unplanned IT service outages is important for organizations to choose strategies and resources to avoid such incidents. The aim of this research is to formulate a cost model to address this problem. Though unplanned IT service outage cost estimations have been studied before, most of those contributions have addressed the problem through citing media and consultancy reports [7], or by plugging-in sample figures of outage costs into mathematical framework to derive an estimation. Furthermore, those studies have used simplified analytical calculations [1] or numerical simulations [2]. Though these works may be accurate, nevertheless it is important to validate the cost factors and how they could be used in a cost model based on empirical evidence. Alternatively, a key reasons for the lack of practical evidences is the significant effort needed to gather data and validate the integrity of the data. Furthermore, participating organizations do not interest to release sensitive cost data to outside the organization.

Section 3.1 presents the research approach. Data gathering methods are discussed in Section 3.2. In Section 3.3 explains how participating organizations are elected and how we plan to evaluate and verify the proposed model is discussed in the Section 3.4.

3.1 Research Approach

We began our study with a methodical review of existing literature on IT service outage cost and recognize key cost factors that are contributing to outage costs. Our general approach is depicted in Figure 3.1. We then formulated a cost model to IT service outage costs estimation. Finally, we conducted an semi-empirical study with the support of organizations to validate the proposed cost model. Moreover, the model is reviewed based on the feedback received from participants. We conducted multiple case study which is methodologically transparent. It consists of several interview sessions and a questionnaire to gather feedback about the proposed cost model and how to improve it further to produce reasonable cost estimation of financial loss of an outage.

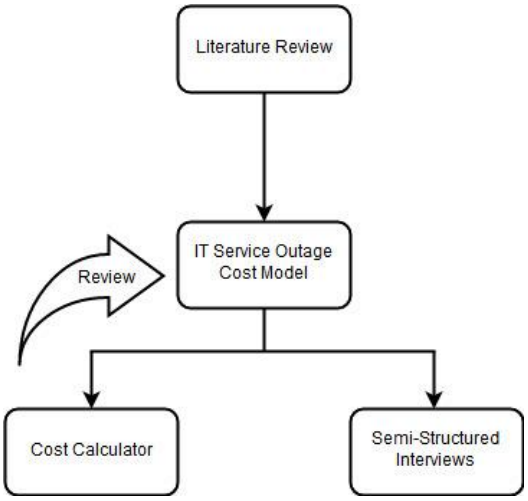


Figure 3.1 – Research Approach

This study is based on multiple case studies where representatives from participating organizations attempted to derive their cost of IT service outage using the proposed cost model. Then they were interviewed to understand the importance of measuring the financial impact of IT service outage and it could be achieved using the proposed cost model. The sampling method is best described as selective-sampling of organizations with varying level of reliance on IT services, aiming to choose them based on objectives of the study.

Cost of outage per unit time depends on the organization type and complexity of business, as well as its level of reliance on IT services for day-to-day operations. The key factors that can be identified as main contributors for the outage cost can also be vary with the business conditions.

Both tangible and intangible costs outlined in Table 3.1 are included in Figure 3.2. Though IT service outages are known threats to organizations, it is rare for an organization to try to quantify the financial impact to their business operations. A good understanding of the key cost factors of IT service outages is important to prevent unplanned outages and minimize financial impact to organizations in future.

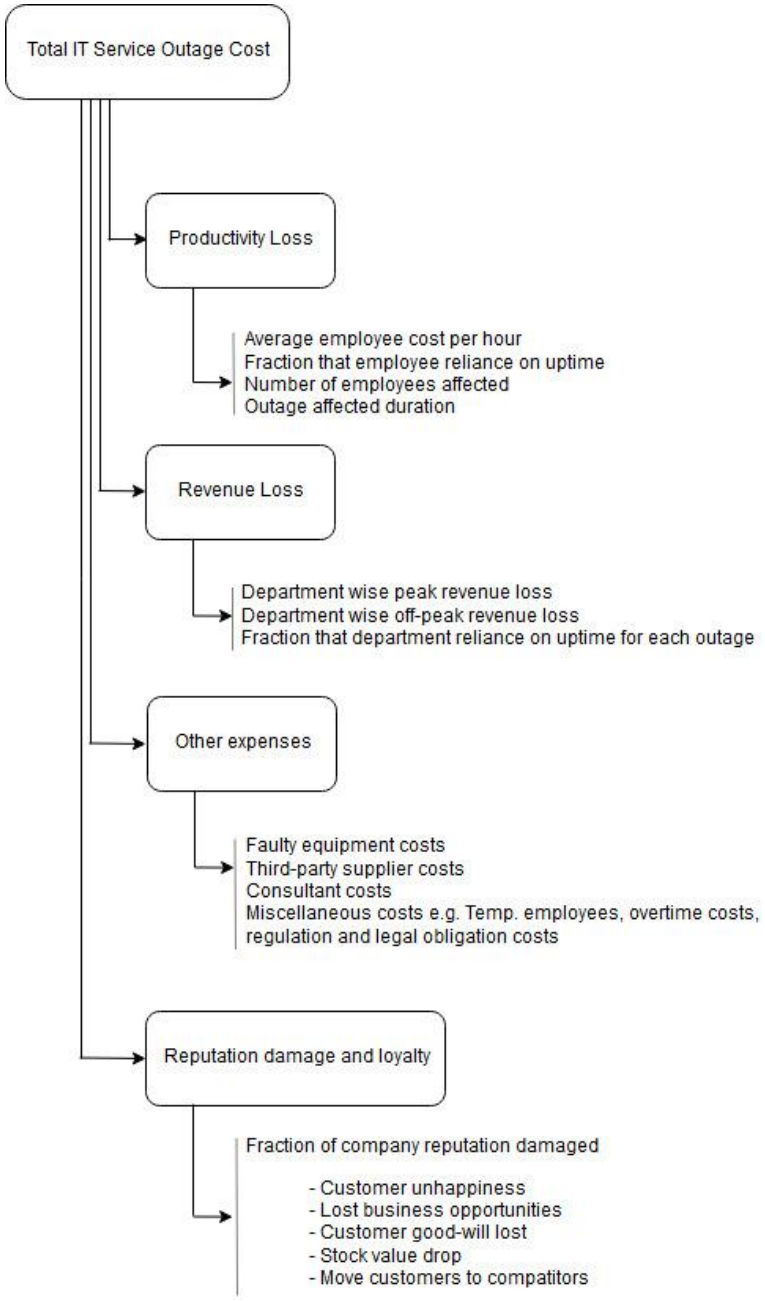


Figure 3.2 – Major cost figures of key cost factors.

IT service outage costs vary not only by the industry, but by the scale of business operations. The exact hourly cost of medium size business maybe lesser, but the impact on business operations maybe proportionally higher. The main cost factors that we identified before, can be categorized into two parts as tangible (or direct) costs and intangible (or indirect) costs. Possible cost factors under each of the two categories are listed in Table 3.1.

Table 3.1 – Major cost types.

Direct/Tangible Costs	Indirect/Intangible Costs
Operational revenue loss	New business opportunities loss
Employee remunerations loss	Employee moral loss
Supportive labor costs	Customer goodwill loss
Faulty component costs	Stock value drop
Advertising and Marketing costs	Damage to reputation
Compensations for SLA violation costs	Move customers to competitors
Financial penalties (e.g., banks)	

3.2 Data Gathering

Employed data collection method was twofold. We developed an Excel worksheet and shared it among senior management of different industry sectors to gather cost of previous outages. Semi-structured interviews were also scheduled with them to explain our Excel worksheet and how it works. We explained about graphs which are generated once data is entered and how managers can use those graphs to understand vulnerable areas in their IT infrastructure. For example, they can take proactive measurements to fix vulnerabilities to reduce future outage impacts and improve their IT service availability. Furthermore, through semi-structured interviews, we wanted to capture more broad knowledge and experiences about outages from respondents.

Though 18 organizations were invited, because of numerous reasons, only two participants responded to our initial case-study. Most of them faced difficulties in gathering data to fill the tool. Therefore, we also developed a set of questions (see Appendix D) to identify challenges respondents faced while attempting to gather and enter data to the model. The questionnaire focused on the importance of estimating IT outage costs, experiences with previous outage incidents, and their perspective of the correctness and usefulness of the proposed cost calculation tool.

3.2.1 Cost Calculator Worksheet

We developed an Excel worksheet to calculate outage costs based on the proposed cost model. This tool was shared among senior managers of different industry segments to collect various facts and figures of previous outages of their organizations.

The tool gathered several details of key cost factors and calculate approximated outage cost based on the given data. The tool was organized in the couple of steps to simplify data gathering. Once appropriated fields are filled, estimated total cost of IT service outage is automatically calculated. If the derived value seems not reasonable to the user, he could refine values until reasonable estimation is derived.

Most cases, management has limited knowledge about the key cost factors which contribute to IT service outage costs. Therefore, different respondents may interpret the questions in different way and their answers may not be accurate and reliable. Therefore, we designed our Excel worksheet to investigate each cost factor in a piecemeal manner where respondents are asked to provide several simpler figures of IT service outages before these figures are combined into grand total of each cost factor. Finally, values of each cost factor are summed to calculate the grand total of IT service outage cost. Respondents are also given an opportunity to refine grand total by modifying the cost figures that they entered in the worksheet until the drawn results for the estimated cost is judged reasonable. So, this way users do not need to worry about the equations used in the cost model and how it estimates the total cost. In addition to satisfying the research objectives, the worksheet can be used by organizations as a practical tool to estimate the financial losses caused by unplanned service interruptions. Depend on the derived cost figures, several predictions can also be made regarding improvements that can be applied to minimize such events in future.

Based on the user provided data, several graphs are generated to forecast outage costs variation. These graphs represent various predictions on cost factors. Users can refine their estimations by adjusting the cost figures. Moreover, this information will help IT service designers to make necessary optimizations in the infrastructure to overcome or minimize financial impacts of future outages.

3.2.2 Semi-Structured Interviews

We conducted interview sessions with the participating organizations to explain the importance of quantifying the financial impact of IT service outage and how to measure it. Moreover, these interviews were used to give them an idea on how we organized our worksheet to estimate the outage cost and how to fill it up.

Data gathering process need to be valid and reliable. It is also a major challenge when collecting data based on semi-structured interviews [27]. Daniel Turner [28] describes that Semi-structured interviews are a structured form of open-ended set of questions that people can show their experience and knowledge throughout the interview session. They are instrumented to draw-out more specific evidence about the respondent's knowledge and experiences about the outage incidents. This type of interviews inspires both interviewer and interviewee to talk naturally and friendly manner which allow them to share insights on the area of focus. Because of these reasons, semi-structured interviews are more effective to gather specific information in the interviewees' mind as they feel like a friendly conversation. Interviewees are also allowed to ask follow-up questions.

We mainly had two expectations from semi-structured interviews. Prior to beginning of an interview, we gave an introduction about our tool (i.e., Excel worksheet) to interviewees how it is to be filled and how these findings would help decision makers to estimate the key contributors to cost of IT service outages and the overall cost. Such insights could also help decision makers to identify areas that need further developments. Next, we start the interview session to query about qualitative figures related to IT service outages that they have experienced in the past. We prepared a set of questions for the semi-structured interview. List of questions is given in Appendix E. While our goal was to capture qualitative data regarding of outages, it also gave interviewees an opportunity to ask follow-up questions on the tool and its usage.

3.3 Population and Sampling

It was decided to select survey respondents based on both selective and convince sampling. We focused on multiple industries, and used connivance sampling to pick organizations from each industry. Once decided the list of organizations, we panned to

interview senior managers of these organizations who are directly interacting with the outage situations. These organizations have been selected based on the known contacts and publicly available information about IT service reliance. First, we contacted them over the phone and gave a brief overview about our research study and got permission to send an e-mail and invitation to participate to the study. Sometimes the person we contacted, guided us to much relevant persons that we can contact and obtain the data. We created a detail invitation letter with overview of our research study; including what we are going to do and how the outcome would help organizations. Complete invitation e-mail and letter are included in Appendix A and C, respectively. It also explained types of information that we want from participating organizations.

The Excel worksheet and another worksheet with sample data were shared with respondents to give an understanding about how the sheet needs to be filled. The shared links for the Excel worksheets were distributed among senior management among selected organizations. The invitation letter and the invitation email can be found in Appendix B and Appendix C, respectively.

3.4 Model Evaluation

While it is impossible to predict the exact loss from an outage, it is still valuable to derive a reasonable estimation on outage costs. Key cost factors identified in Figure 3.2 contribute to the total costs of IT service outages. Based on these considerations, equations in Section 4.2.7 were formulated. Though the reputation and loyalty damage can be difficult to quantify, this cost is important to consider in getting a true estimate to the total cost of IT service outage. However, the impact of this cost may not reflect immediately after the outage occurred.

We did an semi-empirical study with the support of organizations to validate the IT service cost model which was formulated in the Section 4.2.7. Participants need to enter information such as outage durations, employee's reliance to IT service uptime and number of impacted employees, IT uptime dependence to revenue generation of each department, and educated guess of brand name damage because of service interruption. Once initial data is inserted in the tool, the total cost is calculated. If the

respondent believes the estimation is not reasonable, he could refine the values of cost components to adjust the total estimated cost. Refinement of values of cost components could be iterated until the estimation of outage cost becomes a reasonable judgment. When the respondent agrees with the produced estimation, it reflects the financial impact of the organization for the given outages. It can be concluded that the cost model produces a reasonable cost estimation to the outage damage when the participants agree with the estimation generated by the tool.

We shared the worksheet among senior managers of various organizations in different industry sectors. Furthermore, we conducted interview sessions with them to explain our tool and make them aware about importance of quantifying financial impact of IT service outages. While a few organizations were able to quantify the impact of IT service outages, most were able to provide only the qualitative insights. Such organizations reported that they could not fill the tool because of lack of information. Some said they cannot understand the tool anymore. Another reason was the lack of time to fill the worksheet.

As majority of invited organizations did not acknowledge to the survey invitation, we have understood that they experienced practical difficulties when identifying statistics of previous IT service outage incidents and filling the Excel worksheet. Though IT outages are not uncommon experience to the most of businesses every day, management does not have clear view about the financial impact to business operations due to the outages. Therefore, it makes sense for survey participants not having relevant information to fill the worksheet as management do not encourage to document about previous outages.

We decided to prepare a questionnaire and distribute it among the same set of organizations who declined to respond to our previous survey invitation. This questionnaire was mainly focused to identify how participants view about the study of IT outage cost estimation. Furthermore, we wanted to be clear about whether their organizations have already thought about the severity of impact that caused to their businesses due to previous outages. If so, whether they have already taken any

alternative actions to overcome such situations. We also asked them about their view of our Excel worksheet which we shared previously.

3.5 Summary

This chapter explains our research approach which is based on multiple case studies. 18 organizations were invited from various industries for the semi-empirical study. Cost factors which are tangible and intangible were considered for the cost estimation. Once key cost factors are identified, the proposed cost model was formulated in an Excel worksheet. This tool was distributed among top managers of participating organizations. We then conducted interview sessions with them to explain our tool and importance of quantifying financial impact of outages. Furthermore, it was discussed how participating organizations are elected and validated the proposed cost model.

Chapter 4

4. COST MODEL

This chapter describes how the model is derived to estimation of financial costs of IT service outages. Section 4.1 presents the explanation of Patterson et al.' [20] cost model and how we associated that with our proposed model. Further we derive cost factors that were not addressed in the Patterson's simple cost estimation model. Section 4.2 discuss previous IT service outage impact to the businesses and how to identify the main causes of those outages and their business cost impacts. Section 4.3 presents the proposed cost model. Finally, explain the Excel worksheet developed to estimate the outage cost in Section 4.4.

4.1 Estimating Service Outage Cost

The core part of the research is to estimate the cost due to IT service outages. First, we identified well-known cost factors that contribute to the outage cost. Patterson et al. [20] presented a relatively simple way to estimate the average cost per an hour of downtime. As in Eq. 2.1 productivity loss was calculated by multiplying the average employees cost per hour and the fraction of employees affected by the outage. This represents idling hours that the employees still get paid. For example, if 30% of the employees of an organization with 150 employees are affected by IT-related service outage, and if they are paid LKR 500 per hour, then the productivity loss per hour is 500 × 150 × 30% = LKR 22,500 The second cost factor of Eq. 2.1 is the revenue loss, which can be calculated by multiplying the average revenue per hour by the fraction of revenue that got affected by the outage. For an instance, with an average hourly revenue of LKR 200,000 and 20% of the sales are affected by the outage, there will be a revenue loss of 200,000 × 20% = LKR 30,000 per hour. Given these figures, estimated average per hour loss is the sum of these two cost factors, e.g., LKR 62,500.

However, we see some inadequacies in Eq. 2.1. Most importantly, it only considers two key cost factors namely, the productivity loss and revenue loss. Productivity varies among different employee groups and their reliance on IT services, e.g., employees of the customer support department would rely more on the IT services than those who

are in the human resource department. Revenue generation also varies across different business units. For example, while sales department has a direct impact on revenue generation but human resource department does not have a direct influence. In addition to these two factors, several other intangible and intangible cost factors also contribute to the total outage cost and those are listed in Table 3.1. For example, as outages occur during the peak hours are more significant than those are occurring in off-peak hours. Because these must also be considered in the calculation.

While it is not reasonable to predict the exact financial impact of an outage, it is still important to derive reasonable estimate on outage costs. Loses in the following areas contribute to the total cost of outage:

- Productivity/labor
- Revenue
- Reputation and loyalty damage
- Service fees
- Miscellaneous
- Opportunity loss
- Hardware replacement

Based on these considerations, we derive a more comprehensive set of equations in Section 4.2.

4.2 Cost of Downtime

Outages are basically categorized into two parts; planned and unplanned outages. Planned outages are more manageable than unplanned outages. Most of the system service unavailability occurred because of planned outages, such as system maintenance, backups, and upgrades. So planned outages contribute to large portion of the total outage time. It is estimated as 85-90% of total outage time. Unplanned outages on the other hand consume around 10-15% of the total outage time. Though unplanned outages consume small portion of the total time, the business impact is much higher than the planned outages. Estimation of planned outages are usually accurate than that of unplanned outages because planned outages are schedule on a

weekly, monthly, or annual basics to avoid busy or rush times. Furthermore, planned outage estimations are derived using proper assessment of maintenance activities, e.g., backup. For the estimation of each activity, information of previous such activities can be considered. For example, we can get the average of outage duration and time of similar activities and number of occurrences of each activity performed per year. Besides it is important to adjust for any growth trends, so this can be an educated guess. Some maintenance activities such as hardware and software upgrades are consistent, so historical data may not be necessary for the estimation. These estimated figures can be adjusted to take decisions in future planned outages.

Estimation of precise value of financial impact is not easy in an IT service outage. However, it is important to derive a reasonable value. Perhaps that value is a baseline for management to evaluate economically appropriate level of investment in recovery plan to avoid or minimize future outage incidents. Some key cost factors of IT service outage cost can be identified as follows:

A. Productivity (employee expenses) loss
B. Revenue (financial) loss
C. Customer goodwill (reputation) loss
D. Opportunity costs
E. Miscellaneous costs

In our proposed cost model, we consider these cost factors as the key contributors to the total IT service outage cost. Information about outage durations and these cost figures are important for the calculation of total cost. There are several cost figures contribute to each key cost factor. Figure 3.2 shows the reasonable list of cost figures for each key cost factor. Next, we discuss how to calculate the contribution from these factors to the overall loses due to outage.

4.2.1 Productivity Loss

Even the IT services are unavailable for business operations due to an outage, organizations must pay the wages to employees even during the outage priod. Productivity is a key cost factor which affects the total outage cost. Analysis of past

data may help to provide reasonable estimation of cost of productivity loss per unit time. Employees who rely 100% on IT services maybe completely idle during an outage window. However, all is not lost as some employees may continue to involve in somewhat productive work such as cleaning junk emails, drafting mails to customers, work based on papers, and cleaning up their desks during the outage intervals. Hourly loss of productivity is a measure of hourly salary, benefits, and overhead costs for the affected employees. Employee hourly salary is calculated by following equation;

$$Employee\ salary\ per\ hour\ (s_e) = s_a/(d_a \times h_d) \quad (4.1)$$

where s_a is the employee annual salary, d_a is the working days per year, and h_d is the working hours per day. List of symbols are listed in Table 4.1. The cost of average hourly loss of productivity can be specified as follows:

$$Productivity\ loss\ per\ hour\ (P) = s_e \times r_e \times n_e \quad (4.2)$$

where s_e is the employee salary per hour, r_e is the employee's reliance on IT services (number between 0 to 1), and n_e is the number of affected employees. Employee salaries and reliance of their work duties may vary among different employee categories. Hence, Eq. 4.1 and 4.2 must be repeated for each employee category.

4.2.2 Revenue Loss

Another cost factor that contributes to total outage cost is revenue loss. First, we need to estimate the amount of revenue generated per hour. This could be calculated as:

$$Revenue\ per\ hour\ (r_h) = r_a/\ (d_a \times h_d) \quad (4.3)$$

where r_a is the annual gross revenue, d_a is the working days per year, and h_d is working hours per day. An important thing to figure out is the level of revenue's reliant on system uptime. Sometimes revenue generation may highly depend on uptime (e.g., in e-commerce), while it may not (e.g., government services). Uptime is the fraction of time the system is operational to serve for customers. This value is an approximated

guess which incorporates previous data and experience on how system was operating. We derived following equation to calculate hourly loss revenue:

$$Revenue\ loss\ per\ hour\ (R) = r_h \times r_r \quad (4.4)$$

where r_r is the revenue reliant on the system's uptime. To achieve high degree of accuracy, Eq. 4.3 and 4.4 must be repeated for each department as revenue generation and reliant on uptime are varies for each department. Perhaps revenue generation vary with peak and off-peak hours as well as time of the year.

4.2.3 Reputation and Loyalty Damage

When customers experience difficulties to use business services due to the failure of IT services, the confidence that the customers have about the organization may lose. It may damage the goodwill of the customers.

It is difficult to consider how the revenue loss per hour is directly linked with the damage due to loss of customers' loyalty. However, this should also be accounted for the more accurate calculation. If a large portion of customers are very loyal, having experienced a satisfactory service from the organization, the impact factor may be close to one. Whereas if the loyalty is not essential for the functioning of the organization impact factor can be close to zero. Approximating this value may require a long history of data and assumptions:

$$Reputation\ and\ loyalty\ damage\ per\ hour = rl_a\%/(d_a \times h_d) \quad (4.5)$$

where d_a is the annual working days, h_d is the working hours per days, and rl_a is the fraction of revenue that would be guessed as the impact due to the loss of customer confidence and irreparable damage to business reputation. Perhaps reputation and loyalty damage vary with peak and off-peak hours as well as time of the year.

4.2.4 Service and Miscellaneous Costs

Outages usually consists of chain of related costs. Service costs are nearly zero, if the service contracts are up to date and no external parties are connected for system recovery process. In a situation where a service contract is not renewed, organization

may have to hire vendors or suppliers for incident-based payments. Moreover, there are situations in which organizations seek expert advices for critical technical situations. These expenses are categorized as consultant costs. Following equation can be derived to estimate service and miscellaneous cost spent for the service restoration:

$$Service\ and\ miscellaneous\ cost = (o_a + m_a)/(d_a \times h_d) \quad (4.6)$$

where o_a is the annual service cost, m_a is the annual miscellaneous cost, d_a is the annual working days, and h_d is the working hours per day.

4.2.5 Cost for Hardware Replacement

Another cost factors that contributes to the total cost estimation is the hardware replacement cost. This is the cost on fixing or installing new components. Besides, sometimes an organization may have to get necessary equipment on-loan from suppliers or third-parties to provide temporary solutions if the outage impact critical business operations and last for long period [29]. IT team has opportunity to give stable permanent solution for the issue later by scheduling a planned outage window during the off-peak hours. Therefore, the rental and/or new equipment costs fall into this cost factor which can be calculated as follows:

$$Service\ and\ miscellaneous\ cost = e_a/(d_a \times h_d) \quad (4.7)$$

where e_a is the annual expenses for new hardware, d_a is the annual working days, and h_d number of working hours per day.

4.2.6 Opportunity Cost

When new customers are willing to use the business and if the IT service unavailability cause them to not use the business, they are likely to move to competitors to fulfill their requirements. This is not only damaging the organization's reputation but also it lead to loss of new business opportunities. By analyzing the new business records of previous couple of months, it is possible to estimate approximated number of new opportunities per hour. Furthermore, average profit of each customer can also be measured by analyzing previous cost figures. Using these information, hourly opportunity loss can be calculated as follows:

$$Opportunity\ cost\ per\ hour\ (O) = n_o \times p_o \quad (4.8)$$

where n_o is number of new opportunities per hour, and p_o is average profit of a customer. Perhaps new customer opportunities vary with peak and off-peak hours as well as time of the year.

4.2.7 Total IT Service Outage Cost

Sum of all the above costs give an approximated prediction for the financial loss for an hour of outage. Total cost of IT service outage could be calculated by multiplying the hourly cost of outage with the number of outage hours as follows:

$$Total\ outage\ cost = P + R + L + S + E + O \quad (4.9)$$

where P is the productivity loss, R is the revenue loss, L is the reputation and loyalty damage, S is the service and miscellaneous cost, E is the new equipment cost, and O is the opportunity cost.

4.2.8 Time Dependent Costs

Hourly cost of outages very with the time of the day that the outage occurs. In most organizations, there are well-defined peak and off-peak hours. During off-peak hours, neither few or no employees are working and nor revenue generation is generated, e.g., midnight system outages would have a least impact to the business. However, there are situations that some organizations do their business around-the-clock, e.g., eBay and Amazon. Such businesses may have less busy hours during the day, e.g., after mid night to early morning. Therefore, if the outage occurs during such hours or weekends or public holidays, impact would be less.

Because unplanned outages can occur at any time, it is reasonable to use average of all hourly costs during a whole week for the calculation. Moreover, since some outages occur due to specific reasons such as system overload, and if it occurred during peak-times, a more reasonable approach would be to measure the average. Furthermore, unlike unplanned outages, planned outages can be scheduled around the business-

critical times. However, if the maintenance is scheduled after office hours, e.g., at night, weekends, or holidays, organization must pay overtime and other necessary expenses such as food and transport to the employees. These costs must also be accounted for the calculation.

Table 4.1 – List of symbols.

Symbol	Factor
d_a	Annual working days
E	Expenses for new equipment per hour
e_a	Annual expenses for new equipment (replacement due to IT service outages)
h_d	Working hours per day
L	Reputation and loyalty damage per hour
m_a	Annual miscellaneous cost (e.g., rent, transport, foods, etc.)
n_e	Number of employees
o_a	Annual service costs (e.g., recovery, overtime, etc.)
P	Productivity loss per hour
R	Revenue loss per hour
r_a	Annual gross revenue
r_e	Employee reliance to IT services
r_h	Revenue per hour
rl_a	Fraction of annual reputation and loyalty damage
r_r	Revenue reliant on service uptime
S	Service and miscellaneous cost per hour
s_a	Annual salary
s_e	Employee salary per hour
n_o	Number of new opportunities per hour
p_o	Average profit of a customer

4.3 Worksheet to Calculate Cost of Outage

As outline in Section 3.2, we decided to collect cost figures of outages in piecemeal manner. A tool was developed as an Excel worksheet for this purpose. Though it was created to gather data about the outages for our research purposes, it can also be used

in practical purposes too. Therefore, the tool can be used not just only for the survey purposes, but also its findings would support IT service designers and decision makers to identify key contributors to the IT service outages and to decide areas that need developments to overcome or minimize costs of future outage incidents.

An Excel worksheet is prepared to formulate the proposed cost model to gather data through several simpler details of cost figures of key cost factors. Then the tool provides estimated outage cost for entered data as shown in Figure 4.1. Basically, the tool is organized into seven steps. More detailed explanation of each step is described below. Complete set of screenshots of the tool is included in Appendix A.

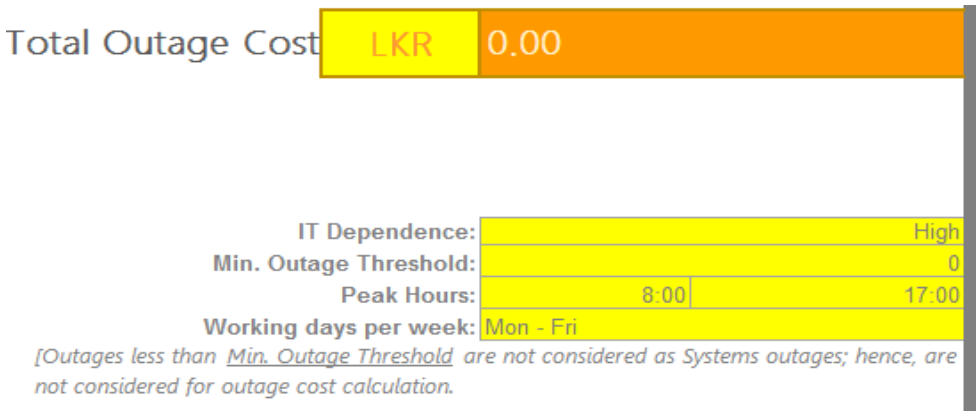


Figure 4.1 – Estimated total outage cost and basic information for the calculation.

In the step one, respondents are asked to provide some demographics of the organization, such as *Name of Enterprise* (e.g., business registered name), *Sector* (e.g., private organization or government agency), *Type of Enterprise* (e.g., education, technology, transport, etc.) and *IT Dependence* of the business operations. As shown in Figure 4.1, three other important figures which are collected in this step are *Min. Outage Threshold*, *Peak Hours* of the business, and *Working Days Per Week*. *Minimum outage threshold* determines the maximum outage time that critical business operations can sustain before business is affected. Respondent can estimate this value by considering the long-term and short-term outages and identifying the recovery objective (RTO) of each critical business operations. *Peak hours* of the business operations are a part of the day during which business operations are at its highest rate. We expect respondents to provide start and end time of peak business window and the

rest of the day is considered as off-peak for the calculations. Last figure that respondent to be provide is *working days of the week.* There are two categories listed here, Monday-to-Friday and Monday-to-Saturday. Respondent may select either one of these categories according to the nature of their business.

In the next step, we expect to collect information about outage durations. Here we have left spaces for 10 outages as shown in Figure 4.2. However, if participants have more outages than ten, they can add new rows as needed. *Start Date & Time* column is used for respondent to provide the timestamps that each outage was noticed and *End Date & Time* column for the timestamp that outage was resolved. Timestamp is accepted in the format of *[mm/dd/yyyy hh:mm]*. *Outage* column is provided to give a meaningful name to each outage incident. This data is displayed in a set of graphs in the Dashboard sheet of the worksheet and can be used to compare incidents. According to the start and end times, the tool will automatically calculate the number of peak and off-peak hours. The tool uses the values of *Peak Hours* field from previous step as the basis for peak and off-peak hours calculation. Furthermore *Min. Outage Threshold* from the previous step is used to determine whether the outage is considered for the outage cost calculation or not. If the number of hours/minutes of an outage is less than *Min. Outage Threshold* that outage is ignored from the calculation. For the outages that are not applicable for the calculation, *Start Date & Time* and *End Date & Time* values are expected be zero. The next two columns of the table namely, *% P. Hrs.* and *% OP. Hrs.* are used for the respondent to estimate fraction of peak and off-peak outage time that could be reduced and resulting some savings in total outage costs. This would help to determine what are the proactive measurements that would help to lower the future outage costs. The fields that are not changed would expect to enter 0%. Once outage windows entered, total peak and off-peak hours are automatically calculated.

Outage	Start Date & Time	End Date & Time	Peak Hrs.	Off-peak Hrs.	% P. Hrs.	% OP. Hrs.
Out. #1	1/0/00 0:00	1/0/00 0:00	0:00	0:00	0%	0%
Out. #2	1/0/00 0:00	1/0/00 0:00	0:00	0:00	0%	0%
Out. #3	1/0/00 0:00	1/0/00 0:00	0:00	0:00	0%	0%
Out. #4	1/0/00 0:00	1/0/00 0:00	0:00	0:00	0%	0%
Out. #5	1/0/00 0:00	1/0/00 0:00	0:00	0:00	0%	0%
Out. #6	1/0/00 0:00	1/0/00 0:00	0:00	0:00	0%	0%
Out. #7	1/0/00 0:00	1/0/00 0:00	0:00	0:00	0%	0%
Out. #8	1/0/00 0:00	1/0/00 0:00	0:00	0:00	0%	0%
Out. #9	1/0/00 0:00	1/0/00 0:00	0:00	0:00	0%	0%
Out. #10	1/0/00 0:00	1/0/00 0:00	0:00	0:00	0%	0%
	Outage Hours (Rounded to nearest hour)		0:00	0:00		

Figure 4.2 – Outage times and peak/off-peak adjustments for decision making.

Step three is used for the respondent to provide an estimation of reputation damage that caused due to the outages given in the previous step. The long history of data may require to be analyzed for this estimation. This is purely an educated guess. It depends on respondent's expertise and experience about the business operations. Reputation damage is denoted as a fraction.

Department		% Reliant On Uptime	Peak		Off-Peak	
			Revenue/Hr.	Lost P. Revenue (LKR)	Revenue/Hr.	Lost OP. Revenue (LKR)
Department #1			0.00	0.00	0.00	0.00
	Out. #1	0.00%				
	Out. #2	0.00%				

Figure 4.3 – Loss revenue calculation.

Step four collects data about how the revenue generation is affected by the outages. First, we estimate revenue loss of each department. Respondent need to provide each department's reliance on IT service up time, as well as average revenue generation during peak and off-peak hours. As depicted in Figure 4.3, department name needs to enter in the *Department* column. Once rows are expanded, department's reliance on each outage can be given in the *% Reliant on Uptime* column. It is a fraction of how dependable each department's revenue generation on outage. Each department's one-hour revenue generation during peak and off-peak hours need to enter in *Peak Revenue/Hr.* and *Off-Peak Revenue/Hr.* columns respectively. Once this data is entered, each department's peak and off-peak loss revenues for the total peak and off-peak outage hours are calculated separately. Finally, we sum each department's loss revenues to get the total revenue loss during the outage hours.

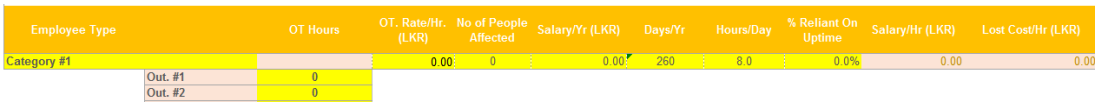


Figure 4.4 – Loss productivity and employee overtime.

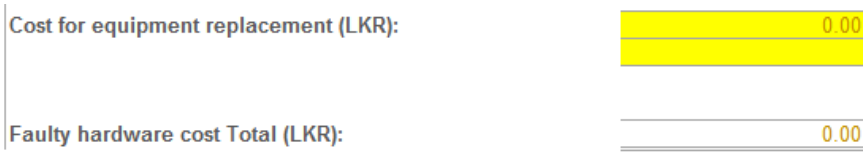
In step five, we estimate the productivity loss during the outage hours. We also consider overtime (OT) hours that employees had to work for recovery of missing production. As seen in Figure 4.4, *Employee Type* column is used for the respondent to list the employee categories of the organization. For each employee category, we collect annual salary, number of annual working days, number of daily working hours in the *Salary Per Year*, *Days Per Year*, and *Hours Per Day* fields respectively to calculate employee's hourly salary. Then we need employee's reliance with the IT service uptime in the *% Reliant on Uptime* column. This value is counted as a fraction. Multiplying the uptime reliance with the employee hourly salary will give an employee productivity loss per hour. Respondent is also expected to enter rough count of employees affected from each employee category in the *Number of People Affected* column. Multiplying number of employees with the hourly productivity loss of an employee category will give hourly productivity loss of that employee category. This is iterated for each employee category. Finally, we sum hourly productivity loss of each employee category to get the total hourly productivity loss of all employees.

We also consider calculating overtime (OT) paid for each employee category to recover the missing production. Respondent can also enter OT hours under the *OT Hours* column of each employee category who worked for an outage incident. Hourly OT rates of each employee category is to be entered in the *OT Rate Per Hour* column. Number of OT hours, OT rate, and affected employees will calculate OT paid for each employee category. Total productivity loss per hour and total OT paid per hour will give hourly lost productivity. Multiplying the hourly loss productivity with total outage hours will give gross productivity loss for outages.

	# Hours	Rate (LKR)
Third-party services cost:	0	0.00
Consultant cost:	0	0.00
Miscellaneous Costs		0.00
Service Cost Total (LKR):		0.00

Figure 4.5 – Costs for external services.

In the step six (see Figure 4.5), we calculate the amount that was paid for external parties to restore normal operations. Organizations get advices from external consultants in some situations. In such situations, hourly rate at which external consultants were paid and total number of hours that consultation services were given are accounted. Organization may also require getting support from external venders and suppliers during the recovery process. If there is no active contract with them, normally organization must pay them in hourly rate. In such situations hourly rate at which they are paid and total number of hours that they have worked are accounted. In some situations, venders or suppliers charge per incident. If the organization must pay incident base, it is entered as miscellaneous payments. Some other miscellaneous expenses are transport, foods, etc., and they also have to be accounted as external service costs.



Cost for equipment replacement (LKR):	0.00
Faulty hardware cost Total (LKR):	0.00

Figure 4.6 – Costs for new hardware.

As shown in Figure 4.6, last step calculates costs for replaced equipment if any. This includes total amount that was spent for any hardware replacement or data recovery activities.

Once the data is entered various graphs are derived according to the outage cost figures entered by the participant. Those graphs may support for management to take proactive measures to improve IT service infrastructure to minimize future outage costs. Basically, there are two sets of graphs. First set represents data that participant entered in the tool other set include various prediction of cost factors variations. Reviewer can

make some estimations by adjusting outage times and some cost components towards proactive actions how to minimize outage costs in future incidents. This adjustment can be compared with originally produced cost figures. It will help IT service designers to make required optimizations in the organization's IT service to lessen the possible financial impact of future IT service outages.

4.4 Summary

This chapter presents details of business impacts of the outages, identify critical areas that outage impacted, and classify key cost factors of those critical areas. Then it describes the formulation of the proposed cost model. Key elements of this model are productivity loss, revenue loss, reputation damage, opportunity loss, and miscellaneous costs. Hourly costs of each cost factor are derived, and total IT service outage cost is the summation of these cost factors. Then formulated the Excel worksheet to calculate the cost of outage based on the derived cost model.

Chapter 5

5. RESULTS AND DISCUSSION

This chapter provides detail analysis of results of outage cost data collected through the Excel worksheet and interview results. We conducted interview sessions with 11 organizations out of 18 that we invited. Nine face-to-face interviews and 2 over the phone interview sessions were conducted for the 11 organizations. Four organizations out of reset of seven could not be contacted. Other three of seven organizations were contacted over the phone, but they did not give a time for a telephone or face-to-face interviews. The Excel worksheet gathers various cost figures of outages from organizations and produced estimated total outage costs of the outages occurred during past 12 months. When filled the data in Excel tool, it calculates the total outage cost. If the estimation is not reasonable, user can refine values in cost components. Once appropriate data was entered, dashboard-style tool generates various graphs. The semi-empirical study primarily focuses on both quantitative and qualitative data of IT service outage incidents. Qualitative data is compiled into sections or groups of information [28] for more simpler form. These data are interpreted and quantified into cost figures with the expertise support of the participants and analyzed series of historical outage cost figures.

Section 5.1 presents the results we gathered using the tool and interviews. We also summarize key findings of those interview sessions. Section 5.2 discuss about the results of follow-up questions. The challenges that participants were experiencing are discussed in Sction 5.3. Section 5.4 describes the revised cost model and the Excel worksheet.

5.1 Data Analysis

We have addressed three areas during the interviews. First, participants were given an opportunity to briefly explain about his role in the organization, background of their business model, key business processes, and what extent IT services interact with the business processes. Second section of the interviews focused on obtaining information about the preparations, recovery procedures, post recovery actions for IT service

outages, and employees' reactions during the outage period. Final section had questions about the participants view about the proposed cost model and the tool, as well as their motivation to participate to this case-study. The organizations that we invited are belonging to apparel, financial, transportation, manufacturing, banking, electricity, and IT service sectors. When we were sending the invitations to participations, we also requested a short meeting with them to discuss about our tool and interview them. While three participants returned the filled Excel worksheet, we got the opportunity to interview representatives of only 11 organizations. Table 5.1 summarize the profile of participated organizations.

Table 5.1 – Summary of interviewed organizations.

Type of Business	Company Size (Average)	IT Dependence	Profile of Interviewee	Number of Invitees
Apparel	200	High	Head of IT	1
Banking	11000	High	Head of IT	4
Service provider	750	High	Senior Executives	6
Finance	200	Medium	Head of Group IT	1
Manufacturing	300	Medium	Head of IT	3
Transport	1000	High	DGM - Information Systems	2
Water supply	7000	Medium	Senior Network Engineer	1

IT service dependency is high in most of the places. According to the interview feedbacks, it is identified that maximum tolerable time period would be 15 minutes before the outage affect to the production operations. Every organization had experienced at least a single outage event in last 12 months. However, considerable numbers of organizations are aware and have implemented some precautions to control accidental service interruptions which may happen due to IT service outages. Even though, these precautions have been taken to minimize the impact of service outages, still they are experiencing substantial business impact due to the service outages. This situation gives an indication that though organizations have implemented recovery solutions, they do not have a clear visibility about the key outage threats, places where service interruptions are badly impacted, and magnitude of the damages.

Three organizations sent us the completed Excel worksheet. They are from trading industry, transportation, and finance businesses. Their business function dependency with IT services is medium, high, and high, respectively. Trading industry organization does not have direct sales to the end-uses. They said that the reputation and loyalty damage due to IT service interruption is considered to be negligible. Financial impact is mainly affected to their manufacturing plants as manufacturing systems use IT services for several operational activities. Most common cause of outages are hardware failures, specifically the network connectivity issues. Other than that, they had few occurrences of server crashes and ISP connection issues. Planned outages are being arranged to perform during out of working hours. But there are situations such as when an urgent order has come, production lines will be working around the clock for several days until the order finishes. In such an event, IT team finds it difficult to schedule a planned outage window, so they may try to manage the situation and wait until rush time is finished. They always try to nullify the outage affects to production operations while planned maintenance activities are performed. The participant from transportation business mentioned that they have high dependency with IT services, and they cannot tolerate more than 30-minutes of outage. They have invested heavily on alternative solutions to deal with sudden service interruptions. Some solutions are redundancy on critical switches and firewall equipment, backup solution, and disaster recovery site. They have experienced only a single outage during the past 12 months. But they said, even it was not really impacted their operations as that outage occurred in the mid night of a weekend and it was Christmas season. Because they did not have any financial impact due to the outage, we excluded that organization for further analysis. The third organization is a financial business and they are also having high dependency on IT services. Their information was used for our analysis. They mentioned that they have implemented redundancy setup for critical network equipment, such as active-standby setup for the critical switches, redundant power sources and power supplies for devices, and daily full backups and hourly incremental backup solutions. They have also mentioned that service interruptions may heavily affect to their brand name, so they always try to take all necessary actions to keep the IT services alive. The longest outage that they have experienced during the past 12 months was ERP server access problem which lasted for 9:30 hours during the peak

time. They said that it would have caused considerable damage to customer confidence. Sales department is their main task force to generate revenue. Hence, they are highly depending on Internet connection. Because of this, they are now planning to implement dual ISP solution. Furthermore, they have mentioned that external consultancy service is also get involved per incident basis for major events.

During the interview sessions, participants mentioned that it is worth to quantify financial damage caused by the IT service outages. But they do not have a broad view about the types of damages caused, the extent of damages, as well as how to measure damages such as customer loss and brand name damage. It was further mentioned that they are unclear on how to be prepared to handle future incidents and to train employees to manage such events. On the contrary, some managers have different view about the study. They said that it is not practical to do such a work, as they do not have enough time and resources to handle data relevant to outage incidents. Furthermore, most of organizations do not keep records of occurrence of previous outages. Moreover, participants have a concern about gathering financial data such as salary and revenue. Because in private organizations, salary particulars of each employee are confidential and do not publish either internally or externally. Revenue information is also not easily available to employees and if anyone needs such data, it needs to come through higher level of approval. Further, peak and off-peak revenue generation is also not preciously measured in most of the organizations. Though they have such a difference in revenue generations, clear qualitative analysis was not delivered in most of the places. Managers were interested in the graphs generated by our tool. They said when data is display in graphs and charts, it makes more sense and also helps to deliver better view about the IT systems and required developments to senior managers. That impression will help to get required approval for the investments for system and human resource developments.

5.2 Results of follow-up questionnaire

As the number of organizations who could complete our tool were low, we conducted a follow up questioner to collect feedbacks from the organizations to identify the

importance of estimation of IT service outage costs, key parameters related to IT service outage, and reasons for not supporting to the survey.

The link for questioner was sent to the 15 organizations who did not respond to our initial study. Ten responses were received to the questioner. Seven (70%) organizations mentioned as their IT dependency as high while other three (30%) have medium. This shows that most organizations are getting IT support to their business operations. Among the ten organizations, nine organizations do not have a mechanism to quantify the cost of IT service outage. However, eight (88.9%) organizations mentioned as it is a valuable practice to quantify outage costs while one (11.1%) participant contradicted to this idea and one (11.1%) participant did not provided his view on it. This indicates that there is an importance of estimating the IT service outage costs.

Seven organizations had outages during the past 12 months. Two organizations did not have any outages during that period and one organization does not have clear recodes about the outages. Six outages were taken place in a manufacturing organization. Four outages were taken place in bank and IT service organizations. Two outages occurred in software and export-oriented organizations. One outage occurred in export-oriented manufacturing and apparel organization. Highest number of outages were recorded in the Manufacturing organization. It is six. This shows that, though they have considerable usages, their IT infrastructure needs improvements to minimize such incidents in future. Least number of outages were experienced by manufacturing and apparel organization. They may have implemented solutions to minimize the outage occurrence and they will have a chance to further reduce the occurrence of outages in future. Banking and IT service organizations are having moderate number of outages. This indicate they need further improvements in their IT infrastructure.

Software organization had a 48-hour outage which was the longest among the responses we received. Manufacturing organization had 24-hour outage (second longest) and IT service organization had a 12-hour outage. Other organizations had outages of less than one hour. Eight organizations have already defined their acceptable outage duration. Maximum defined value was 24 hours and minimum were zero. Though the export-oriented organization had defined the maximum value as 24

hours, they are planning to reduce it to 4 hours. All the other organization defined their acceptable outage window in a range of two to zero hours. The bank and manufacturing organizations have defined it as zero hours.

The apparel and manufacturing organizations have taken proactive actions to minimize outage costs. Only apparel organization has quantified the cost of IT service outage and implemented proactive actions as dual ISP and cloud solution. As mentioned earlier, they have a single outage during past 12-months, and it was recovered within 10 minutes. The manufacturing organization has taken backup options as a proactive measure. Eight respondents out of ten think it is valuable to quantify outage impact while one respondent expressed otherwise. One respondent has not given a feedback to that question.

Different organizations have different aspects to quantify towards the impact of outage. It was generally agreed that direct loss is the most important aspect to quantify. It is 70% of the total responses. One organization (10%) mentioned indirect costs such as brand name damage have also been important to consider for the cost calculations. Two organizations (20%) believe both direct and indirect costs are important to be quantified. One organization mentioned about the penalty fee as another aspect to quantify. 60% of organizations believed quantified value of IT outage impact can be take management's attention for better investment on IT infrastructure upgrade. However, the rest did not agree.

We also included additional four questions to capture participant's view about the tool that we distributed among them previously. 80% of them expressed their interest about the tool and they believe tool like this is useful. Two (20%) participants responded that they do not think such a tool is useful to measure the IT service outage costs. One participant out of them mentioned as they cannot understand the content of our tool. Other participant mentioned as this is not relevant to their company. However, they further mentioned that parameters listed in the tool is meaningful. The 20% of participants who mentioned as the tool is not useful have not meant, our tool is not useful. Moreover 90% out of ten participants agreed that parameters listed in the tool is meaningful.

Five participants (50%) mentioned the key challenge in filling the tool was lack of data. Two participants (20%) have also stressed the difficulty to quantify intangible costs like reputation damage. Few participants (10%) responded as the main challenge they had were lack of time and difficulty in understanding the tool. However, 90% of the participants expressed their interest about the graphs and responded that the graphs are useful and informative. But one participant (10%) said that they cannot understand these. Also, four participants (40%) wanted to visualize the areas that need further developments and forecast more information to make better decisions. Furthermore, 60% of the participants believe that adjustments that they have made in cost figures towards the savings in total outage costs in future outage incidents is clearly reflected in the graphs. But 40% of participants disagreed with this.

Finally, participants shared their free ideas about this study. One has mentioned that if they have been given more time, they could have obtained more information to fill the tool. One participant from IT company mentioned that our target audience should be industries like garment factories and supermarkets who use IT partially. Because they may not have a good idea about outage recovery precautions, and they will be aware with those once they go through this survey.

5.3 Reasons to Not Supporting

Having distributed the invitation emails with links for Excel worksheet, we typically allowed participating organizations 1-2 weeks to respond. However, none of them responded within that period. We gave them follow-up calls. Three organizations said they can fill and send the Excel worksheet. As agreed, they have sent the completed Excel worksheet in few days. A responsible personal of four organizations could not be contacted. Seven organizations said they would be sending the completed worksheet, but they did not send. For some of them, there was no way of knowing why they have decided not to respond. But some invitees have acknowledged with reasons for not responding. One key reason that most people said is lack of time. Other reason for declining is lack of data. Those who responded with not enough data to fill the worksheet, have realized that they did not have necessary data because consequences of IT service outage vary across various divisions and it was difficult to calculate it

given the its size and diversity. Two organizations said they do not have data and difficult to gather it. One organization highlighted was lack of incidents or at least of incidents entailing costs. When we went to meet them, some participants said that uptime was 99.99%, so there were no real costs worth mentioning.

5.4 Modified Cost Model

Based on the financial impact, primarily outage cost factors can be categorized into two, namely direct and indirect costs. Direct costs refer to as the losses generated directly from the business operations due to IT service outages. These costs are related to restore the normal business operations. It includes *compensations for work overtime, faulty equipment, repair labor*, *external consultant,* and *vendors and suppliers*. Indirect costs type refers to long-term costs that are not directly associated with the outages. Indirect costs mainly generated from *revenue loss* and *reputation damage.*

Formulated cost model is;

$$Total\ outage\ cost = P + R + L + S + E + O \tag{4.9}$$

where P is the productivity loss, R is the revenue loss, L is the reputation and loyalty damage, S service and miscellaneous costs, E is new equipment costs, and O is opportunity loss. Opportunity cost is added new and its details and how to calculate the opportunity cost is described in Section 4.2.6.

5.5 Summary

This chapter present how we gather outage data using the Excel worksheet. We also conducted interview sessions with organizations with whom the Excel worksheet was distributed to explain about it and how to fill it. Eighteen organizations were invited to fill the worksheet. However, only two organizations responded us with quantified data. Other organizations mentioned several reasons for not responding. Then we distributed follow-up questionnaire to grab ideas of those who did not fill the tool. While the tool generates estimated value for the outage cost, it generates several graphs which can be

helpful for decision makers to get some ideas about the IT infrastructure for further improvements for minimize impact of future outages. According to the feedbacks of follow-up questionnaire, majority of managers interested to quantify financial impact of outages.

Chapter 6

6. SUMMARY

6.1 Conclusion

Modern businesses heavily integrated their operations with IT services. With the varying nature of business activities, IT service infrastructures are becoming complex. Due to this complex nature of IT services architecture, understanding its intervention to the business operations is a difficult task. Therefore, the ability to quickly identify and provide a solution for an emergency issue is challenging. Thus, a clear understanding of interdependencies between critical business operational components and IT services is essential. In this research we studied financial impact of IT service outages. With the outcome of this analysis, we identified a set of key cost factors and a formulated cost model to estimate the financial impact of outages.

While, IT service outages are a well-known problem, there is no clear and effective model to estimate the cost of outages. This is further complicated by lack of understanding about key factors that affect to outage cost, ways to measure them, and difficulty in capturing indirect losses. We address this gap by developing a model to estimate IT service outage costs. First, we derived a set of IT service outage cost factors based on related work and expert judgment. Based on those factors, we then formulated an IT service outage cost model. Third, this model was formulated as a spreadsheet and was shared with senior managers of varying set of organizations. This model may enable IT managers and decision makers to understand the business impact of IT service outage. Clear understanding of cost factors can also give insights on weaknesses in existing infrastructure and where the fixes are to be applied to minimize or overcome financial damages in future IT service outages. There may be various financial impacts happen to organizations due to outages. So, it is important to quantify the financial damage of each cost factor and if the value is high on them, senior managers or decision makers will have to take necessary actions in the IT infrastructure for further improvements to minimize impact of future outages.

When appropriate cost figures of previous outages are entered to the worksheet, it automatically calculate the total cost of IT service outages. Users are also allowed to

refine values of the cost components to derive a reasonable cost estimation. We conducted a semi-empirical study to evaluate the proposed cost model with the help of three organizations. We further conducted a set of interviews to explore how our cost model will help organizations to estimate their financial losses. We also explained them the chances that they have to identify areas of the IT infrastructure that need development to improve the efficiency. The decisions can be taken based on the derived values of different cost factors. In addition to generating estimated total outage costs, the tool generates several graphs to forecast outage costs trends and estimations. e.g., *Peak: Off-peak (%) vs. Revenue Loss for Each Outage* graph shows how the loss revenue varies when *Peak: Off-peak* time ratio changes. Another example is *Reputation Damage % vs. Total Outage Cost* graph shows varying fraction of reputation damage affect to the total outage costs. These predictions would help decision makers to plan how to optimize the IT infrastructure to lower the future outage incident costs.

Based on the literature review and expert judgement, we derived set of key cost factors, such as productivity (employee expenses) loss, revenue (financial) loss, customer goodwill (reputation) loss, new hardware costs, and miscellaneous costs. There are series of costs associated with an outage. These costs are addressed as miscellaneous costs which includes third party support, equipment on-loan, consultant fees, data recovery, and employee overtime. Based on the feedback, opportunity cost has been identified and it is included in the proposed cost model.

6.2 Research Limitations

Due to time constraints, we could invite only 18 participants for the semi-empirical study. However, only three of them contributed to the study by providing us a time for an interview and filling the tool. Perhaps measuring the financial impact caused by qualitative cost factors are important for a reasonable cost estimation. Accuracy of quantifying qualitative cost factors such as reputation damage and loss of potential new sales opportunities depend on person's experience and expertise of analyzing long history of data. This is entirely an educated guess and need to do several rounds of iterations to fine tune to draw close approximated value. As we allow them to refine

the numbers until the organization feels that the total losses are a good representation, given values are perceived than the true numbers. Hence, an organization is likely to underestimate its true losses.

Business operations of some organizations vary depending on the seasons of the year. Most of the organizations start sales promotions and discounted prices for their products during seasonal times. During this period, sales volume goes up. Besides, organizations may have to spend some extra money on advertisements and promotions. Moreover, some organizations open temporary sales outlets and keep them open during extended working hours as people tend to buy items when they are heading back to homes after office. For after office hour works, employees are paid overtime. Also, as a motivation factor, organizations introduce some extra payments if the sales volume exceeds a threshold value. It would be worth to include these types of costs in the calculations as some organizations are using these types of promotions in two or three times in the year, such as New Year and Christmas seasons.

It needs to apply derived cost model to more organizations to make sure the accuracy of cost estimation. Expansion of semi-empirical study to several organizations would offer opportunities to collect more details of IT service outages. It helps validate the derived model. If new cost factors which are having potential to contribute to outage costs are identified, they also need to be included in the cost model. Though these factors are important to consider for the cost calculation, it is further complicated the cost model and participants will be facing further challenges when gathering and filling data in the tool.

6.3 Future Work

In future studies, the formulated Excel worksheet can be distributed among more organizations to get considerably large number of outage statistics. Though our cost model is estimate-based, several organizations have felt that they do not have necessary data to complete the tool. Because of this view, most of the participants have reported that they have problems in quantifying the cost factors. Therefore, several interview sessions must be conducted to explain them about the assumption on this

study and how we aim to capture the cost values. Furthermore, to make sure the reliability and integrity of the information provided by the participant must be validated using a third-party such as auditing company.

Another research direction could be to conduct a questionnaire to collect more general information about outages and make them understood in what extent does the organization can get benefits from the outage prevention planning. Furthermore, this type of study would be much beneficial for organizations who use IT services in their business operations partially like garment factories and supermarkets. These organizations may not have incorporated advanced technologies for service interruption handling. If they are aware with information that we use in our study, it will be helpful for those organizations. However, the proposed cost model is better for organizations that are not purely online like e-commerce. Because profit generation is completely reliant on the availability of the website, the profit generation will have stopped 100% in the service unavailability. Even though new orders cannot be taken as customer cannot access the website, already placed orders may be processed to deliver to customers. As customers cannot place new orders, they may feel like entire services are unavailable and they disappoint about the business. Moreover, there are several external businesses such as vendors and suppliers who are entirely or partially depending on these services and those external businesses are also impacted the online service unavailability. In our model we have not included these costs, but it is worth to consider that too.

6.3.1 Availability of Required Data

A major challenge that participants faced was lack of data to filling the Excel worksheet. There are industry standards and set of best practices (frameworks) push organizations to keep records of such data. As an example, the most applicable and widely used standards are Control Objectives for Information and Related Technologies (COBIT), and Information Technology Infrastructure Library (ITIL) [30]. Though different words used in these two frameworks, they address the same problem.

ITIL framework uses incident management process. Incident is an unplanned interruption or a quality degradation of IT services [31]. Help desk is the single point of contact for Incident management. It keeps all the IT related records such as incident occurred and resolved time, actions taken, etc.

This information will help to fill Step 2, Step 6 and Step 7 of the Excel worksheet.

6.3.2 Increase Chances to Gather More Data

According to the feedbacks received for Excel worksheet from participants and follow-up questionnaire, we hope following amendments will increase possibilities of participants to fill the Excel worksheet.

Select organizations who have implemented at least either COBIT, ITIL, or ISO/IEC 20000 standard, because these standards define proper maintenance of IT process information [30]. Participants are only expected to provide approximated cost figures and do not need to worry too much to gather exact values. As it is not practical to expect high accurate data as we are working with historical incidents. Furthermore, quantifying intangible costs such as reputation damage is entirely depending on person's experience and expertise of analyzing historical data, so generated value can always be varying to person to person. We also have to give participants reasonable time frame to complete the tool. Further we may have to deploy follow-up sessions to remind them in timely manner.

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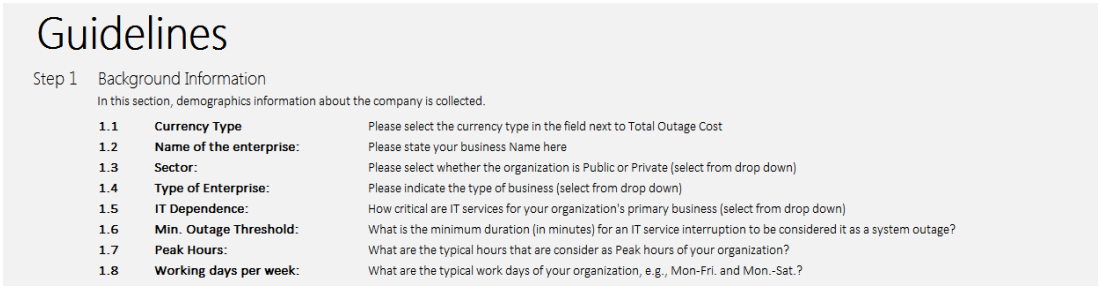
APPENDIX A – EXCEL OUTAGE COST ESTIMATION TOOL

GUIDELINES WORKSHEET

This worksheet provides guidance to fill the calculator worksheet. Data entered in the calculator worksheet divided into seven steps. Each step has several fields to fill. Types of information and data formats are described in these guidelines.

Step 1:



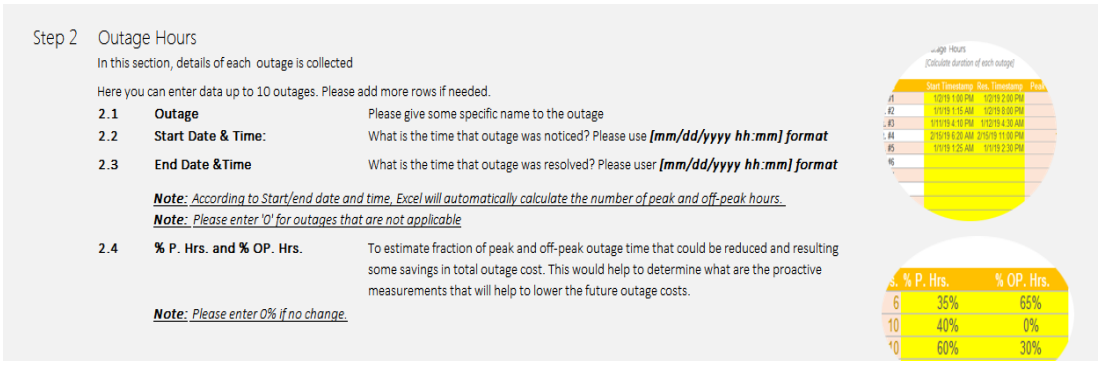
Guidelines

Step 1 Background Information

In this section, demographics information about the company is collected.

1.1	**Currency Type**	Please select the currency type in the field next to Total Outage Cost
1.2	**Name of the enterprise:**	Please state your business Name here
1.3	**Sector:**	Please select whether the organization is Public or Private (select from drop down)
1.4	**Type of Enterprise:**	Please indicate the type of business (select from drop down)
1.5	**IT Dependence:**	How critical are IT services for your organization's primary business (select from drop down)
1.6	**Min. Outage Threshold:**	What is the minimum duration (in minutes) for an IT service interruption to be considered it as a system outage?
1.7	**Peak Hours:**	What are the typical hours that are consider as Peak hours of your organization?
1.8	**Working days per week:**	What are the typical work days of your organization, e.g., Mon-Fri. and Mon.-Sat.?

Step 2:



Step 2 Outage Hours

In this section, details of each outage is collected

Here you can enter data up to 10 outages. Please add more rows if needed.

2.1	**Outage**	Please give some specific name to the outage
2.2	**Start Date & Time:**	What is the time that outage was noticed? Please use ***[mm/dd/yyyy hh:mm] format***
2.3	**End Date &Time**	What is the time that outage was resolved? Please user ***[mm/dd/yyyy hh:mm] format***

Note: *According to Start/end date and time, Excel will automatically calculate the number of peak and off-peak hours.*

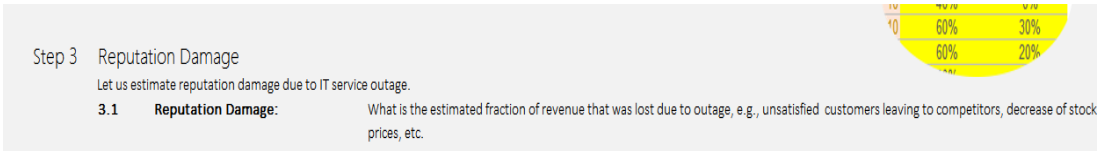
Note: *Please enter '0' for outages that are not applicable*

2.4	**% P. Hrs. and % OP. Hrs.**	To estimate fraction of peak and off-peak outage time that could be reduced and resulting some savings in total outage cost. This would help to determine what are the proactive measurements that will help to lower the future outage costs.

Note: *Please enter 0% if no change.*

	% P. Hrs.	% OP. Hrs.
6	35%	65%
10	40%	0%
10	60%	30%

Step 3:



10	60%	30%
	60%	20%

Step 3 Reputation Damage

Let us estimate reputation damage due to IT service outage.

3.1	**Reputation Damage:**	What is the estimated fraction of revenue that was lost due to outage, e.g., unsatisfied customers leaving to competitors, decrease of stock prices, etc.

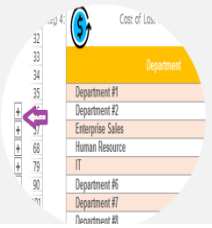
Step 4:

Step 4 Cost of Lost Revenue

In this section, we estimate revenue loss for each department. Please provide each department's reliance on uptime as well as average revenue generation during peak and off-peak hours.

Note: Please expand group of rows under department names by using 'plus' mark in the left most side of the row to enter department's reliance on uptime

4.1	**Department Name**	Enter department names of your company
4.2	**Peak Revenue/Hr.**	Average revenue that is generated by the department during a peak hour
4.3	**Off-Peak Revenue/Hr.**	Average revenue that is generated by the department during an off-peak hour
4.4	**% Reliant on Uptime**	How dependable each department on IT services?



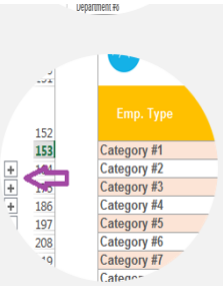
Step 5:

Step 5 Cost of Lost Productivity

Next, we estimate the productivity loss. Also, consider any OT hours that employees had to work for recovery of missing production during the outage hours.

Note: Please expand group of rows under employee type/category names using '+' mark of the left most side of the row to enter number of OT hours.

5.1	**Employee Type**	Enter types/categories of employees of your company
5.2	**No of People Affected**	How many employees are affected by the outage? Please indicate rough count under each employee category
5.3	**Salary Per Year**	Annual salary of each employee category
5.4	**Days Per Year**	No of working days per year, e.g., 5 days per week, 52 weeks per year; Total days 260
5.5	**Hours Per Day:**	No of working hours per day
5.6	**% Reliant on Uptime**	How dependable each department on IT services?
5.7	**OT Hours**	How many OT hours each employee category worked to recover any missed production?
5.8	**OT Rate Per Hour**	OT rate per hour



Step 6:

Step 6 Cost for External Services

This section calculates costs paid for external parties who supported the recovery process.

6.1	**Third-party service cost (per Hour)**	Rate at which external vendors and suppliers are paid for during recovery process.
6.2	**Third -Party Service Hours:**	Total no of hours that third-party support is taken
6.3	**Consultation Cost Per Hour:**	Rate at which external consultants were paid?
6.4	**Consultation Hours:**	Total number of hours of consultation services
6.5	**Miscellaneous Costs:**	If there is any miscellaneous cost, enter here

Step 7:

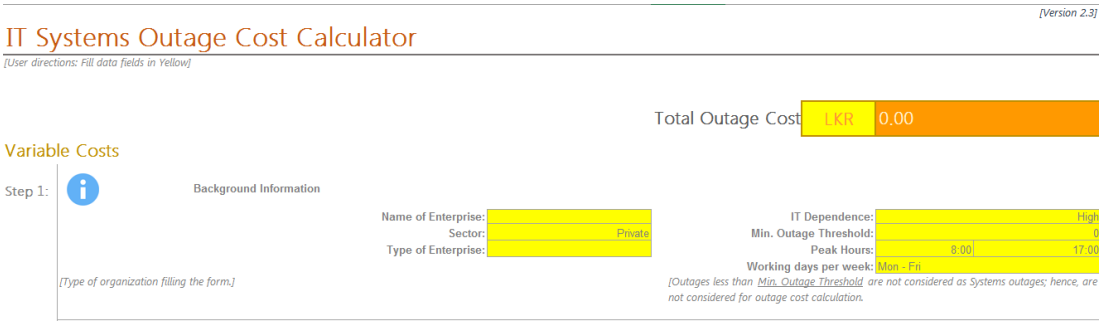
Step 7 Cost for Hardware Replacement

7.1	**Cost of equipment replacement:**	Total amount that was spent for any hardware replacement or data recovery.

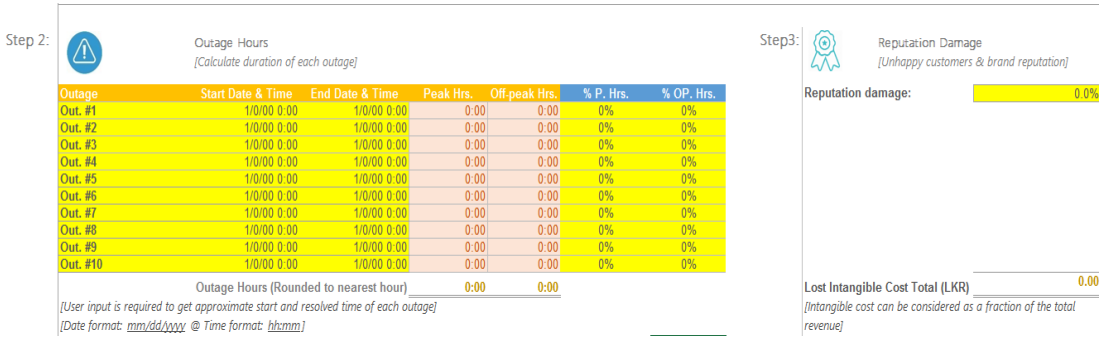
CALCULATOR WORKSHEET

Calculator worksheet accepts several facts and figures about participating organization and outages. Accepting information is divided into seven steps such as background information, reputation damage, outage hours, costs of loss revenue, costs of loss productivity, costs for external services, and costs for hardware replacements. Upon completion of the worksheet, calculator derived an estimated cost for the provided information.

Step 1:



Step 2 & 3:



Step 4:

Step 4: Cost of Lost Revenue

Department		% Reliant On Uptime	Peak Revenue/Hr.	Peak Lost P. Revenue (LKR)	Off-Peak Revenue/Hr.	Off-Peak Lost OP. Revenue (LKR)
Department #1			0.00	0.00	0.00	0.00
	Out. #1	0.00%				
	Out. #2	0.00%				
	Out. #3	0.00%				
	Out. #4	0.00%				
	Out. #5	0.00%				
	Out. #6	0.00%				
	Out. #7	0.00%				
	Out. #8	0.00%				
	Out. #9	0.00%				
	Out. #10	0.00%				
Department #2			0.00	0.00	0.00	0.00
Department #3			0.00	0.00	0.00	0.00
Department #4			0.00	0.00	0.00	0.00
Department #5			0.00	0.00	0.00	0.00
Department #6			0.00	0.00	0.00	0.00
Department #7			0.00	0.00	0.00	0.00
Department #8			0.00	0.00	0.00	0.00
Department #9			0.00	0.00	0.00	0.00
Department #10			0.00	0.00	0.00	0.00
		Revenue Lost P & OP Each (LKR)		0.00		0.00
					Revenue Lost Total (LKR)	0.00

Step 5:

Step 5: Cost of Lost Productivity

[Category-wise employee cost per hour]

Employee Type		OT Hours	OT. Rate/Hr. (LKR)	No of People Affected	Salary/Yr (LKR)	Days/Yr	Hours/Day	% Reliant On Uptime	Salary/Hr (LKR)	Lost Cost/Hr (LKR)
Category #1			0.00	0	0.00	260	8.0	0.0%	0.00	0.00
	Out. #1	0								
	Out. #2	0								
	Out. #3	0								
	Out. #4	0								
	Out. #5	0								
	Out. #6	0								
	Out. #7	0								
	Out. #8	0								
	Out. #9	0								
	Out. #10	0	0.00							
Category #2			0.00	0	0.00	260	8.0	0.0%	0.00	0.00
Category #3			0.00	0	0.00	260	8.0	0.0%	0.00	0.00
Category #4			0.00	0	0.00	260	8.0	0.0%	0.00	0.00
Category #5			0.00	0	0.00	260	8.0	0.0%	0.00	0.00
Category #6			0.00	0	0.00	260	8.0	0.0%	0.00	0.00
Category #7			0.00	0	0.00	260	8.0	0.0%	0.00	0.00
Category #8			0.00	0	0.00	260	8.0	0.0%	0.00	0.00
Category #9			0.00	0	0.00	260	8.0	0.0%	0.00	0.00
Category #10			0.00	0	0.00	260	8.0	0.0%	0.00	0.00
									Productivity Lost Per Hour (LKR)	0.00
									Productivity Lost Total (LKR)	0.00
									Production Recovery Total Cost (LKR)	0.00

Step 6:

Recovery Costs

Step 6: Cost for External Services

[Cost spend for third-party companies or individuals]

	# Hours	Rate (LKR)
Third-party services cost:	0	0.00
Consultant cost:	0	0.00
Miscellaneous Costs		0.00
Service Cost Total (LKR):		0.00

Step 7: Cost for Hardware Replacement

[Costs for faulty equipment]

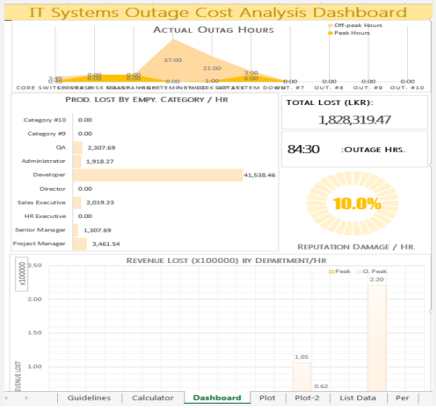
Cost for equipment replacement (LKR):	0.00
Faulty hardware cost Total (LKR):	0.00

DASHBOARD WORKSHEET

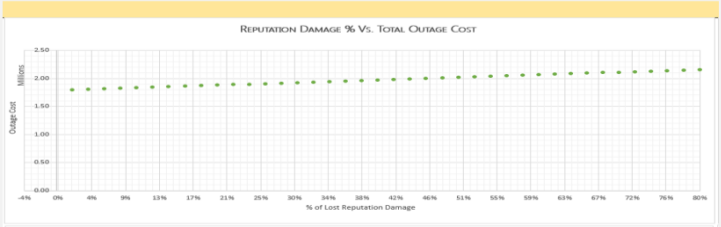
According to provided information about previous outages, several graphs are generated. These graphs forecasts trends of how expenses go down or up with governing cost factors of outages.

When you entere appropriate data, sheet automatically calculates estimated total cost of IT service outages. If you think estimate is not reasonable, you may refine values of the cost components. You can see entered data in graphical form in the left most graphs in the 'Dashboard' form.

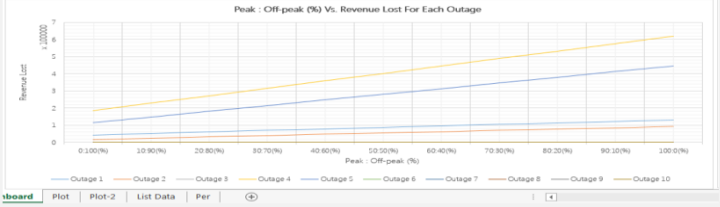
Peak and Off-peak outage hours, Productivity lost by each employee categories, and Revenue lost by Departments are displayed in these graphs.



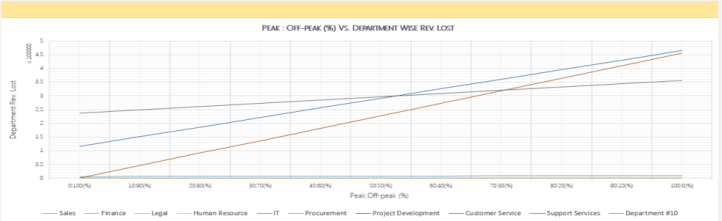
Reputation Damage % vs. Total Outage Cost graph shows varying fractions of reputation affect the total outage cost, e.g. if reputation damage is 38%, Total outage would be 2M according to sample data.



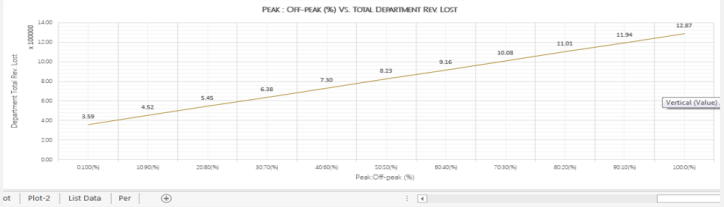
Peak : Off-peak (%) vs. Revenue Lost for Each Outage' graph shows, how revenue lost varies when Peak : Off-peak time ratio changes



Peak : Off-peak (%) vs. Department-Wise Revenue Lost' graph shows, how each department's revenue varies when Peak : Off-peak time ratio changes



Peak : Off-peak (%) Vs. Total Department Rev. Lost' graph shows how the total revenue of the company varies when Peak : Off-peak time ratio changes



APPENDIX B – INVITATION EMAIL

We have invited 18 organizations to participate for this research study. The invitations were sent through emails. Brief introduction of the research such as why we are doing this research, what the benefits of the outcome, etc., is included in the email body. Besides, the more detailed invitation letter to a senior management of the inviting organization is attached with the email. Email body is also comprised with the shared links of our Excel worksheet which is used to collect cost figures of past outages and the workbook with sample data which may help respondent to get a better idea about the information which required to be entered about outages.

Dear [Full Name],

We are conducting a research on to identify key elements of IT service outage costs and derive an semi-empirical model for cost estimation. As a member of the senior management of [Organization Name], we are inviting you to participate in this study.

You can download the Excel worksheet to indicate cost figures of past outages from,

https://drive.google.com/file/d/1-nACfnpsnkU9VUtUCBOn0AlGkLDGmhne/view?usp=sharing

We highly appreciate if you could devote ~15 min to fill the worksheet to help estimate total outage costs for your organization during previous outage incidents. Once filled, the worksheet will automatically estimate the total cost of IT service outages. If you think the estimate isn't reasonable, you may refine values and cost components.

Further, we are grateful if you could also give my MSc student a short meeting (~15 min) to discuss our worksheet, and how it may or may not help organizations to manage IT outage cost figures in the future.

A more detailed invitation letter is attached herewith. Also, an example Excel worksheet with sample data is available at

https://drive.google.com/file/d/1TpOvOSPeutOWabj8f30H-tMb-Hiroior/view?usp=sharing

This study is stipulated confidential, and sensitive information is used only for this study. Your responses will not be identified with you or your organization personally, and all findings will appear in the aggregated form only.

Your participation in the research would be much appreciated. If you have any queries or wish to know more, please feel free to contact us.

Thank you very much for your support.

Best Regards,

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Senior Lecturer | Coordinator Industrial Training & MBA in IT
Dept. Computer Science & Engineering, University of Moratuwa, Sri Lanka.
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APPENDIX C – INVITATION LETTER

This is the more detailed version of the invitation letter to a senior management of the invited organization. The letter explains our requirements on this study and how we are going to conduct it. Furthermore, it describes the benefits that organizations can gain upon successfully completion of it. We are also requesting from the management of the organization to allocate us ~15-minute meeting with them to describe our workbook on how the fields are filled and upon completion of filling the sheet, what type of decisions can management can take according to data representation on dashboard.

Following is the template of letter we used to invite organizations.

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING
Faculty of Engineering
University of Moratuwa
Katubedda, Sri Lanka (10400)

Tel: *+94 11 2 650 301 Ext. 6022* *E-mail:* *Dilum.Bandara@uom.lk*
Mobile: *+94 71 2 082 071* *Web:* *http://dilum.bandara.lk*
Fax: *+94 11 2 650 622*

Dr H M N Dilum Bandara *PhD/MS (Colorado State), BSc Eng Hons (Moratuwa), AMIE(SL)*

February 11, 2019

[Designation of Invitee],

[Company Address].

Dear [Full Name of Invitee],

Study on IT Service Outage Costs

We are conducting a research study to identify the key elements of IT service outage costs and derive an semi-empirical model for the cost estimation. We believe these findings would help decision makers to estimate the cost of IT service outage and take proactive measures to minimize costs of future incidents. This research study is

conducted as part of the MSc in Computer Science Thesis of Mr. Eranda Welgama at the Dept. of Computer Science and Engineering, University of Moratuwa.

As a member of the senior management of your esteemed organization, we are inviting you to participate in this study by sharing statistics of previous IT service outage incidents. We are sharing with you an Excel worksheet which collects several cost figures associated with IT service outage. We highly appreciate if you could devote about 15 minutes to fill in appropriate fields in the worksheet to help estimate total outage costs for your organization during the previous outage incidents. Once you fill the appropriate fields, you would see automatically estimated total cost of IT service outages. If you think the estimate is not reasonable, you may refine values and cost components.

Further, we are grateful if you could also give us a short meeting to discuss our worksheet for IT service outage calculation, and how it may or may not help organizations to manage IT outage cost figures in the future.

This study is stipulated confidential, and sensitive information is used only for this study. Your responses will not be identified with you or your organization personally, and all findings will appear in the aggregated form. You and your organization will not be linked in any manner.

Your participation in the research would be much appreciated. If you have any queries or wish to know more, please feel free to contact us using the details provided below.

Thank you very much for your time and help in making this study possible.

Sincerely,

Dr. Dilum Bandara

Research Supervisor

APPENDIX D – FOLLOW-UP QUESTIONNAIRE

Dear Sir/Madam,

Thank you for the valuable time and effort on helping us to identify the key elements of IT service outage costs and validate the proposed semi-empirical model for the cost estimation. We have understood that you have experienced some practical difficulties when identify statistics of previous IT service outage incidents and fill our Excel worksheet with relevant cost figures. We highly appreciate if you could still provide a bit more qualitative insight on IT service outage and its impact to your organization by discussing the following with us.

This part of the study is also stipulated confidential, and sensitive information is used only for this study. Your responses will not be identified with you or your organization personally, and all findings will appear in the aggregated form. You and your organization will not be linked in any manner.

Thank you very much for your time and help in making this study possible.

Sincerely,

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Demographic Information

1. How would you characterize as the type of your enterprise?

Interdependence of IT services and business operations

1. How much daily functioning of your enterprise depends on IT services? *
2. Approximately how many outages your organization has experienced during last 12 months?
    a. Could you explain a bit about what happened during the most signification outage, in terms of time, cost, and impact?
3. If you have defined, what is the duration of an acceptable IT service outage?
    a. If not defined, what do you think is reasonable time that your enterprise can tolerate without key IT services?

Participant's view on this study

1. Has the enterprise attempted to quantify the cost of IT service outage?
    a. If yes, what proactive actions have been taken to minimize outage costs in future incidents?
    b. If not, do you think it would be valuable and practical exercise to quantify it?
2. If you are to quantify, what are the aspects you would consider, e.g., direct loss of revenue, overtime, and service fees?
3. Do you use impact/cost of IT service outage as a way of justifying better investment on IT services and hardware to your management?

Participant's view on our tool

1. Do you believe, it would be useful to have a tool like the one we shared with you to measure IT service outage costs?
    a. Do you believe, the parameters listed in our tool is meaningful?

2. What are the challenges that you experienced when trying to fill data in the tool?
3. What do you think about the various the graphs we generate based on the given data?
    a. Will they be useful?
    b. What else you like to visualize that may help you with the decision process?
4. Do you think, the adjustments that you have done on cost figures toward the savings in total outage costs are clearly reflected in the graphs?

Anything else that you may wish to share about your experiences with IT service outage and handling them?

APPENDIX E – INTERVIEW QUESTIONS

1. How could you explain about your contribution to the organization?
2. What would be the key business operations your organization is doing?
3. In what level do you categorize IT operations and daily business operations' interaction?
4. Have you experienced an outage during past 12 months? If yes, how did that impact to business operations? Were you able to identify root causes of that outage and do you have any plan in place to face to such an incident?
5. Have you ever tried to quantify outage cost for the previous outages? If yes, what did you identify as the key cost factors which you quantified for your calculation?
6. Do you have any practice keep records of outages such as impacted areas of the business, expenses during the recovery activities, etc.?
7. How was the stress among outage affected employees, IT staff and technical managers, and senior managers during the outage windows and what were their reactions?
8. What were the alternative plans that were already been taken to fulfil any critical business tasks during the outage window and were those planes helped to manage the situation?
9. What do you think about the quantifying outage business impact? Do you think it is useful for your organization?
10. Do you believe the estimation drawn from our cost calculation tool is reasonable? And do you see any improvements required or all the relevant cost factors are addressed in our calculation?
11. What were the difficulties that you experienced when you were filling the Excel worksheet calculator?
12. What do you think about the result of our research work?
13. Do you have anything that you may wish to share with us about the previous IT service outage experiences?