MODELING AND SIMULATION OF KNOWLEDGE

WORKER ATTENTION FOR EVALUATION OF

EMAIL PROCESSING STRATEGIES

By

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TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

Figure Page

1. INTRODUCTION

1.1 Statement of the Problem

Information overload is a growing problem faced by increasing numbers of knowledge workers. Email is one significant aspect of information overload. It is not difficult to find someone willing to complain about the amount of time he or she spends "messing with" email. The number of email messages received per day has become a frequent subject of conversation among knowledge workers, and companies have begun to look for strategies to combat the steady stream of email messages faced by their employees. Many strategies aimed at this dilemma have been suggested. These strategies usually involve reducing the email workload by eliminating any unnecessary email transmissions. This is typically done with filtering software, or could take the form of policies limiting the use of the carbon copy field. Other strategies mentioned in the literature involve prioritizing messages so that time sensitive messages receive their proper attention.

Another strategy looks at the timing of email processing. Jackson, et al. (2003) suggested that a particular group limit checking email messages to every 45 minutes. The aim of this strategy was to limit email's interruptive effects. Through audible and visual notifications, email is often used much like the telephone. An email is received, the knowledge worker is made aware of the email, and the email is promptly responded to. This sounds effective: prompt replies. However, one frequently touted benefit of email is its asynchronous nature or the ability to process messages at a convenient time.

By treating email like the telephone, knowledge workers lose this key benefit and accept additional interruptions to other important activities. A tradeoff clearly exists between interruptions and potentially slow responses. The basic problem addressed by this study is: Can the problem of information overload be better managed by proactively choosing the *timing* of email processing? By selecting a specific time frame or frames dedicated to email, and not answering email outside of this time frame, can we control email's interruptive nature, without sacrificing our ability to resolve email messages in a timely manner?

1.1.1 Email Processing Strategies

Asynchronism is a key benefit of electronic mail, allowing users to communicate at a more convenient location and time. Interestingly, audible and visual notifications of email are among the most popular features of email management applications. In a recent study by Osterman Research, 68% of respondents indicated that they check their email "more or less continually" while at work. Another 17% indicated that they checked email "a few times per hour" (D'Antoni, 2004). Responding to messages as they arrive could be viewed as an attempt to turn email into a more phone-like medium. When we process email in this way, we move towards temporal concurrence and away from an intended benefit of electronic mail. We may offer a prompt response to those needing to communicate with us, but when we allow all email to interrupt our work in the same way as the telephone; we most likely suffer the consequences in terms of productivity and efficiency. Clearly a tradeoff exists. The aim of this study is to look for email processing strategies that best manage these tradeoffs under various knowledge work environments. Table 1.1 provides an overview of all strategies explored in this study.

One type of email processing strategies that this study considers involves only processing email during "email hours," or at a specific planned time(s) during the knowledge worker's day. These "email hours" allow us to control interruptions. This policy can take several forms involving both the number of controlled interruptions and the timing of the controlled interruptions. Throughout this document the terms "email hours" and "controlled interruptions" are used interchangeably.

A second proposed type of email processing strategy involves processing email messages only in batches. This balances the need for avoiding interruptions with the need to make sure that our email inbox does not get out of hand. Again, this policy could take several forms by choosing various batch sizes. Larger batch sizes would result in fewer interruptions, and vice versa.

A third email processing strategy involves continuously monitoring and responding to email as they arrive, as is often done when using audible or visual notifications of arriving email. Because this is often the strategy prevalent among users (Hymowitz, 2004; D'Antoni, 2004), this strategy served as a control, and was compared against other proposed strategies.

Table 1.1. The EmailProcessing Strategies

Processing Strategies	Descriptions
Continuous Attention	This processing strategy requires processing email as they arrive (giving first priority to email).
Scheduled Attention-1M	This processing strategy requires holding email hours once daily, every morning.
Scheduled Attention-1A	This processing strategy requires holding email hours once daily, every afternoon.
Scheduled Attention-2	This processing strategy requires holding email hours twice daily.
Scheduled Attention-2P	This processing strategy requires holding email hours twice daily, during two peak email arrival periods.
Scheduled Attention-4	This processing strategy requires holding email hours four times daily.
Scheduled Attention-4P	This processing strategy requires holding email hours four times daily, during four peak arrival periods.
Scheduled Attention-6	This processing strategy requires holding email hours six times daily.
Jackson Attention	This processing strategy requires holding email hours every 45 minutes.
Batch Attention-1	This processing strategy requires processing email once a batch size corresponding to a "day's worth" of email has arrived (an average of one batch per day).
Batch Attention-2	This processing strategy requires processing email once a batch size corresponding to ½ of a day's worth of email has arrived.
Batch Attention-4	This processing strategy requires processing email once a batch size corresponding to ¼ of a day's worth of email has arrived.
Batch Attention-6	This processing strategy requires processing email once a batch size corresponding to 1/6 of a day's worth of email has arrived.

1.1.2 Performance Measures

One focus of this study was the email processing strategy's effect on the worker's ability to respond to email *in a timely manner*. For example, moving away from continuously processing email and towards processing email only once daily will clearly affect the knowledge worker's *email resolution time*. On a similar note, the knowledge worker's *efficient completion of ongoing work* is also of interest. To what extent do interruptions (or a lack of interruptions) affect the ability to complete ongoing work? If work is interrupted, some time is needed to reorganize our thoughts, our workspace, etc. Prior to switching tasks, some time is spent mentally preparing for an interruption. During this time we are not fully focused on our primary task. Interruptions cause work to take longer; This study is interested in this inefficiency and its increased burden on the knowledge worker. The knowledge worker's efficiency and total hours worked is also captured. Efficiency represents the percentage of time that the knowledge worker is productive, and correlates to the extent of information overload experienced by the knowledge worker. Total hours worked reflects the need to "stay late" when faced with an unproductive day.

This study's research questions and hypotheses center on the tradeoff that exists between the benefits of replying promptly to colleagues' communications and the costs of doing so. Because email interrupts important work, it is desirable to keep these interruptions to a minimum or "control" the interruptions. Because accessibility and awareness of one's work environment are also important, it may not be desirable to ignore email for extended periods of time.

1.1.3 A Synchronism Continuum

As we purposely process email more and more frequently, at some point the cost associated with allowing more interruptions (inefficient completion of work and decreased knowledge worker efficiency) will outweigh the benefit of prompt responses.

As illustrated in Figure 1.1, below, we need not choose asynchronism or temporal concurrence, but rather these can be viewed as two ends of a continuum.

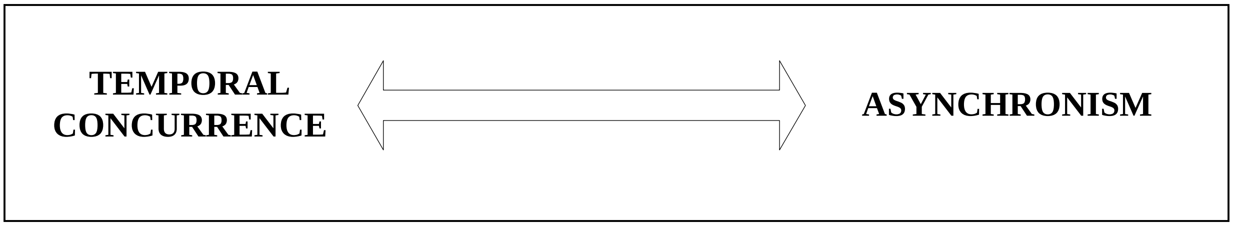


Figure 1.1. A Synchronism Continuum

We can choose an appropriate middle ground. This middle ground will depend on our individual environment and performance objectives. Furthermore, this middle ground need not apply to *all* arriving email messages. The chance of a *single* email arriving that does require our prompt attention should not force us to be interrupted by *all* incoming email. Technology certainly exists that allows for only certain email (specific senders or subjects, for example) to trigger an audio or visual notification.

Figure 1.2. Screenshot from Microsoft Outlook

Within Microsoft Outlook, as seen in Figure 1.2 for example, it is a simple matter of creating a rule, a point-and-click operation requiring only a moment of time. In this study, “priority-email” triggers notification to the user. By categorizing or separating incoming email according to their temporal needs, and applying appropriate processing strategies to each category of temporal need, all incoming email need not cause interruptions in order to ensure appropriate resolution times.

1.2 Importance of the Topic

> "To make knowledge work productive will be the great management task of this century just as to make manual work productive was the great management task of the last century. The gap between knowledge work that is left unmanaged is probably a great deal wider than was the tremendous difference between manual work before and after the introduction of scientific management” (Drucker, 1969).

Peter Drucker’s quote from three decades ago predicted the situation now faced by growing numbers of workers. As information has become more and more available (Varian and Lyman, 2000), the speed at which we process information has remained the same (Horvitz, et. al., 2003). What we can do, however, is better manage knowledge work. This gap that Drucker spoke of is this study’s focus. In order to better manage knowledge work, we must first understand it. Analysis and simulation of the knowledge work environment leads to better understanding, and it is hoped that this study will lead to solutions to the challenge of information overload resulting from email.

Information overload occurs when a knowledge worker is presented with more information than he or she can possibly process in a timely manner. Lyman and Varian (2000) estimated that “the world’s total yearly production of print, film, optical, and magnetic content would require roughly 1.5 billion gigabytes of storage. This is the equivalent of 250 megabytes per person for each man, woman, and child on earth.” Clearly, as information becomes more and more available, information overload is not a problem that will go away. Information overload is known to have an adverse effect on performance (O'Reilly, 1980; Klap, 1986). When information overload occurs, the knowledge worker must make important decisions regarding how to best manage the stream of incoming information.

This study focuses on one contributor to information overload, email. The use of email has exploded over the past decade, and frequently consumes a significant portion of a knowledge worker's day. The Radicati Group (http://www.radicati.com) reports that over one half billion email users send and receive over 57 billion email messages daily, and the average corporate user receives 81 email messages per day and sends 29 email per day (Frauenheim, 2003). Not only does email consume time directly, but it also serves as a distraction and causes inefficiencies in other important work. In this study, it is assumed that email is a necessary component of knowledge work, and the study's focus is on email's indirect effect on information overload, specifically, email's interruptive nature.

Jackson, et al. (2003) studied email's effect as an interruption and found that employees take an average of 1 minute 44 seconds to react to new email notification, and it took employees an average of 64 seconds to return to their work at the same pace. Consider this in light of the "81 email messages per day" statistic mentioned previously! They conclude that "*while email is still less disruptive than the telephone, the way most users handle incoming email causes far more interruption compared to what is commonly expected*." Among their recommendations, they suggest checking for email no more frequently than every 45 minutes. However, email is often used as a collaboration tool, and prompt responses are often important. Responding to email less frequently will certainly limit email's effect as an interruption to important work, but it may delay other knowledge workers in need of a response from completing their tasks. By separating email according to its timeliness, all email need not interrupt work. This study models and analyzes the tradeoffs between responsiveness and efficient completion of work.

In addition to directly analyzing the effects of the knowledge workers' processing strategy on performance, parallels can be drawn between the knowledge worker's performance measures and the knowledge worker's perception of information overload. The worker's efficiency, the amount of time needed to respond to email and accomplish work, and the frequency of interruptions that the knowledge worker faces can all be seen as precursors to perceived information overload (Pitney Bowes, 1998).

1.3 Purpose of the Study

Ultimately, the goal of this study is to prescribe solutions to a growing problem, information overload. Information overload results when a knowledge worker faces the challenge of processing more information than he or she can process in a timely manner. An email processing strategy represents how a knowledge worker manages/prioritizes his or her email within the context of all of his or her work. For purposes of this study, work includes projects in need of time allocation and incoming email messages in need of resolution. The term "resolution" is used instead of "reply," because many, perhaps most, email messages do not require a response. In this case, "resolution" indicates the time at which the email has served its purpose; it has been read or responded to. Specifically, the aim of the following study is to answer questions concerning the impact of a knowledge worker's email processing strategy on the knowledge worker's performance. Specific research questions follow.

Research Question 1: Where is the middle ground? How many controlled interruptions is enough to allow for appropriate resolution times? More specifically, is there a certain number of controlled interruptions that will not significantly affect the appropriateness of non-priority email resolution times when compared to continuously processing email messages?

Research question 2: Will fewer interruptions result in more efficient work completion? Specifically, can a particular email processing strategy significantly improve knowledge worker efficiency?

Research question 3: Will fewer interruptions lower information overload, as indicated by the numbers of hours worked daily?

Research Question 4: To what extent will email arrival patterns influence the success of given email processing strategies? It is intuitive that scheduling email hours *during* periods of rapid email arrival rates will allow for prompt resolutions. With batch processing, rapid arrivals of email can trigger processing and therefore email processing might naturally tend to occur during peak email arrival time periods.

Research Question 5: Can an optimization tool be used in conjunction with simulation to automate the analysis of email processing strategies in finding an optimal email processing strategy for specific performance objects and constraints?

Optquest is an optimization tool that finds optimal values for simulation variables, given specific performance objectives and constraints. This study considers its use as a tool for finding optimal email processing strategies and compares the results from Optquest to those of the analysis of the simulations.

Having stated the research questions this study aims to answer, the next section describes the research approach used in answering these questions.

1.4 Research Approach

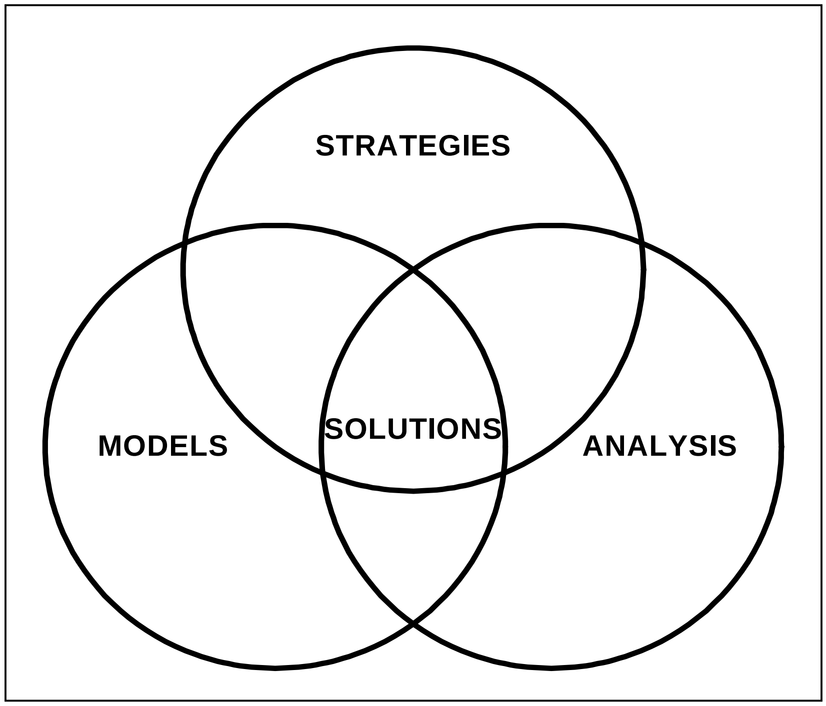


Figure 1.3. Research Approach

Figure 1.3 illustrates the general approach of the research. *Analysis* helps us to understand and model phenomena. A focus group was used in guiding the development of models in order that the models reflect reality. The *models*, in turn, are used to explore the effects of various proposed email processing *strategies* with the aim of finding *solutions*. A focus group investigation into the email habits of knowledge workers was performed concurrently with the creation of both schematic and mathematical models in order to both validate the structure of the models and establish the models' parameters. Next, a simulation model was used to investigate the research questions outlined above.

Knowledge work scenarios, including both the "flow" of the knowledge worker's attention and the flow of emails in need of processing were modeled. The models were used for subsequent analysis. The knowledge worker's environment, as well as the knowledge worker's attention and the rules governing this attention were represented and analyzed using discrete event simulation. The "rules governing attention" are defined by the knowledge worker's email processing strategy and direct the "flow" of the knowledge worker's attention. The environment was captured by the simulation model, and using the simulation model, the performance measures of the various email processing strategies was analyzed.

The research study involved several phases. First, the modeling of the knowledge work environment and a focus group assessment of email's role in knowledge work were performed concurrently; the focus group was used to validate the structure of the models and establish the models' parameters. Next, the knowledge work environment was simulated, and an experiment to test hypotheses drawn from the research questions was performed. Finally, an optimization (of processing strategies) through simulation was performed, and the results of the optimization were compared against the simulation analysis results.

1.5 Potential Contributions

This study is in a unique stream that looks at the *timing* of email processing. Gupta, et al. (2005) considers various email processing strategies and their effect on knowledge worker performance. These studies differ in several ways, and bring different contributions to the same problem domain. This study contributes differently from Gupta, et al. (2005) in that it considers additional email processing strategies and different performance measures. It models a different type of knowledge worker, and it takes different approaches to modeling the knowledge work environment, including modeling attention as an entity and the use of optimization software on top of simulation. This study considers email processing strategies not considered in Gupta, et. al. (2005) including matching email processing schedules to arrival patterns and batching email in various group sizes. Gupta, et al. (2005) studies email strategies' effects on utilization and task completion time. This study considers a different type of knowledge worker – project managers who primarily handle complex tasks and are rarely, if ever "caught up." Instead of utilization, which implies that the knowledge worker experiences some "caught up" time, this study considers knowledge worker efficiency and the total amount of time needed by the knowledge worker to complete a daily threshold of work. This study also allows for one type of email message to always take priority over other email messages, so that all email need not interrupt the knowledge worker – just those in need of urgent resolution. The modeling approach is different as well. Rather than modeling the knowledge worker as a server, this study models a knowledge worker's attention as an entity that flows from one area of focus to another. Modeling knowledge worker attention as an entity, as described in Chapter 5, allows for easily manipulating and capturing data about either the email environment or the email processing strategy. Finally, this study considers the use of optimization tools in an attempt to find the ideal (optimal) email processing strategy, given a specific objective and constraint.

Other studies aimed at reducing email overload consider ways of eliminating some of the email processing. This study allowed for testing the effects of various processing strategies on email related outcomes and work-related outcomes, as well as the effect on the individual knowledge worker's level of information overload. This study balanced the need for the knowledge worker to minimize information overload while remaining accessible to colleagues and maintaining an awareness of his or her environment. The simulation of knowledge work brings a new perspective to tackling the problem of information overload. Studies have prescribed solutions for managing a cluttered email inbox. These prescriptions have included primarily heuristic solutions with only anecdotal support. Simultaneously modeling the flow of the knowledge worker's attention and the flow of knowledge objects allows for an actual analysis of specific processing strategies, while considering the strategies' effects on knowledge worker efficiency.

In summary, the contribution to knowledge comes through proposing and analyzing creative email-processing strategies. We demonstrate that through adoption of specific email processing strategies, an organization can improve the efficiency of their employees without adversely affecting the effectiveness of their employees. Through limiting the interruptions faced by a knowledge worker, literature would support that the level of *information overload* has also been reduced (Cohen (1980), Zijlstra, et al. (1999), Speier et al. (1999, 2003), Kock (2000)). This was the goal all along.

The following chapter provides a review of the literature that points to a need for further research. Chapter 3 describes the study's research methodology. Chapter 4 gives the results of a knowledge worker case study, which lead to the creation of models of the knowledge work environment described in Chapter 5. Chapter 6 describes the development of the simulation model. Chapter 7 then discusses the results of the study and finally Chapter 8 provides a summary of the study.

2. LITERATURE REVIEW

2.1 Introduction

The following will provide background information pertaining to the aforementioned research questions. First, literature pertaining to interruptions and their link to performance and information overload will be considered. Next, asynchronous communication and its relationship with knowledge worker performance will be discussed. Following this, we discuss proposed solutions to email overload found in the literature.

2.2 Interruptions

Several research studies have looked into the effects of interruptions on worker productivity. The literature has consistently shown that if an interruption requires mental capacity beyond what is available given the current task, then it will have an adverse effect on the current task. There seems to be a connection between the complexity of the task, and therefore the mental effort, at the time of the interruption and the interruption's disruptive effect. Also, the relevance of the interruption to the task has been shown to influence the disruptive nature of an interruption.

Speier et al. (1999, 2003) studied the effects of interruptions on individual decision-making. She found that interruptions actually improved performance of simple tasks, while lowering performance of complex tasks. A heightened level of awareness caused by the distractions explains the improvement in simple task performance. The combined mental requirements of both the distractions and simple tasks were still below the subject's mental capacity. Speier also found that if the interruption was dissimilar to the task at hand, then it had a greater impact on performance, and the format of information affects how well a knowledge worker handles interruptions. Knowledge workers were found to be better supported by graphs than by tables.

Zijlstra, et al. (1999) found interruptions to have a negative impact on emotion and well being. Like Speier, they found that interruptions could cause people to perform a primary task more quickly, but postulated that the relationship between interruptions and task performance would be an inverted U-shape, indicating that the cumulative effect of interruptions at some point does have a negative effect on primary tasks.

Czerwinski, et al. (2000a) studied the effect of instant messaging (IM) interruptions on ongoing computer tasks. They found a significant difference in overall task times (the task studied) when comparing interrupted to uninterrupted tasks. Similar to Speier et al. (1999), Czerwinski, et al. (2000b) found that interruptions took less of a toll if they were relevant to the primary task at hand. They also demonstrated that "the delays associated with an IM disruption depends on the point in a computing task that a user is presented it." Interruptions were shown to have a more harmful effect when users were engaged in an activity than when users were just starting an activity. Cutrell, et al. (2000) also found that the phase of a task influences the effect of an interruption. Cutrell, et al. divided a web search task into three phases: the planning phase, the execution phase, and the evaluation phase. They found that interruptions had their greatest effect during the evaluation phase, suggesting again that the type of work that is interrupted determines the extent to which an interruption affects the task. Like Speier et al. (1999) and Czerwinski, et al. (2000b), they found that relevant interruptions were less disruptive than interruptions that had little to do with ongoing tasks. A further study by Cutrell, et al. (2001) considers the effect of instant messaging on a list evaluation task. They again found disruptive effects of instant messaging, and that instant message interruptions had the greatest impact during “fast stimulus-driven search tasks.”

Monk, et al. (2002) found that interrupting tasks during the middle of a task or when a task is nearly complete resulted in longer resumption lags. They were unable to show that the complexity of the interruption itself influenced the effect of the interruption.

Trafton, et al. (2003) proposes that the resumption lag is a function of the interruption lag. The interruption lag is that period of time between the interruption itself and when action is taken on the interruption. They identify the events of an interruption as those illustrated in Figure 2.1 below.

Begin Primary Task → Alert for Secondary Task → Begin Secondary Task → End Secondary Task → Resume Primary Task

Figure 2.1 The Events of an Interruption (Trafton, 2003)

Figure 2.2 provides an example in this study’s context. An email notification occurs while the knowledge worker is engaged in a particular project, seconds or minutes elapse, and then the knowledge worker checks the email. This time between the email notification and opening the email inbox (the interruption lag) can be used to prepare for the interruption. The knowledge worker might make mental notes, save a document, or mark the page that he or she is reading. These preparations can influence the amount of time needed after the interruption to get back up to speed with the primary task (the resumption lag).

Project Work → Email Alert → Interruption Lag → Email Processing → Resumption Lag → Project Work

Figure 2.2. Interruption and Resumption Lags Resulting from an Email Interruption

Both the interruption lag and the resumption lag are needed to facilitate the interruption and do not represent productive time with respect to the interrupted project.

Jackson, et al. (2003) studied email's effect as an interruption and provides insight into the durations of the lags discussed in Trafton (2003). They state that "there is no reported empirical research on how long it takes to recover from an email interrupt." They found that on average, it took workers 64 seconds to recover from an email interruption and return to work at the same rate prior to the email. Each of the subjects in their study received notification of the arrival of an email message through an icon in the system tray, and 57% of the subjects saw a pop-up notification as well. Interestingly, the average time taken to react to an arriving email was only 1 minute 44 seconds. Over 70% reacted to the email within six seconds of the email arrival, indicating that email's interruption lag is frequently brief, but may range up to well over a minute. The longer resumption lags may have represented the knowledge worker choosing to ignore the email a bit longer, or as suggested by Trafton (2003), this may represent time spent by the knowledge worker in preparation for the interruption. Reacting to the email within six seconds by 70% of subjects also lends further support to the notion that email tends to not be used asynchronously.

2.3 Asynchronism vs. Temporal Concurrence

The central concept underlying this study is that as we move towards temporal concurrence, and away from asynchronism, we add unnecessary inefficiency to our work.

In describing temporal issues faced by organizations and individuals, McGrath (1991) proposes three generic problems, and both organizational and individual responses to these problems. McGrath (1991) proposes, “All collective action entails (at least) three generic temporal problems that both organizations and individuals must reckon with.” These problems include: 1) temporal ambiguity (when particular events will occur and recur and how long they will last), 2) conflicting temporal interests and requirements, and 3) scarcity of temporal resources. Individual responses include: 1) making temporal commitments, 2) negotiating norms for behavior sequencing, and 3) regulating flow of task and interpersonal interaction. By controlling the timing of and time committed to email processing (making temporal commitments), an organization is also helping to control the timing of and time committed to other work. By not simply reacting to email, but proactively scheduling email responses, the individual will establish (or “negotiate”) a normal pattern of behavior. By choosing to manage knowledge work in a particular way, the individual has hope of “regulating flow of task and interpersonal interaction.”

Massey, et al. (2001) studied the effects of temporal coordination on virtual team performance. Temporal coordination involved providing “a process structure to serve as a temporal coordination mechanism for organizing team communication, sequencing work, and facilitating problem-solving activities.” Following McGrath’s (1991) recommendations, “…The process structure included schedule deadlines, guidelines for coordinating the pace of effort, and specifications for time spent on tasks.” Essentially, they imposed structure on the timing of the groups’ interactions. The imposed structure was found to affect performance in a positive way. Without proactively choosing a structure for our email work, we accept a lack of structure not only for our email work, but also for all work that we allow email to interrupt.

The following studies point out the need to balance the control of interruptions with the need for prompt email responses. Hightower and Sayeed (1996) noted that “asynchronous meetings require more time than synchronous meetings because information exchange takes longer,” and found that groups using a computer mediated communication system exchanged information less efficiently than face-to-face groups.

While highlighting the need for group decision support systems, Dufner, et al. (2002) discuss problems with asynchronous communication. “Without the embedded coordination structures the longer delays between questions and responses in the asynchronous mode of communication can cause a group member to report feeling isolated. Lack of coordination structures may also contribute to group fragmentation, member withdrawal, unproductive communication, and failure to complete the group work or task” (Dufner, et al., 2002). In their study, they found support for their hypothesis that “Groups working in the asynchronous mode of communication will report that the group’s problem solving process is less efficient than will groups working in the face-to-face mode of communication.”

Ocker, et al. (1995) found support for their hypothesis that computer conferencing groups would produce solutions of higher quality and creativity than face-to-face groups. The study was not focused on the asynchronous aspect of the communication. They attributed the success of the computer conference mode of communication to the anonymity associated with the technology. Group members were less likely to conform to group ideas, and were more likely to contribute. While considering the disadvantages of asynchronous communication, Ocker, et al. (1995) noted that, "days can elapse between communication events, resulting in communication that can seem disjointed."

Burke & Chidambaram (1999) compared the perceived performance of both synchronous and asynchronous groups. They postulated that the delays in communication would have a negative impact on performance. They hypothesized that "perceptions of communication effectiveness will be higher for synchronous groups than asynchronous groups." They were unable to support this hypothesis. However, they argued that the reason for their counter intuitive results was that subjects found adequate strategies for dealing with the delays imposed by the communication medium. Similarly, we need to find adequate strategies for dealing with email as a communication medium. With email, we have some control over the delay imposed by the communication medium. We do not need to choose asynchronous or temporal concurrence, but rather these are two ends of a continuum. We can choose an appropriate middle ground depending on our individual environment and performance objectives.

2.4 Email Overload Solutions

Email overload solutions include strategies for filtering, organizing, and prioritizing incoming email messages. Extensive work has been done on the filtering of email messages in an effort to reduce email overload. Most research and applications are aimed at fighting SPAM. However, some filters aim to filter legitimate email. For example, a means of filtering electronic messages for a new product development team was proposed by Sharda et al. (1999), the aim of which was to limit the arrival of messages to only those needed or of interest. Other efforts aim to better organize arriving email. "Sieve" is an email filtering language that can be supported in an email server and client software (Marsan, 2000). Sieve allows users to sort and even forward email messages automatically. SurfControl offers a similar product, the SurfScout Email Filter (Surfcontrol, 2002), which allows organizations to block spam and virus infected email from their employees. An interesting feature of the filter is the ability to block nonessential email until after business hours, thus ensuring that employees focus on email that is important. Ifile (Rennie, 2000) uses machine learning to automatically generate rules for classification of email messages. Initially, the user's own manual classifications provide the training set, and updates to the rules occur as a result of correcting incorrectly filed emails. The Bifrost Inbox Organizer (Balter & Sidner, 2000) takes a different approach by allowing users to easily customize rules, which result in the organization of email by category. The user is then able to prioritize tasks more easily. Losee (1989) proposed a method to predict the usefulness of a message based on available message features. Messages awaiting processing were ranked according to their usefulness. The messages having the greatest probability of being useful were processed first. The idea was to minimize the probability of processing less useful knowledge objects at the expense of more useful knowledge objects. The PRIORITIES system developed by Horvitz, Jacobs, and Hovel (1999) actually infers an expected criticality of an email message based on a number of factors from both the email itself and from the user's environment. The email is then prioritized according to this criticality. Other actions, including prompting the user and opening the email onto the screen, can also be automated according to the criticality of the email. The objective is to interrupt the user if the benefits of the interruption outweigh its costs.

Filtering and organizing incoming email messages attempts to minimize the amount of time needed to effectively process an email workload. Prioritizing aims to ensure that less important or timely email are not processed before those of greater importance or urgency. One gap in the research involves how email affects *other knowledge work* and how the *timing* of email processing can improve the negative interruptive aspects of email discussed in Jackson (2003). We need to consider how the need to reduce interruptions can be balanced with the need to communicate effectively as discussed in Ocker, et al. (1995), Hightower and Sayeed (1996), and Dufner et al. (2002). Furthermore, we need an effective tool to investigate the effects of various email processing strategies. Because it is difficult to require knowledge workers to adopt specific email processing strategies for extended periods of time for purposes of study, knowing just how an email processing strategy will affect knowledge work outcomes becomes arduous at best. The modeling and simulation of knowledge work represents a relatively unexplored tool for such analysis. Gupta et al. (2005) is an example of research beginning to fill this void. Gupta, et al. (2005) considers the impact of various email processing schedules on knowledge worker performance measures including knowledge worker utilization, the number of interruptions faced by the knowledge worker, and the knowledge worker's task completion times. This study aims to further fill this gap in several ways. First, this study considers different email processing strategies and different performance measures. Second, this study models a different type of knowledge worker. Third, this study takes new approaches to modeling the knowledge work environment that include modeling knowledge worker *attention* as an entity and using optimization software in addition to simulation. And fourth, this study takes into consideration the ability of software to separate urgent email messages from non-urgent email messages and the knowledge worker's resulting ability to treat each message type accordingly.

Having recognized the need for studies exploring the effects of the timing of email processing, the next chapter describes the research methodology and spells out specific propositions and hypotheses and how they can be tested using simulation and optimization tools.

3. RESEARCH METHODOLOGY

The premise of this research is that knowledge worker performance is not simply a result of the knowledge work environment faced by the knowledge worker, but rather the email processing strategy chosen by the knowledge worker can and does affect performance (Figure 3.1, below).

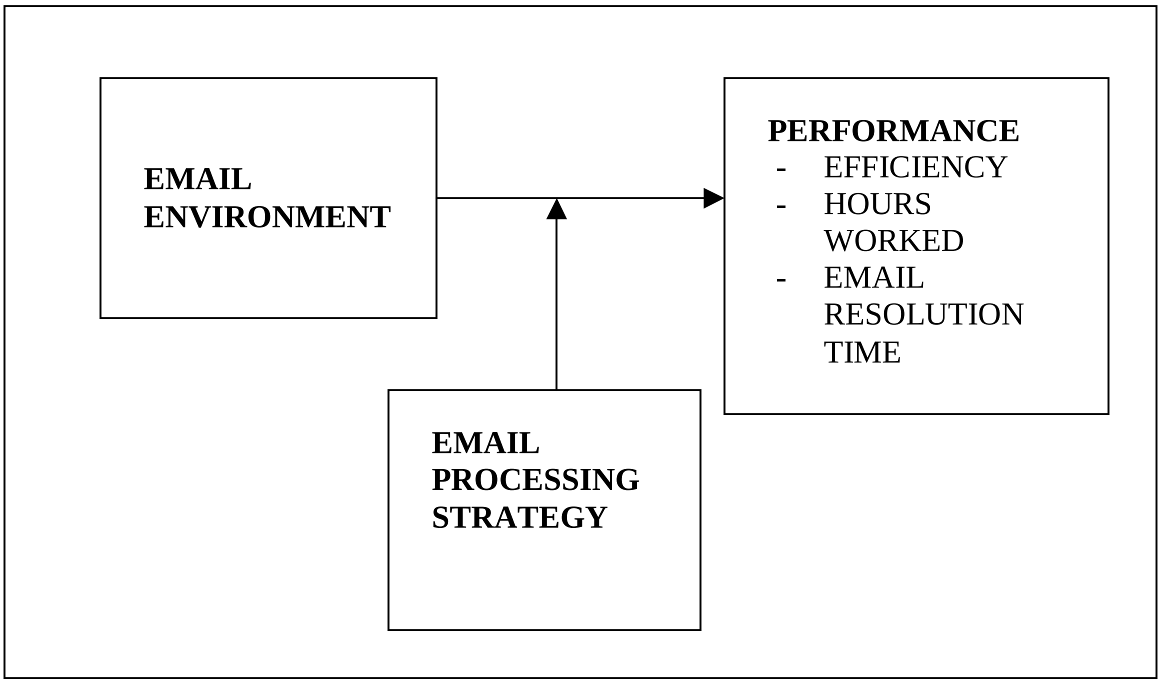


Figure 3.1. The Research Model

The experiment involves the use of simulation to test propositions and hypotheses corresponding to earlier stated research questions. The research questions, specific propositions and hypotheses and their testing are described below.

3.1 Research Questions, Propositions, and Hypotheses

A multivariate analysis of variance (MANOVA) allows for testing the hypotheses. Because the study is looking for differences between experimental treatments (email processing strategies) on multiple dependent variables (performance measures), MANOVA is an appropriate choice. MANOVA allows for testing whether or not differences in treatment groups exist, while controlling the experiment-wide Type 1 error rate. Assuming the significance of the overall model, testing each proposition and hypothesis is straightforward.

Research Question 1: Where is the middle ground? How many controlled interruptions is enough to allow for appropriate resolution times? More specifically, is there a certain number of controlled interruptions that will not significantly affect the appropriateness of non-priority email resolution times when compared to continuously processing email messages. In order to answer the question, of course, we must define "appropriate." Recall that those email not defined as urgent must be processed within either one business day (priority-2) or within one week (priority-3). If we define appropriate as "within 24 hours," then all non-priority email would be processed within an appropriate time period. The following propositions apply.

> ***Proposition 1(a)****: Dividing non-priority email work into two specific time frames (holding email hours twice daily – Scheduled Attention-2) will allow for successfully resolving all email within a 24-hour appropriate time frame.*

> ***Proposition 1(b)****: Processing email in batches corresponding to 1/2 of an average daily email processing load (Batch Attention-2) will allow for successfully resolving all email within a 24-hour appropriate time frame.*

Regarding proposition 1(a), the study considers the mean daily percentage of non-priority email that were successfully resolved within 24 hours using simulations employing the Scheduled Attention-2 processing strategy. Proposition 1(b) is tested in this manner as well.

Proposition 1(a) is intuitively obvious. Clearly processing email twice daily will not allow an email to remain unanswered for more than 16 hours (assuming processing scheduled at the beginning and end of a knowledge worker's business day), and only unusual circumstances could cause proposition 1(b) to be unsupported. The first propositions are in place to make the point that the alternative processing strategy may be employed without adversely affecting performance defined as the ability to respond to email within an appropriate time frame. Having made this point, we turn to research questions 2 and 3.

We learn from Speier, et al. (1999, 2003) that interruptions can adversely affect complex tasks. We learn from Trafton (2003) that interruptions can cause waste in worker productivity in the form of both interruption and resumption lags. Jackson (2003) gives further evidence of the existence of these lags and approximations for the durations of these lags. By eliminating email interruptions, knowledge worker efficiency should improve.

Research question 2: Will fewer interruptions result in more efficient work completion? Efficiency is defined as the knowledge worker's productive time at work divided by the knowledge worker's total time at work. Productive time includes working on both primary work and email. Total time includes primary work and email work as well, but also includes time wasted in interruption and resumption lags. Specifically, will the proposed email processing strategy significantly improve knowledge worker efficiency?

> ***Hypothesis 2(a)****: Dividing non-priority email work into two specific time frames (Scheduled Attention-2) will result in significantly greater efficiency when compared to processing email continuously.*
>
> ***Hypothesis 2(b)****: Processing email in batches corresponding to 1/2 of an average daily email processing load (Batch Attention-2) will result in significantly greater efficiency when compared to processing email continuously.*

Regarding hypothesis 2(a), the study compares the mean daily knowledge worker efficiency from simulations employing the Scheduled Attention-2 processing strategy to the mean daily knowledge worker efficiency from simulations employing the Continuous Attention email processing strategy. A significant difference between the two measures supports the hypothesis that holding email hours only twice daily will allow for greater efficiency. Hypothesis 2(b) is tested in this manner as well.

Research question 3: Will fewer interruptions lower information overload, as indicated by the numbers of hours worked daily?

> ***Hypothesis 3(a)****: Holding email hours twice daily (Scheduled Attention-2), will result in significantly fewer total hours worked daily when compared to processing email continuously (Continuous Attention).*
>
> ***Hypothesis 3(b)****: Processing email in batches corresponding to 1/2 of an average daily email processing load (Batch Attention-2) will result in significantly fewer total hours worked daily when compared to processing email continuously.*

Regarding hypothesis 3(a), the study compares the mean daily hours worked from simulations employing the Scheduled Attention-2 processing strategy to the mean daily hours worked from simulations employing the Continuous email processing strategy. A significant difference between the two measures supports the hypothesis that holding email hours only twice daily will allow for fewer hours to be worked on the average. Hypothesis 3(b) is tested in this manner as well.

Research Question 4: To what extent will email arrival patterns influence the success of given email processing strategies? Just as you would schedule employees during the busiest times of day, it is intuitive that scheduling email hours *during* periods of rapid email arrival rates should allow for prompt resolutions.

> ***Proposition 4(a)****: Email hours scheduled during peaks in arrival patterns (Scheduled Attention-2P and Scheduled Attention-4P) will have significantly shorter resolution times when compared to email hours not scheduled during peaks in arrival patters (Scheduled Attention-2 and Scheduled Attention-4).*

Because an email is more likely to arrive during time periods with greater arrival rates, the email that completes a batch is also more likely to occur during periods of time with greater arrival rates. With batch processing, time periods with rapid arrivals of email are more likely to trigger processing and therefore email processing may tend to occur during peak email arrival time periods. Therefore, the resolution times resulting from batch processing may be comparable to those resulting from email processing schedules that follow email arrival patterns.

> ***Proposition 4(b)****: Email processed in batches (Batch Attention-2, Batch Attention-4, & Batch Attention-6) will have significantly shorter average resolution times when compared to email hours not scheduled during peaks in arrival patters (Scheduled Attention-2, Scheduled Attention-4, and Scheduled Attention-6).*

> ***Proposition 4(c)****: Email processed in batches (Batch Attention-2 and Batch Attention-4) will not have significantly different average resolution times when compared to email hours scheduled during peaks in arrival patterns Scheduled Attention-2P and Scheduled Attention-4P).*

Proposition 4(a) will be tested by comparing resolution times from the Scheduled Attention-2 and Scheduled Attention-4 processing strategies to their corresponding Scheduled Attention-2P and Scheduled Attention-4P average resolution times. A significant difference between the two measures lends support to the hypotheses.

Proposition 4(b) was tested in a similar manner. In proposition 4(c) a significant difference would correspond to a lack of support for the hypothesis.

Research Question 5: Can an optimization tool be used in conjunction with simulation to automate the analysis of email processing strategies in finding an optimal email processing strategy for specific performance objects and constraints?

Proposition 5: Optquest, coupled with the Arena simulation tool will produce results consistent with those obtained through analysis of the Arena simulation's output.

Proposition 5 will be tested through the use of Optquest to determine the optimal email processing strategies for the performance objectives and constraints outlined in Table 3.1 below.

Table 3.1. Optquest Optimization Tool, Performance Objectives and Constraints

Performance Objective, Constraint
Maximize Efficiency, no constraint
Minimize the average Resolution Time of Priority-2 Email Messages, no constraint
Minimize Priority-2 Email average Resolution time, Efficiency > 97%
Maximize Efficiency, Mean Email Resolution Time < 3 hours

The results of the Optquest optimizations will be compared against the analysis of the simulation results in order to confirm the results' validity.

Having outlined the study's research questions, propositions, and hypotheses, Chapter 4 describes a case study of knowledge workers. The case study is later used as a basis for simulations that allow for testing the research propositions, and hypotheses.

4. KNOWLEDGE WORKER CASE STUDY

While modeling the knowledge work environment, a group of knowledge workers was interviewed regarding their email processing habits and how those habits interplay with their day-to-day work. The process of building the models pointed out appropriate questions for the knowledge workers, while interviewing the knowledge workers allowed for refinement of the models. Seven knowledge workers from a major North American corporation were interviewed. The purpose of the interviews was to gain an understanding of one knowledge work environment. This understanding allowed for ensuring that the study's purpose was on target, the performance measures were appropriate and relevant, and the models' structures were valid.

4.1 Knowledge Worker Interviews

Figure 4.1 lists the questions that were used to guide the discussions.

1) *To what extent do you feel that email is…*

-essential?

-intrusive?

-a burden?

2) *Do you experience information overload/email overload?*

How would you define this?

3) *How do you define success with respect to processing email?*

4) *Are you concerned with others' impressions of you based on your ability to respond to email promptly? / Do you form an impression of others based on their email response time?*

5) *What "rules" govern how you process email?*

-Do you have set times during the day?

-Do you process email continuously?

-Do you employ some other rule of thumb?

-Do you use a Blackberry and/or automatic notification feature?

6) *What "rules" govern how you end your work day?*

-Do you a) watch the clock, b) go home when some amount of work is finished?

7) *How would you describe/categorize your incoming email messages?*

-Read only, Reply, Irrelevant, SPAM

-Urgent, Not so urgent…

8) *Do you always have something to do, or do you experience periods of "caught up" time?*

9) *How do you spend your days? How do you describe your role?*

-management of projects, projects, tasks, … ?

10) *Do you file / delete / ignore messages as you process them?*

How do you decide?

11) *We intend to capture the number of minutes saved during the day. Does this performance measure seem appropriate / interesting? / Do other performance measures come to mind?*

Figure 4.1. Knowledge Worker Interview Questionnaire

Question one was used to assess the knowledge workers' general impression of email. All of the knowledge workers viewed email as an essential tool. Throughout the interviews, the topic of collaboration in a global business environment repeatedly presented itself. This was consistent with the knowledge workers' answers to question nine: all of those interviewed were involved with managing projects. All but one of the subjects found email to be intrusive. One subject described email as, "where I live," indicating his challenge of separating the communication tool from his work. It was as if he was asked, "Do you find *your job* intrusive?" This knowledge worker, more than others, seemed to embrace email's role in his work life. Other subjects mentioned the continuous need to monitor email and the interruptive effect that this can have. Most subjects indicated that email was a burden. One subject described email as a "necessary burden." Another subject compared email to the telephone, adding that with the telephone, "at least you can screen your calls."

All but one subject (the same subject that did not find email to be intrusive) experienced information overload and email overload. Subjects mentioned the obvious definition of overload in terms of the volume of information and messages received. The subjects' descriptions of the symptoms of overload were perhaps more interesting. Several subjects described the challenge of isolating the important email in need of processing from the "junk." Overload was defined by one knowledge worker as having to go through email to find out if it is relevant, indicating that even irrelevant messages require some processing. He mentioned that email's urgency is rarely apparent, and is frequently "ambiguous." These ideas were echoed by other respondents.

The subjects' definitions of email processing success (question 3) corresponded to their definitions of email overload. One knowledge worker defined success as correctly isolating "correspondence" email, or that email in need of a prompt reply. Another knowledge worker defined success as "being able to get email work completed quickly." Again, this was a function of his ability to distinguish relevant from irrelevant messages. One knowledge worker stated that successful email processing occurs when "nothing bites me." His concern was that an important email would get past him. He described what he meant with two examples. First, he did not want to receive a phone call that included the question, "Didn't you receive my email?" He described how email is sometimes used to cover one's tracks. Second, he described his priorities as dynamic: a lack of information could cause him to spend time on tasks that may have become irrelevant. Still another subject defined success as "not missing something," and another knowledge worker defined success as accurate prioritization. All subjects faced the challenge of dealing with *all* incoming email, despite the fact that *not all* email requires prompt resolution. One consistent challenge seemed to be separating the important from the irrelevant.

Most knowledge workers were concerned with others' perceptions that are based on their ability to respond to email promptly. This was one reason that distinguishing important email from irrelevant email was seen as so important. One knowledge worker indicated that he would not think of responding later to a correspondence email. "It just looks bad…like you're not working." Another respondent described email response time as a "measure of your job dedication." Email that did not have a legitimate urgency would tend to take on an artificial urgency for these political reasons.

All of the knowledge workers interviewed except one monitored their email accounts continuously. The one exception estimated that he checked his email about 10 times daily.

Interestingly, all knowledge workers interviewed indicated that they ended their work day when a particular milestone was reached or when they felt comfortable that they were somewhat caught up. None of the knowledge workers had a set time at which they would end their day. This seemed to correspond to the answers received to question eight, ”Do you always have something to do, or do you experience periods of ‘caught up’ time?” Some laughed at the question, and all indicated that they always have something that they can be working on.

All knowledge workers agreed with the categorizations of email messages (read only, reply, irrelevant, and SPAM) and acknowledged receiving some of every category.

Four of the seven knowledge workers interviewed did not actively file email messages as they arrived. Only one of the knowledge workers used filters to automatically file incoming email. Everyone deleted irrelevant email and SPAM, and everyone interviewed saved legitimate email either by filing or simply leaving the message in the inbox. In this way, the email application appeared to be used to manage and archive knowledge work.

Finally, all of the knowledge workers found the performance measure “minutes saved during the day” to be interesting. One knowledge worker would like to see the *total amount of time spent processing email* captured. Another knowledge worker suggested *efficiency* as would be derived from the total amount of time spent recovering from interruptions resulting from email, and another subject suggested collecting the amount of time wasted due only to SPAM and irrelevant email. Overall, subjects were quite interested in receiving the final results of the study. Having gained a general understanding of the knowledge work environment, section 4.2 discusses establishing parameter values that describe an email environment. These parameters are later used for simulations.

4.2 Parameter Validation

In order to ensure for valid parameters and that we were simulating a realistic email environment, we asked one knowledge worker to complete and submit the form in Figure 4.2 below, which categorizes email received throughout a typical business day. Each row of the form represents a particular category of email that the knowledge worker may or may not face. First, the knowledge worker was asked to indicate the total number of email received in a typical business day. Second, the knowledge worker was asked to break down this total according to the timing of the emails' arrivals. Next, the knowledge worker was asked to categorize each of the total email received according to its urgency and the time needed to process each email. Finally, the knowledge worker was asked to divide each category of email according to the time they were received throughout the day. Email was categorized as SPAM, irrelevant email, email only in need of reading, or email requiring a reply. SPAM and irrelevant email require only minimal processing. Email only in need of reading and email requiring a reply can be further categorized according to their urgency (timeliness of the message) and the amount of time needed to process the email.

TYPE	URGENCY	TIME NEEDED	Total	8am - 10am	10 am - noon	noon - 2pm	2pm - 4pm	4pm - 6 pm	6pm - 8 am
Totals			38	8	6	6	5	8	5
SPAM	N/A	N/A	0						
IRRELEVANT	N/A	N/A	5	2	1		1		1
READ	URGENT	< 1 MINUTE	2	2					
READ	URGENT	1 - 10 MINUTES	1					1	
READ	URGENT	> 10 MINUTES	1					1	
READ	WITHIN BUS DAY	< 1 MINUTE	11	2	1	3	1	2	2
READ	WITHIN BUS DAY	1 - 10 MINUTES	3			1	1		1
READ	WITHIN BUS DAY	> 10 MINUTES	1				1		
READ	WITHIN 1 WEEK	< 1 MINUTE	1			1			
READ	WITHIN 1 WEEK	1 - 10 MINUTES	2		2				
READ	WITHIN 1 WEEK	> 10 MINUTES	3	1	1			1	
REPLY	URGENT	< 1 MINUTE	2	1	1				
REPLY	URGENT	1 - 10 MINUTES	0						
REPLY	URGENT	> 10 MINUTES	0						
REPLY	WITHIN BUS DAY	< 1 MINUTE	2			1			1
REPLY	WITHIN BUS DAY	1 - 10 MINUTES	1				1		
REPLY	WITHIN BUS DAY	> 10 MINUTES	0						
REPLY	WITHIN 1 WEEK	< 1 MINUTE	0						
REPLY	WITHIN 1 WEEK	1 - 10 MINUTES	1					1	
REPLY	WITHIN 1 WEEK	> 10 MINUTES	2					2	

EMail Response

Figure 4.2. Knowledge Worker Categorization of Daily Email

Having gained an understanding of email's role in the knowledge worker's environment and the characteristics of the emails typically received, the study's attention shifted towards representing the environment first schematically, and then mathematically. These models are described in the next chapter, Chapter 5.

5. MODEL DEVELOPMENT

5.1 Introduction

This chapter describes the representation of a knowledge work environment schematically and mathematically. Two separate entities are modeled. First, a knowledge worker's "attention" and its flow are modeled. "Attention" represents the focus of the knowledge worker's mental efforts. The "flow of attention" implies that the knowledge worker's attention shifts between different areas of focus. Second, the flow of email messages is modeled. The flow of email messages is modeled separately from the flow of knowledge worker attention. This separation of the flow of attention from the flow of email messages allows for manipulation of the email processing strategy (rules that govern attention) without manipulating the flow of email messages (email arrival patterns) and vice versa. This becomes important in simulating the knowledge work environment: email processing strategies can be added to the model without altering those aspects of the model that pertain to email arrivals. Alternatively, email arrival schedules may be changed without altering those aspects of the model pertaining to the flow of attention. This is explained further in Chapter 6. Section 5.2 describes schematic models of the flow of Attention and the flow of email. Section 5.3 provides a mathematical formulation of the problem.

5.2 Schematic Models of the Flow of Attention and the Flow of Email

Figure 5.1 illustrates the flow of knowledge worker attention if the knowledge worker monitors his or her email activity continuously (email is always given first priority). Because email takes first priority, each morning the knowledge worker (attention entity) will begin his or her workday by processing email messages. The knowledge worker will process email messages until all email messages are complete or noon, at which time the knowledge worker breaks for lunch. If the knowledge worker completes his or her email processing before lunch, then the knowledge worker, assuming a minimum amount of work has not been completed for the day, will shift attention to his or her primary work. Before beginning the primary work, however, the knowledge worker must take time before resuming primary work. This time, the resumption lag, represents those moments during which the knowledge worker "re-engages" her mind in preparation for the primary work. This resumption lag may include rereading material, gathering notes, collecting ones thoughts, etc. Once fully engaged again, the knowledge worker begins her primary tasks, and continues with those tasks until one of three things happen: lunch, an email arrival, or enough work is completed to "call it a day." More times than not, the reason for the knowledge worker stopping her primary work and shifting her attention is the arrival of an email. Regardless of the reason, the knowledge worker will take a brief period of time, the interruption lag, to prepare for the interruption. The interruption lag might consist of making mental or physical notes, marking a paragraph for continued reading, or saving a PC file for later processing. From this point, the knowledge worker processes email messages again, goes to lunch, or goes home. If the knowledge worker processes email messages, then the cycle repeats. If the knowledge worker goes to lunch, upon returning, the knowledge worker will begin with email messages, and the cycle repeats. If the knowledge worker goes home for the day, then the cycle repeats again in the morning.

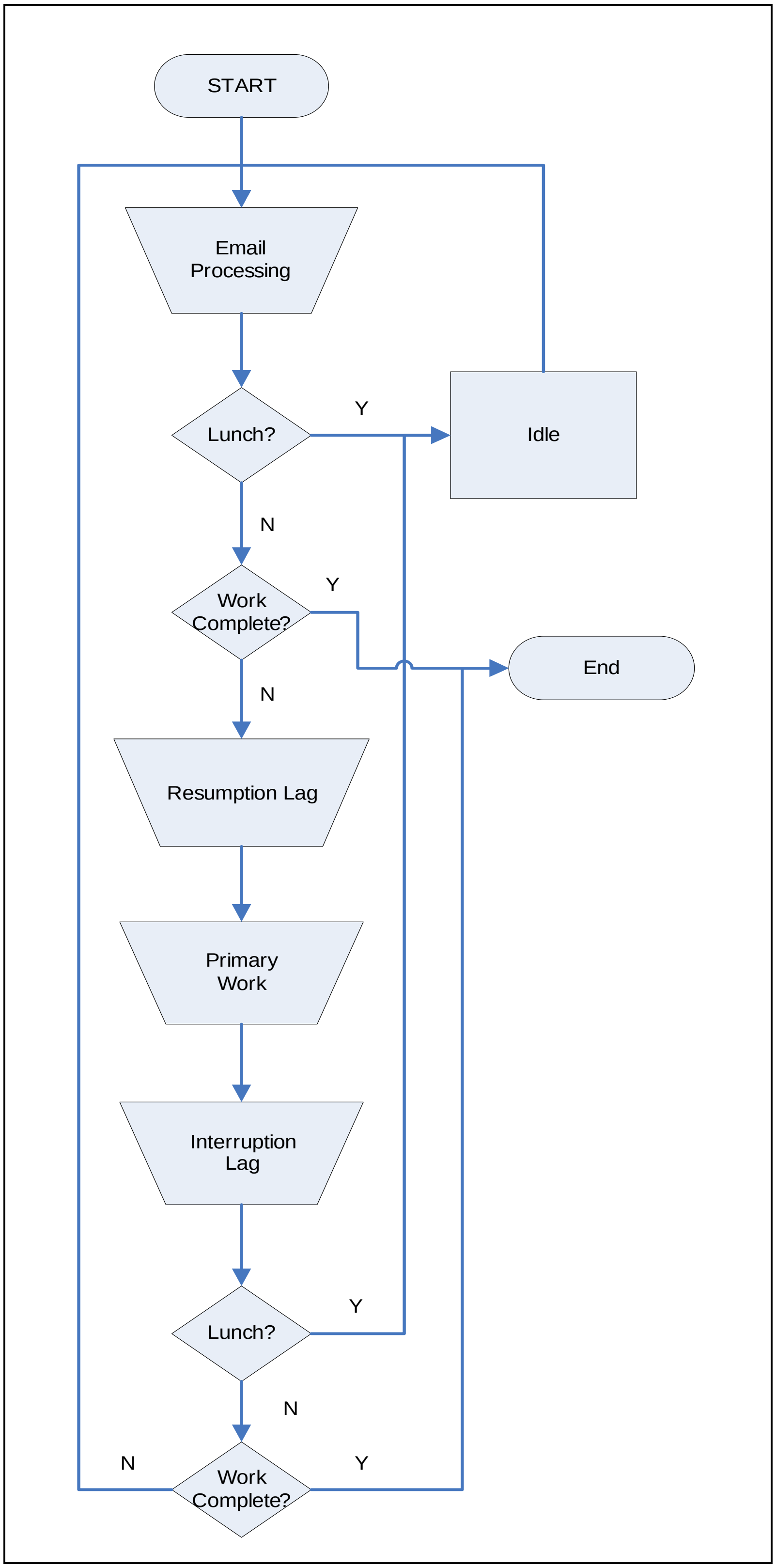


Figure 5.1. Flow of Attention with Continuous Email Processing

Figure 5.2 models the flow of knowledge worker attention if the knowledge worker does not employ the continuous email processing strategy, but instead interjects specific rules governing when email will be processed. Although urgent email messages will still have first priority, all other email messages do not interrupt the knowledge worker's primary work unless certain circumstances (rules) are met. These circumstances differ according to the specific email processing strategy employed. As indicated in the model, upon starting the workday, the knowledge worker will begin with his or her primary work, unless the specific email processing strategy calls for processing email at this time. For example, email hours could be scheduled first thing in the morning. Before the primary work takes place, the knowledge worker must take time to again familiarize herself with the work that is to be performed (the resumption lag). The primary work continues until one of four things happen. First, an urgent email message could always interrupt the knowledge worker. Second, the knowledge worker may break for lunch; third, the knowledge worker's email processing strategy may dictate that it is time to process non-urgent email messages. And fourth, the knowledge worker may have completed a given level or work and leave for the day. Any break from primary work will cause an interruption lag, that period of time needed to prepare for the interruption. After processing an urgent email message or returning from lunch or processing non-urgent email messages, the knowledge worker will return to her primary work, beginning with a resumption lag, and the cycle repeats. If the knowledge worker has completed a certain level of work and leaves for the day, then the cycle will repeat beginning again in the morning.

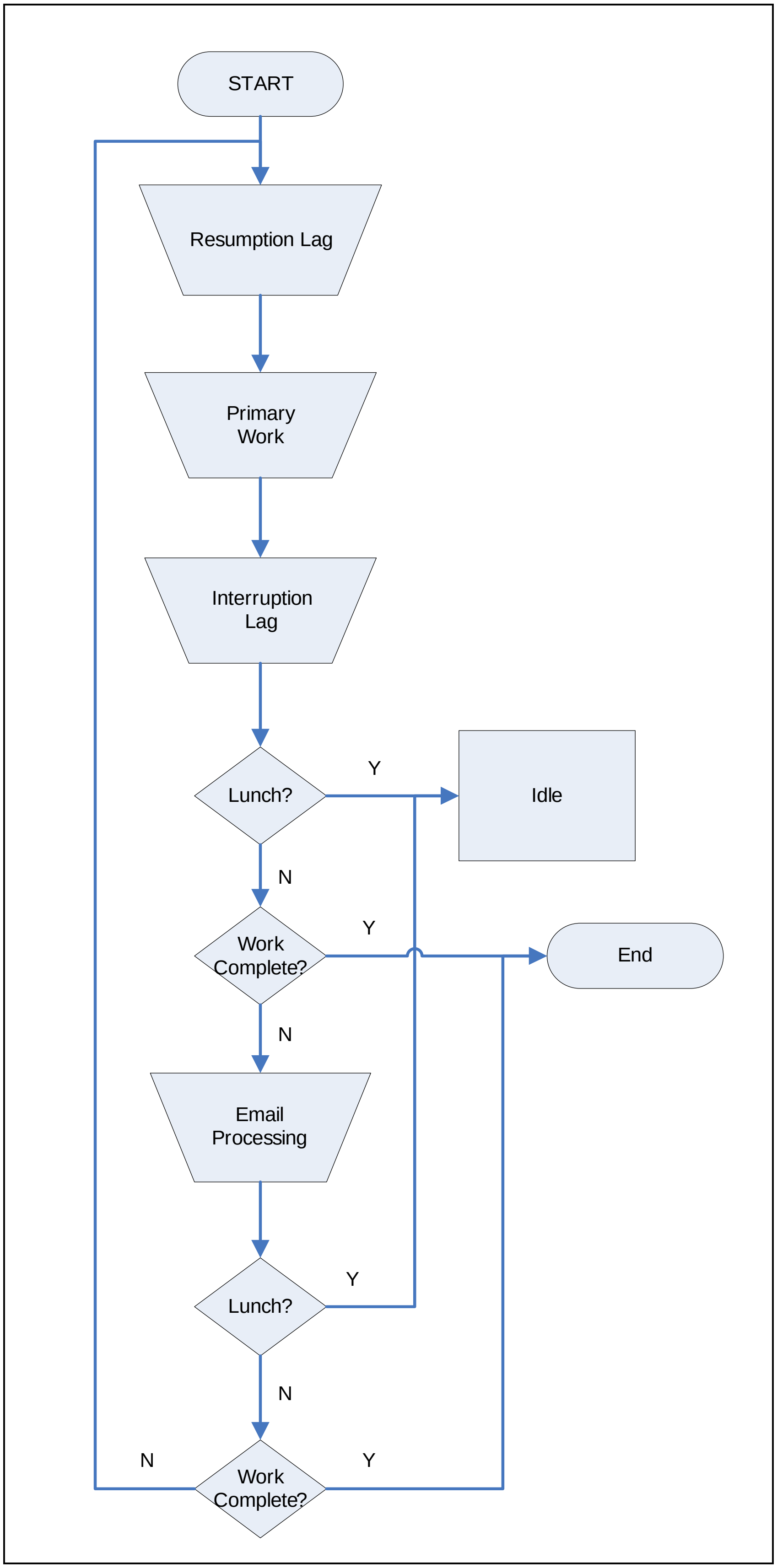


Figure 5.2. Flow of Attention with Non-Continuous Email Processing

The efficiency of the knowledge worker corresponds to the amount of time that the knowledge worker spends either processing email or working on primary work divided by the total amount of time spent by the knowledge worker. Interruption and resumption lags are not included in the numerator, because they do not represent productive work, and can be avoided. Total time at work (the denominator of the efficiency equation) includes time spent processing email messages, time spent on primary work, and interruption and resumption lags.

Figure 5.3 illustrates the flow of an email message. Upon arrival in the knowledge worker's inbox, the email message must wait for the knowledge worker's attention.

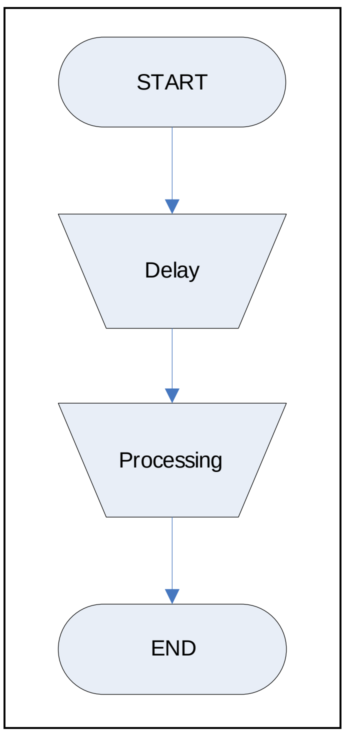


Figure 5.3. The Flow of an Email Message

The delay incurred by the email message is dependent upon the priority of the email message, and the knowledge worker's email processing strategy. Email messages are prioritized according to urgency, and queued accordingly. A priority-1 (urgent) email message immediately gains the attention of the knowledge worker provided that the knowledge worker is not idle (at lunch or gone for the day) and all priority-1 email messages having arrived earlier have been processed. Non-urgent email messages gain the attention of the knowledge worker under differing circumstances depending on the knowledge worker's email processing strategy. If the knowledge worker employs a "continuous" email processing strategy, then an email is processed after all email of higher priority have been processed and after all email of equal priority having arrived earlier have been processed. If the knowledge worker employs a "scheduled attention" email processing strategy, then non-priority email messages must wait for a specific time or times during the day during which the knowledge worker processes non-priority email messages. During these time periods an email is processed after all email of higher priority have been processed and after all email of equal priority having arrived earlier have been processed. . If the knowledge worker employs a "batch" email processing strategy, then a specific number of non-priority email must accumulate before any email are processed, and an email is processed after all email of higher priority have been processed and after all email of equal priority having arrived earlier have been processed. The following section describes a mathematical formulation of the schematic models described above.

5.3 The Mathematical Model

Notation

i	type of email message	$i = 1,2..I$
		{i = 1 for SPAM, i = 2 for Irrelevant, i = 3 for Read only, i = 4 for Reply}
j	urgency (priority) of message	$j = 1,2..J$
		{j = 1 for Urgent (Priority-1), j = 2 for within Business Day (Priority-2), j = 3 for within 1 week (Priority-3), j = 4 for Irrelevant}
k	category of processing need	$k = 1,2..K$
		{k = 1 for < 1 minute, k = 2 for 1 to 10 minutes, k = 3 for > 10 minutes}
d	day	$d = 1,2..D$
s	sequence number	$s = 1,2..S$
t	time period of day	$t = 1,2..T$
		{t = 1 for 8:00 a.m. until 10:00 a.m., t = 2 for 10:00 a.m. until 12:00 p.m., t = 3 for 12:00 p.m. until 2:00 p.m., t = 4 for 2:00 p.m. until 4:00 p.m., t = 5 for 4:00 p.m. until 6:00 p.m., t = 6 for 6:00 p.m. until 8:00 a.m.}

X — email processing strategy employed

λ_{ijkt} — arrival rate of email messages of type i, urgency j, processing need k, occurring during time period t

P_{kds} — random variable that represents the processing time required for email of type k, occurring on day d, having sequence number s

p_{kds} — $E(P_{kds})$

$f_{kds}^{P}(x)$ — probability density function (pdf) of P_{kds}

R_{ds} random variable that represents the resumption lag occurring on day d, sequence number s

r_{ds} $E(R_{ds})$

$f_{ds}^{R}(x)$ pdf of R_{ds}

L_{ds} random variable that represents the interruption lag occurring on day d, sequence number s

l_{ds} $E(L_{ds})$

$f_{ds}^{L}(x)$ pdf of L_{ds}

Q_d random variable that represents the threshold of productive work (email processing and primary work) to be completed on day d

q_d $E(Q_d)$

$f_d^{Q}(x)$ pdf of Q_d

Wq_{js} email's wait in the queue (time spent waiting for the knowledge worker's attention) for email of urgency j having sequence number s

Ws_{js} email's wait in the system (email resolution time) for email of urgency j having sequence number s

$$Ws_{js} = Wq_{js} + P_{kds}$$

$\overline{Ws}_{js}$ mean email resolution time for email of urgency j

$$\overline{Ws}_j = \sum_s Ws_{js} / S$$

Y_d total email processing occurring on day d

$$Y_d = \sum_k \sum_s P_{kds}$$

Z_d total amount of primary work completed on day d

G_d total lag time occurring on day d

$$G_d = \sum_s L_{ds} + \sum_s R_{ds}$$

H_d total hours worked by the knowledge worker on day d

$$H_d = Y_d + Z_d + G_d$$

$\overline{H}$ mean hours worked by the knowledge worker

$$\sum_d H_d \; / D$$

E_d knowledge worker efficiency occurring on day d

$E_d = (Y_d + Z_d) / H_d$

$\bar{E}$ *mean knowledge worker efficiency*

$\sum_d E_d / D$

Q_d threshold of productive work (email processing and primary work) to be completed on day d

$Q_d <= Y_d + Z_d$

Having modeled knowledge work schematically and defined it mathematically, in Chapter 6, we turn our attention towards implementation of the models within the simulation environment.

6 IMPLEMENTATION OF THE SIMULATION MODEL

The knowledge work environment captured by the schematic models and the mathematical model was modeled within Arena 8.0 simulation software. The implementation of the simulation model is described on the pages that follow. The Arena simulation software allows for simultaneously modeling both the flow of the arriving email and the flow of the knowledge worker's attention. The simulation model can then be used for testing the various rules that govern the flow of attention. Figure 6.1 depicts the high level Arena model consisting of multiple submodels. The submodels, seen within the high level model, can be grouped into three categories. The "Time Allocation" submodel falls into the first category. The strategy submodels consisting of the "Strategy Choice" submodel, the thirteen different email processing strategy ("Attention") submodels, and the "Attention Statistics and Disposal" submodel make up the second category. The flow of email is captured in the "Email Arrivals" and the "Email Flow Statistics and Disposal" submodels, which make up the third category. Each of these categories of submodels is described below.

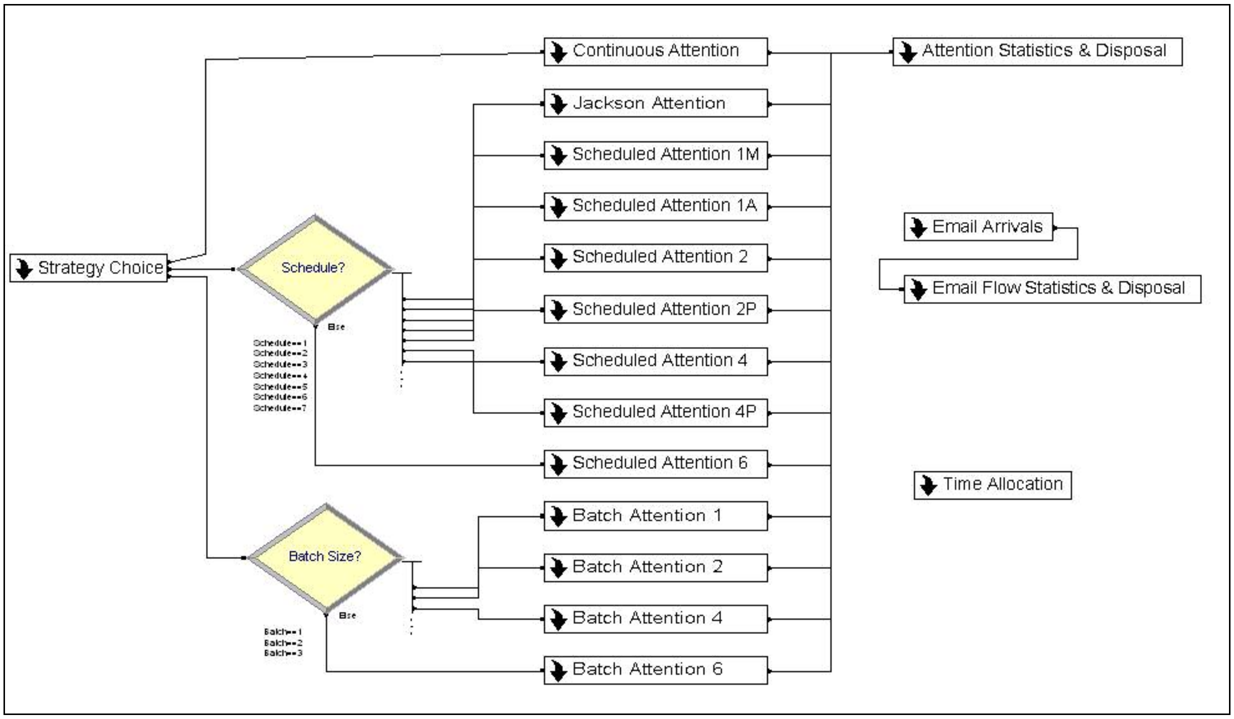


Figure 6.1. The High-level Arena Model

6.1 The Time Allocation Submodel

The "Time Allocation" submodel is used to track the time spent by the Attention entity on various areas of focus (email, primary work, and interruption and resumption lags). In a sense, the Time Allocation Submodel *connects* the Strategy Submodels that govern the flow of attention, to the Flow of Email Submodels, which govern the flow of email. By tracking the time spent by the Attention entity on various tasks, the simulation model "knows" when enough attention has been spent on a particular email in order to release the email entity.

Figure 6.2 depicts the Time Allocation submodel. The six modules within the submodel collectively allocate time to the various areas of focus with respect to the Attention entity. Areas of focus include processing email messages, interruption and resumption lags, and primary work.

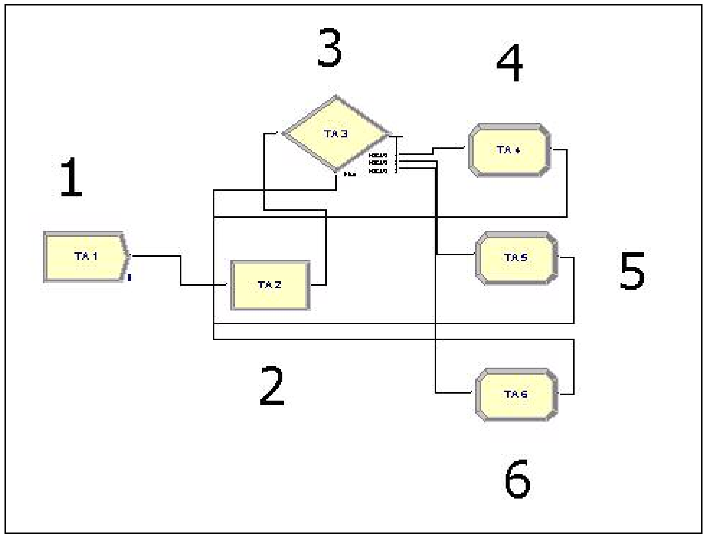


Figure 6.2. The Time Allocation Sub Model

Module 1 causes the arrival of one and only one entity that will circulate within the Time Allocation submodel throughout the entire simulation, allocating time to various areas of the Attention entity's focus. Module 2 delays this entity for four seconds. The submodel updates the amount of time spent focusing on one of the areas of attention every four seconds. Because each update represents a simulation event, choosing to update every single second causes four times as many simulation events, and therefore causes the simulation processing time to quadruple. Updating every four seconds allows for reasonable accuracy, while allowing the simulations to be processed within a reasonable time frame. Module 3 routes the entity to one of four modules depending on the current area of the Attention entity's focus. The current area of the Attention entity's focus is captured by the Focus variable. The values of the Focus variable correspond to the activities that the Attention entity is *focusing* on. If the Focus variable is 1, then the entity is routed to module 4. Module 4 updates the time spent on email processing by 4 seconds. If the Focus variable is 2, then the entity is routed to module 5. Module 5 updates the time spent on interruption or resumption lags. If the Focus variable is 3, then the entity is routed to module 6, which updates the time spent on the knowledge worker's primary work by four seconds. Modules 4, 5, and 6 update, by 4 seconds, the time spent by the Attention entity on email, interruption or resumption lags, or primary work, respectively, before routing the entity back to module 2. If the Attention entity is not focused in one of the three areas (the Focus variable does not equal 1, 2, or 3), then the Attention entity is idle, and the time allocation entity continues to loop without allocating time to a specific activity. Specific parameters for each module can be found in Appendix A.

6.2 The Strategy Submodels

The Strategy Submodels consist of the "Strategy Choice" submodel, all of the "Attention" submodels, and the "Attention Statistics and Disposal" submodel. The Strategy submodels accomplish several things. First, the Strategy Choice submodel directs the flow of the Attention entity into one of the Attention submodels, and by doing so, controls the email processing strategy that is simulated. Second, the various Attention submodels simulate the flow of the knowledge worker's attention. Said differently, the Attention submodels simulate the various email processing strategies. And third, the Attention Statistics and Disposal submodel captures the statistical performance measures of each daily Attention entity.

6.2.1 The Strategy Choice Submodel

The Strategy Choice submodel, Figure 6.3 controls the email processing strategy by directing the flow of the Attention entity into one of thirteen submodels, each corresponding to a particular email processing strategy. The first module, a "create" module, is usedto simulate the creation of an Attention entity.

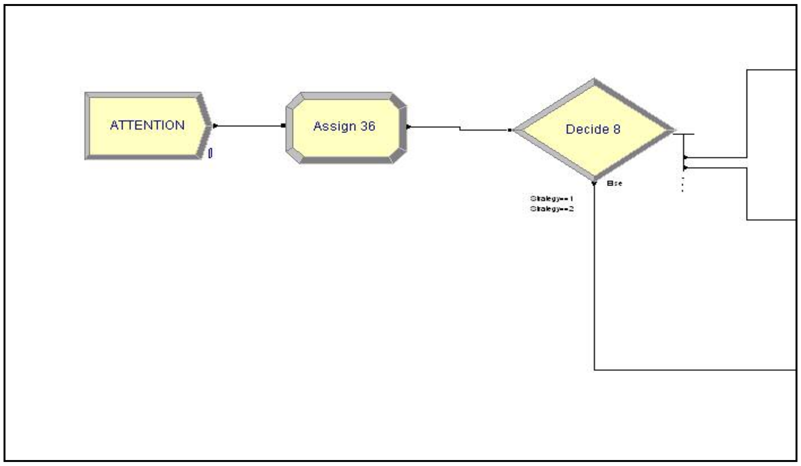


Figure 6.3. The Strategy Choice Submodel

As illustrated in Figure 6.4 the Attention entity is created once every 24 hours, beginning 8 hours into the simulation. As discussed in section 6.2.3, each Attention entity is "disposed of" at the end of each simulated day after collecting the entity's performance statistics. In this way, one Attention entity arrives each morning at 8:00 a.m. and only one Attention entity will exist per day. Thus it simulates a single knowledge worker's one business day.

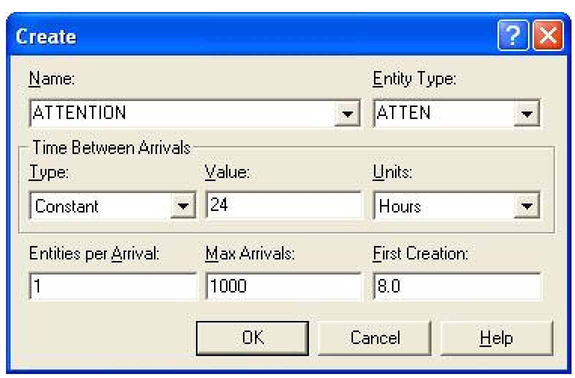


Figure 6.4. The Create Module for the Attention Entity

Next (see Figure 6.5), two attributes of the Attention entity are assigned. The goHOME (Q_d) attribute assigns a random value between 540 and 570 following a uniform distribution. This number corresponds to the number of minutes of work (the sum of email processing minutes and primary work minutes) that must be completed before the knowledge worker can “call it a day.” The Interruptions attribute tracks the number of times that the Attention entity is interrupted each day by email messages. The assign module is also used to assign values to variables that control the email processing strategy employed by the Attention entity. The variables Strategy, Schedule, and Batch are set before each simulation run, and are used to determine the route taken by the Attention entity and therefore the corresponding email processing strategy followed by the Attention entity. As can be inferred from the top level model (Figure 6.1), the “Strategy” variable can have three values, corresponding to the three exit points of the Strategy Choice submodel. A value of 1 causes the Attention entity to be routed to the Continuous email processing strategy. A value of 2 causes the Attention entity to be routed to one of the “Scheduled” email processing strategies, and a value of 3 causes the Attention entity to be routed to one of the “Batch” email processing strategies. The Schedule variable only comes into play if the Strategy variable is assigned a value of 2. The Schedule variable can take on one of eight values corresponding to eight different “scheduled” email processing strategies. The Batch variable only comes into play if the Strategy variable is assigned a value of 3. The Batch variable can take on one of 4 values corresponding to the four different possible Batch email processing strategies.

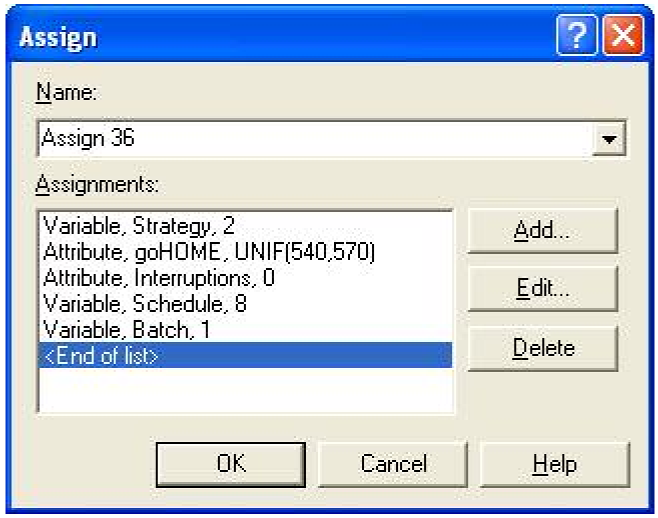


Figure 6.5. The Assign Module for the Attention Entity

This allows for simulation of any particular email processing strategy within the one Arena model. The thirteen email processing strategy submodels include the "Continuous Attention" submodel, seven different "Scheduled Attention" submodels, the "Jackson Attention" submodel, and four different "Batch Attention" submodels.

6.2.2 The Attention Submodels

The processing strategies, outlined in Table 6.1, describe the timing of the email processing that is to be performed. Said differently, the processing strategies describe the rules that govern the flow of the knowledge worker's attention. Within the simulation model, these same rules govern the flow of the Attention entity. The total amount of time allotted to processing email is determined by the nature of arriving email, while the specific time frames during which the emails are processed are determined by the processing strategy. A description of how each processing strategy is implemented in its corresponding submodel follows.

Table 6.1. EmailProcessing Strategies

Processing Strategies	Descriptions
Continuous Attention	This processing strategy requires processing email as they arrive (giving first priority to email).
Scheduled Attention-1M	This processing strategy requires holding email hours once daily, every morning.
Scheduled Attention-1A	This processing strategy requires holding email hours once daily, every afternoon.
Scheduled Attention-2	This processing strategy requires holding email hours twice daily.
Scheduled Attention-2P	This processing strategy requires holding email hours twice daily, during two peak email arrival periods.
Scheduled Attention-4	This processing strategy requires holding email hours four times daily.
Scheduled Attention-4P	This processing strategy requires holding email hours four times daily, during four peak arrival periods.
Scheduled Attention-6	This processing strategy requires holding email hours six times daily.
Jackson Attention	This processing strategy requires holding email hours every 45 minutes.
Batch Attention-1	This processing strategy requires processing email once a batch size corresponding to a “day’s worth” of email has arrived (an average of one batch per day).
Batch Attention-2	This processing strategy requires processing email once a batch size corresponding to ½ of a day’s worth of email has arrived.
Batch Attention-4	This processing strategy requires processing email once a batch size corresponding to ¼ of a day’s worth of email has arrived.
Batch Attention-6	This processing strategy requires processing email once a batch size corresponding to 1/6 of a day’s worth of email has arrived.

The Continuous Attention submodel is illustrated in Figure 6.6. In the Continuous Attention submodel, email is the knowledge worker’s number one priority and will always interrupt other knowledge work.

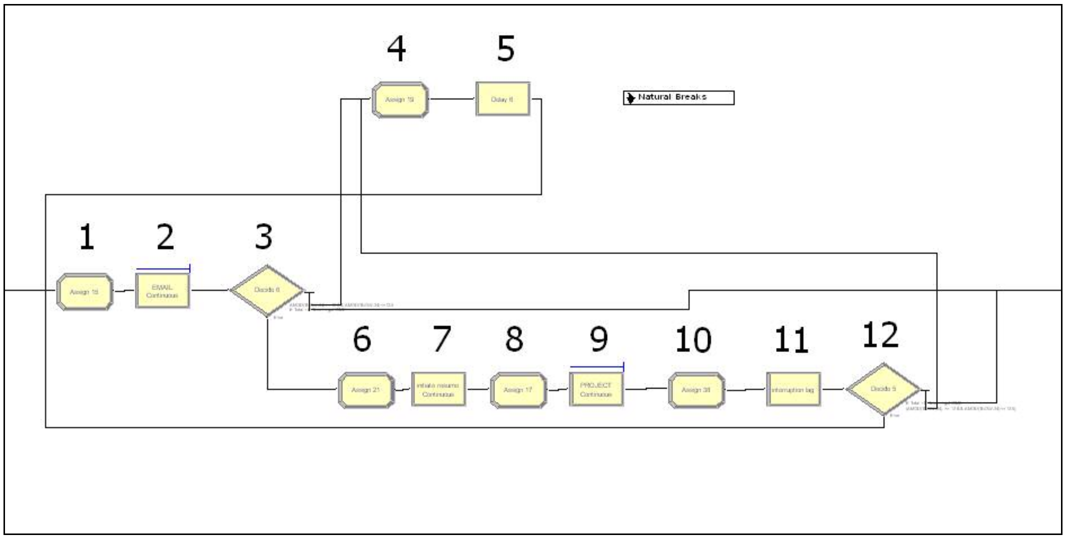


Figure 6.6. The Continuous Attention Submodel

Having been routed from the Strategy Choice submodel, the Attention entity will initially enter the submodel from the left at module 1. Module 1 is an assign module. In this instance, module one is assigning the Focus variable a value of 1, indicating to the Time Allocation submodel that the Attention entity is *focusing* on the processing of email. Next, the Attention entity will enter module 2, a hold module. The attention entity will stay at module 2 until all email have been processed or until noon, at which time the knowledge worker (Attention entity) is unavailable for a period of 30 minutes during the lunch break. Module 3 directs the Attention entity in one of three directions. The Attention entity is directed to module 4 if it is lunch time, to the exit point if a threshold of work has been completed for the day ($Q_d <= Y_d + Z_d$), or to module 6 if the Attention entity's focus is shifting towards primary work. Module 4 assigns the Focus variable a value of 4, indicating to the Time Allocation submodel that the knowledge worker is idle. Module 5 delays the Attention entity for ½ hour, before releasing it back to module 1. Module 6 assigns the Focus variable a value of 2, indicating to the Time Allocation submodel that the attention entity has shifted its focus to what will be a resumption lag, that time during which, having been interrupted, the knowledge worker prepares to resume his primary work. Module 7 simulates the resumption lag, and delays the Attention entity for a randomly determined time period (R_{ds}) following the exponential distribution with a mean of one minute (Jackson, 2003). Occasionally a knowledge worker might encounter an interruption at a "natural breaking point" in his or her work. If the interruption were to occur during a natural break, then the resumption lag would not be relevant. This possibility is captured within the model using the Natural Breaks submodel.

The Natural Breaks submodel, Figure 6.7 simulates the occurrence of natural breaks throughout the knowledge worker's day.

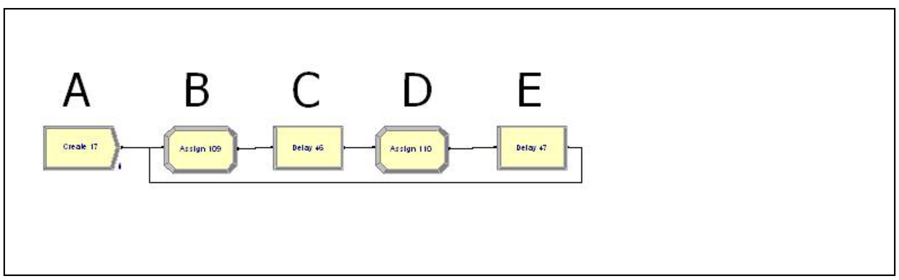


Figure 6.7. The Natural Breaks Submodel

Module A creates an entity that will then exist indefinitely in modules B through E. Module B assigns a value of zero to the "Naturalbreak?" variable. A value of zero corresponds to the occurrence of a natural break. The Naturalbreak? variable is multiplied by the resumption lag, so that if an interruption occurs during a natural break, the resumption lag will be zero. Module C holds the entity (and therefore the Naturalbreak? variable value of zero) for one to five minutes (uniform distribution). Module D changes the Naturalbreak? variable to one, indicating that a natural break is no longer occurring. Module E holds the entity (and therefore the Naturalbreak? variable value of one) for ½ hour to 2 hours (uniform distribution) before the entity's return to module B. Specific parameters for each module within the Natural Breaks submodel can be found in Appendix C.

Turning our attention back to the Continuous Attention submodel, module 8 assigns the Focus variable a value of 3, indicating to the Time Allocation submodel that the Attention entity has shifted its focus to the knowledge worker's primary work. The Attention entity is held at module 9, corresponding to primary work, until an email arrives, it is lunch time, or a threshold of work has been completed for the day. Module 10 shifts the Focus variable back to a value of 2, indicating to the Time Allocation submodel that the Attention entity has shifted its focus to what will be an interruption lag, that time between the interruption stimulus and the response to the interruption, during which the knowledge worker is preparing for the interruption, and therefore is not fully engaged in his primary task (Trafton, 2003). Module ten also adds one to the Attention entity attribute "Interruptions." The interruption lag (L_{ds})is simulated in module 11. The attention entity is held for a delay following a triangular distribution with a minimum of zero seconds, a mode of 6 seconds, and a maximum of 2 minutes. This results in an average interruption lag of approximately 42 seconds. This lag is again multiplied by the Naturalbreak? variable to account for the fact that the interruption may have occurred during the knowledge worker's natural break. Jackson (2003) indicated that 70% of workers reacted to an email interruption within 6 seconds, and that workers reacted to an email's interruption on average within 1 minute and 44 seconds. A maximum of two minutes was used in the triangular distribution to cause a conservative average interruption lag of 42 seconds. This was done, because we do not know the proportion of that 1 minute 44 seconds that was spent preparing to be interrupted (the interruption lag), and the proportion of that time that was spent on the primary task. Module 12 then directs the Attention entity to either the exit if a threshold of work has been completed, to lunch if it is 12:00, or back to email in need of processing.   Specific values for the parameters of the Continuous submodel can be found in Appendix B.

The Scheduled Attention processing strategies, the Jackson Attention processing strategy, and the Batch Attention processing strategies all share the same flowchart outlined in Figure 6.8 below. Differences in the processing strategies are captured within the logic of the modules described.

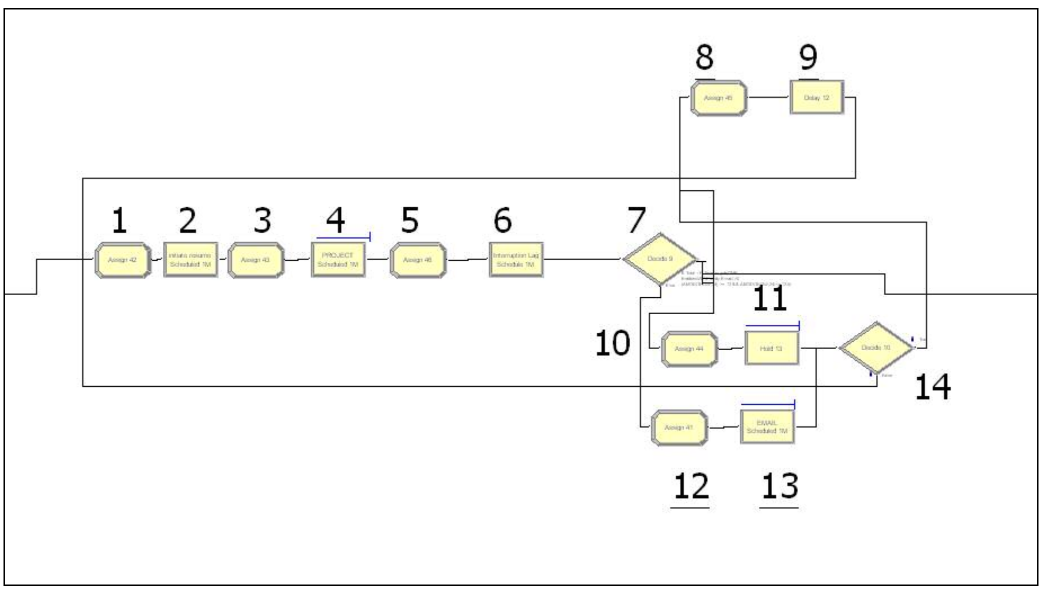


Figure 6.8.   The Arena Model for Scheduled Attention Processing Strategies, the Jackson Attention Processing Strategy, and Batch Attention Processing Strategies

Module 1 assigns the Focus variable a value of 2, indicating to the Time Allocation submodel that the Attention entity has shifted its focus to what will be a resumption lag. Module 2 simulates the resumption lag, and delays the Attention entity for a randomly determined time period (R_{ds}) following the exponential distribution with a mean of one minute (Jackson, 2003). Module 3 assigns the Focus variable a value of 3, indicating to the Time Allocation submodel that the Attention entity has shifted its focus to the knowledge worker's primary work. Module 4 holds the Attention entity, and therefore the knowledge worker's focus on primary work, until one of a set of conditions is met. The differences in processing strategies are captured in these differing sets of conditions. The sets of conditions and their corresponding processing strategies are outlined in Tables 6.2 through 6.4.

Table 6.2. The Conditions for Processing Email, Given Various Scheduled Email Processing Strategies

Processing Strategy	Conditions for Changing Focus (Module 4)
Scheduled Attention 1A	The time is between 3:20 and 6:00 p.m. & non-priority email is present *OR* A threshold of work has been accomplished *OR* Priority email is present *OR* The time is between Noon and 12:30
Scheduled Attention 1M	The time is between 8:00 and 10:40 a.m. & non-priority email is present *OR* A threshold of work has been accomplished *OR* Priority email is present *OR* The time is between Noon and 12:30
Scheduled Attention 2	The time is between 8:00 and 9:20 p.m. & non-priority email is present *OR* The time is between 4:40 and 6:00 p.m. & non-priority email is present *OR* A threshold of work has been accomplished *OR* Priority email is present *OR* The time is between Noon and 12:30
Scheduled Attention 2P	The time is between Noon and 1:20 p.m. & non-priority email is present *OR* The time is between 4:40 and 6:00 p.m. & non-priority email is present *OR* A threshold of work has been accomplished *OR* Priority email is present *OR* The time is between 11:30 a.m. and Noon (lunch time is altered to accommodate the email processing schedule)
Scheduled Attention 4	The time is between 8:00 and 8:40 p.m. & non-priority email is present *OR* The time is between 11:07 and 11:47 p.m. & non-priority email is present *OR* The time is between 2:14 and 2:54 p.m. & non-priority email is present *OR* The time is between 5:20 and 6:00 p.m. & non-priority email is present *OR* A threshold of work has been accomplished *OR* Priority email is present *OR* The time is between Noon and 12:30
Scheduled Attention 4P	The time is between 10:00 and 10:40 p.m. & non-priority email is present *OR* The time is between 12:30 and 1:10 p.m. & non-priority email is present *OR* The time is between 2:00 and 2:40 p.m. & non-priority email is present *OR* The time is between 5:20 and 6:00 p.m. & non-priority email is present *OR* A threshold of work has been accomplished *OR* Priority email is present *OR* The time is between Noon and 12:30
Scheduled Attention 6	The time is between 8:00 and 8:27 p.m. & non-priority email is present *OR* The time is between 9:55 and 10:21 p.m. & non-priority email is present *OR* The time is between 12:30 and 12:57 p.m. & non-priority email is present *OR* The time is between 1:44 and 2:10 p.m. & non-priority email is present *OR* The time is between 3:38 and 4:05 p.m. & non-priority email is present *OR* The time is between 5:33 and 6:00 p.m. & non-priority email is present *OR* A threshold of work has been accomplished *OR* Priority email is present *OR* The time is between Noon and 12:30

Table 6.3. Conditions for Processing Email, Given Various Batch Email Processing Strategies

Processing Strategy	Conditions for Changing Focus (Module 4)
Batch Attention 1	A batch of at least 32 non-priority email has accumulated *OR* A threshold of work has been accomplished *OR* Priority email is present *OR* The time is between Noon and 12:30
Batch Attention 2	A batch of at least 16 non-priority email has accumulated *OR* A threshold of work has been accomplished *OR* Priority email is present *OR* The time is between Noon and 12:30
Batch Attention 4	A batch of at least 8 non-priority email has accumulated *OR* A threshold of work has been accomplished *OR* Priority email is present *OR* The time is between Noon and 12:30
Batch Attention 6	A batch of at least 5 non-priority email has accumulated *OR* A threshold of work has been accomplished *OR* Priority email is present *OR* The time is between Noon and 12:30

Table 6.4. Conditions for Processing Email, Given the Jackson Email Processing Strategies

Processing Strategy	Conditions for Changing Focus (Module 4)
Jackson Attention	45 minutes have elapsed since email have been processed *OR* A threshold of work has been accomplished *OR* Priority email is present *OR* The time is between Noon and 12:30

Once a condition for leaving module 4 has been met, the attention entity moves to module 5. Module 5 shifts the Focus variable back to a value of 2, indicating to the Time Allocation submodel that the Attention entity has shifted its focus to what will be an interruption lag, that time between the interruption stimulus and the response to the interruption, during which the knowledge worker is preparing for the interruption, and therefore is not fully engaged in his primary task (Trafton, 2003). The interruption lag (L_{ds}) is simulated in module 6. As described with the Continuous Attention submodel, the Attention entity is held for a delay following a triangular distribution with a minimum of zero seconds, a mode of 6 seconds, and a maximum of 2 minutes. Module 7 routes the Attention entity according to the condition that caused the attention's focus to shift from the primary work of the knowledge worker. From module 7, the Attention entity will: a) exit the submodel if a threshold of work (Q_d) has been accomplished, b) move to module 10 if a priority email is awaiting processing, c) move to module 8 if it is lunch time, or d) move to module 12 to process non-priority email. Modules 8 and 9 simulate the knowledge worker's attention during the lunch break. Module 8 assigns the Focus variable a value of 4, indicating to the Time Allocation submodel that the knowledge worker is idle. Module 9 delays the Attention entity for ½ hour, before releasing it back to module 1. Modules 10 and 11 simulate the processing of priority email. Module 10 assigns the Focus variable a value of 1, indicating to the Time Allocation submodel that the Attention entity is focusing on the processing of email. Module 11 holds the Attention entity's focus on email until all priority email has been processed. Similarly, modules 12 and 13 simulate the processing of non-priority email. Module 14 directs the Attention entity to either module 8 (lunch time) or module 1. Specific parameters for each module can be seen in Appendixes D and E.

6.2.3 The Attention Statistics and Disposal Submodel

The Attention Statistics and Disposal Submodel consists of three modules that collect statistical data about each Attention entity. Each Attention Entity is in the system for one day. At the end of each day, the entity's statistics are recorded and the entity is disposed. The Attention entity's path thru this final set of modules corresponds to the end of a knowledge worker's day. The modules of the Attention Statistics and Disposal submodel are illustrated in Figure 6.9.

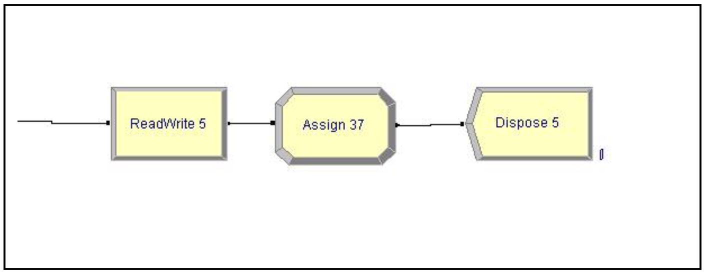


Figure 6.9. The Attention Statistics and Disposal Submodel

The first module writes the Attention entity's attributes to a Microsoft Excel file for subsequent analysis. As illustrated in Figure 6.10 the attributes that are collected include the simulation replication (NREP), the simulation time at the time of the entity's creation (Entity.CreateTime), the time of the entity's disposal (TNOW), the total amount of time spent in interruption and resumption lags (R Total), the total amount of time spent working on primary work (P Time), the time spent working on email (E Total), and the goHOME value. From these statistics, daily performance measures are captured.

TNOW – Entity.CreateTime = E Total + P Time + R Total

or

$H_d = Y_d + Z_d + G_d$

Finally, the number of interruptions experienced by the Attention entity during the day (Interruptions) is collected and written to the Excel file.

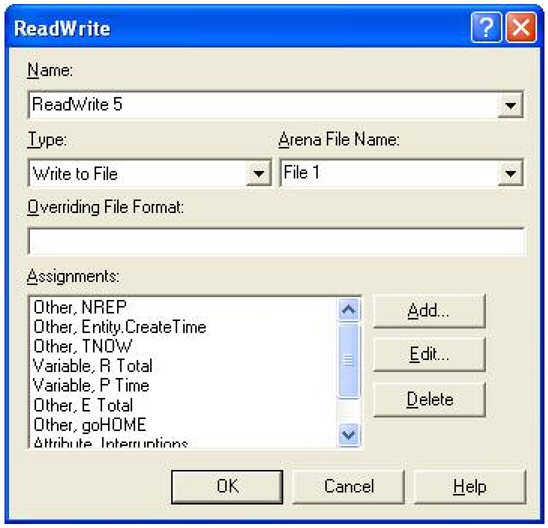


Figure 6.10. The Write Module for the Attention Entity

The second module within the submodel is an assign module (Figure 6.11). The assign module is used to assign (reset) values of variables collected for each day's Attention entity. The assign variable is illustrated below, and includes the following assignments: E Total is reset to zero, R Total is reset to zero, the Attention entity's Focus is reset to 4 (4 corresponds to idle), and the P time is reset to zero.

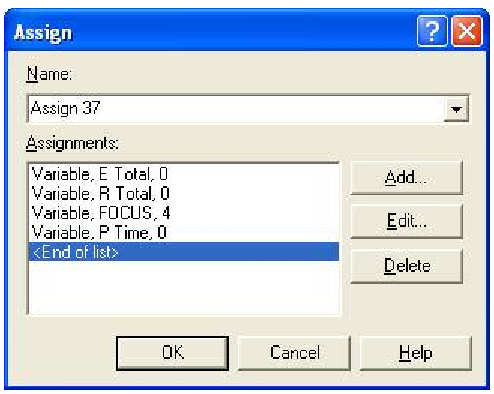


Figure 6.11. The Assign Module for the Attention Entity

Finally, the third module simply serves as a disposal point for the day's Attention entity.

6.3 The Flow of Email Submodels

The "Email Arrivals" submodel simulates the arrival of the various types of email messages. The "Email Flow Statistics & Disposal" submodel collects performance measures pertaining to each individual email message.

The simulation model's parameters can be grouped into two categories: the nature of the arriving email and the strategy chosen for processing the arriving email. The nature of the arriving email is described by the email arrival patterns and the processing needs of the arriving messages, both in terms of the timeliness or urgency (needed resolution time) and the amount of time needed to process the various types of arriving email. These parameters describing the nature of arriving email were collected with the use of the form described in chapter 4. Each row from the table corresponds to a potential category of email, the arrival pattern of which is captured within the row. Values for $\lambda_{i,j,k,t}$ are derived from each cell of the form. The completed form in Figure 6.12, represents one day in the email-life of one knowledge worker, and is used as the basis for the "email environments" simulated.

TYPE	URGENCY	TIME NEEDED	Total	8am - 10am	10 am - noon	noon - 2pm	2pm - 4pm	4pm - 6 pm	6pm - 8 am
Totals			38	8	6	6	5	8	5
SPAM	N/A	N/A	0						
IRRELEVANT	N/A	N/A	5	2	1		1		1
READ	URGENT	< 1 MINUTE	2	2					
READ	URGENT	1 - 10 MINUTES	1					1	
READ	URGENT	> 10 MINUTES	1					1	
READ	WITHIN BUS DAY	< 1 MINUTE	11	2	1	3	1	2	2
READ	WITHIN BUS DAY	1 - 10 MINUTES	3			1	1		1
READ	WITHIN BUS DAY	> 10 MINUTES	1				1		
READ	WITHIN 1 WEEK	< 1 MINUTE	1			1			
READ	WITHIN 1 WEEK	1 - 10 MINUTES	2		2				
READ	WITHIN 1 WEEK	> 10 MINUTES	3	1	1			1	
REPLY	URGENT	< 1 MINUTE	2	1	1				
REPLY	URGENT	1 - 10 MINUTES	0						
REPLY	URGENT	> 10 MINUTES	0						
REPLY	WITHIN BUS DAY	< 1 MINUTE	2			1			1
REPLY	WITHIN BUS DAY	1 - 10 MINUTES	1				1		
REPLY	WITHIN BUS DAY	> 10 MINUTES	0						
REPLY	WITHIN 1 WEEK	< 1 MINUTE	0						
REPLY	WITHIN 1 WEEK	1 - 10 MINUTES	1					1	
REPLY	WITHIN 1 WEEK	> 10 MINUTES	2					2	

EMail Response

Figure 6.12. One Day in the Email-life of One Knowledge Worker

As indicated in Figure 6.12, above, a typical day for the knowledge worker consisted of a diverse mix of email messages, in terms of the types of email messages, the urgency of the messages, and the time needed to process the various types of email messages. In order to allow for the possibility of arriving email during those time periods when no email arrival occurred, each arrival rate was multiplied by 0.9, and 10% of daily arrivals of a particular type of email (one row in the form above) is redistributed across *all* time periods. The following example illustrated in Figure 6.13 explains this further. Emails that need only to be read, are urgent, and require less than one minute to process (the READ, URGENT, < 1 MINUTE row of the form) are combined with the "REPLY, URGENT, < 1 MINUTE" email, because the simulation does not differentiate between email that are only read and emails that are replied to. This creates the arrival pattern seen in Table A of Figure 6.13. As seen in Table B, these numbers are then converted from total arrivals to *hourly arrival rates*. For example, 3 arrivals occurring between 8 a.m. and 10 a.m. corresponds to an hourly arrival rate of 1.5. Next, in Table C, these numbers are then multiplied by 0.9. Finally, in Table D, 10% of the total email arrivals (0.1 * 4 = 0.4 / 24 = 0.0167) are then added to the hourly arrival rate of all time periods. In this example, $\lambda_{i=3,j=1,k=1,t=1} + \lambda_{i=4,j=1,k=1,t=1} = 1.3667$.

Table A

8am – 10am	10am – Noon	Noon – 2pm	2pm – 4pm	4pm – 6pm	6pm – 8am
3	1	0	0	0	0

↓

Table B

8am – 10am	10am – Noon	Noon – 2pm	2pm – 4pm	4pm – 6pm	6pm – 8am
1.5	0.5	0	0	0	0

↓

Table C

8am – 10am	10am – Noon	Noon – 2pm	2pm – 4pm	4pm – 6pm	6pm – 8am
1.35	0.45	0	0	0	0

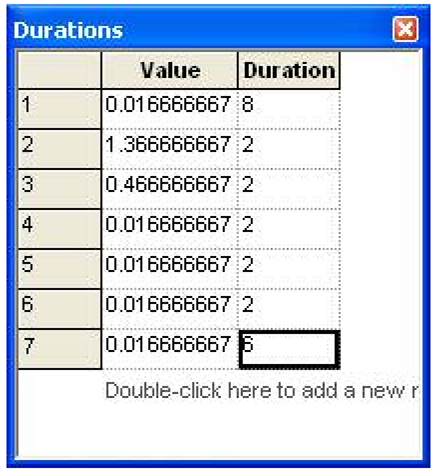
↓

Table D

8am – 10am	10am – Noon	Noon – 2pm	2pm – 4pm	4pm – 6pm	6pm – 8am
1.3667	0.4667	0.0167	0.0167	0.0167	0.0167

Figure 6.13. The Establishment of Email Arrival Pattern

Figure 6.14 is a screenshot of the schedule as it was implemented in Arena. Because the Arena simulation begins at midnight, the first eight hours of the schedule correspond to the 6pm – 8am time frame on the table above.



Durations

	Value	Duration
1	0.016666667	8
2	1.366666667	2
3	0.466666667	2
4	0.016666667	2
5	0.016666667	2
6	0.016666667	2
7	0.016666667	6

Double-click here to add a new r

Figure 6.14. Arrival Schedule 2

Similarly, all email schedules are established. Figure 6.15 is a screenshot of the Email Arrivals Submodel.

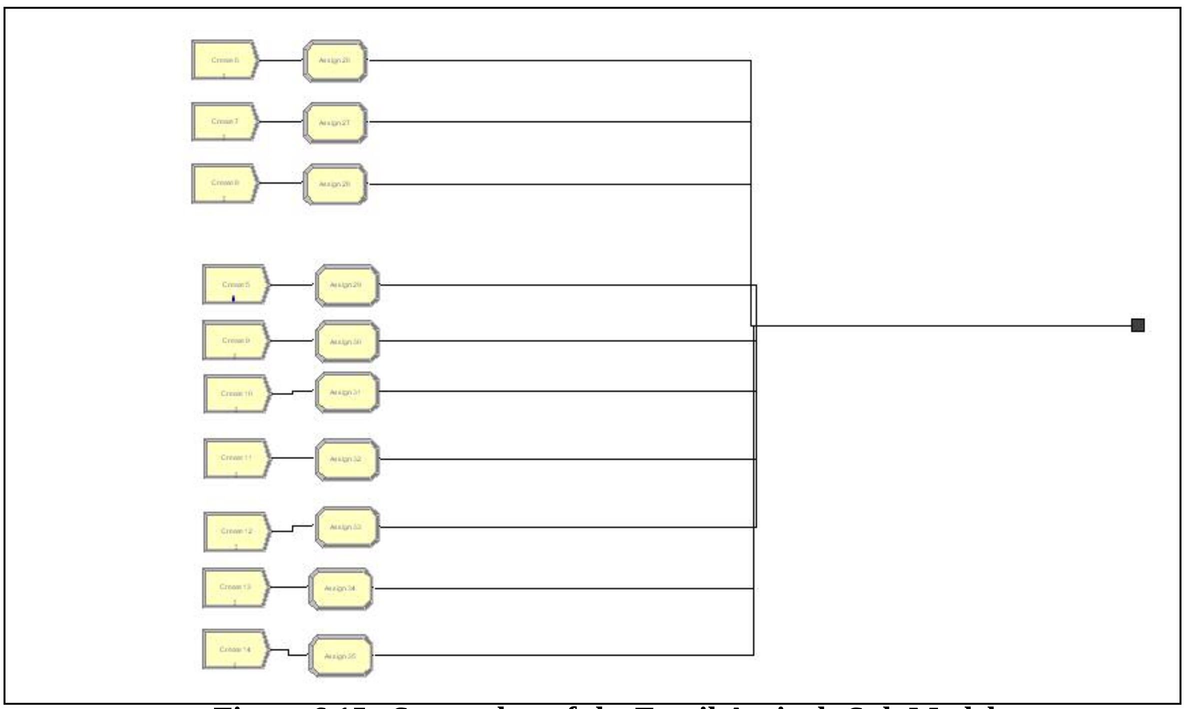


Figure 6.15. Screenshot of the Email Arrivals Sub Model

Each "create" module ( ) is followed by an "assign" module ( ). Each create module simulates the arrival of a particular type (urgency and time needed to process) of email message. Each create module follows a particular schedule, and each assign module assigns a processing time and priority to the arriving email. For example, in the Create module illustrated in Figure 6.16 priority email arrivals are simulated according to schedule 2. They are then assigned an email processing time (EPT). In this example, the processing time follows a uniform distribution between 0.01 and 1 minute, because these particular emails are said to require less than, but up to 1 minute to process. The email also, because it is "Urgent," is assigned a priority of "1." "Within business day" email messages are assigned a priority of 2. "Within one week" email messages are assigned a priority of 3. Finally, "SPAM" and "Irrelevant" email messages are assigned a priority of 4. These priorities correspond to the email's order in the processing queue. Schedule 2 (Listed in the "Durations" window) indicates hourly exponential arrival rates and the duration of these rates. Recall that Schedule 2 was derived above in Figure 6.13. For example, from midnight until 8:00 a.m. (the first row of the schedule), emails arrive exponentially at a mean rate of 0.01666667 arrivals per hour. The ten create and assign pairs in Figure 6.15 above correspond to the ten combinations of email arrivals (SPAM is combined with irrelevant email, READ, URGENT, < 1 MINUTE is combined with REPLY, URGENT, < 1 MINUTE …). . In this way, the "email environment" derived from the knowledge worker is implemented.

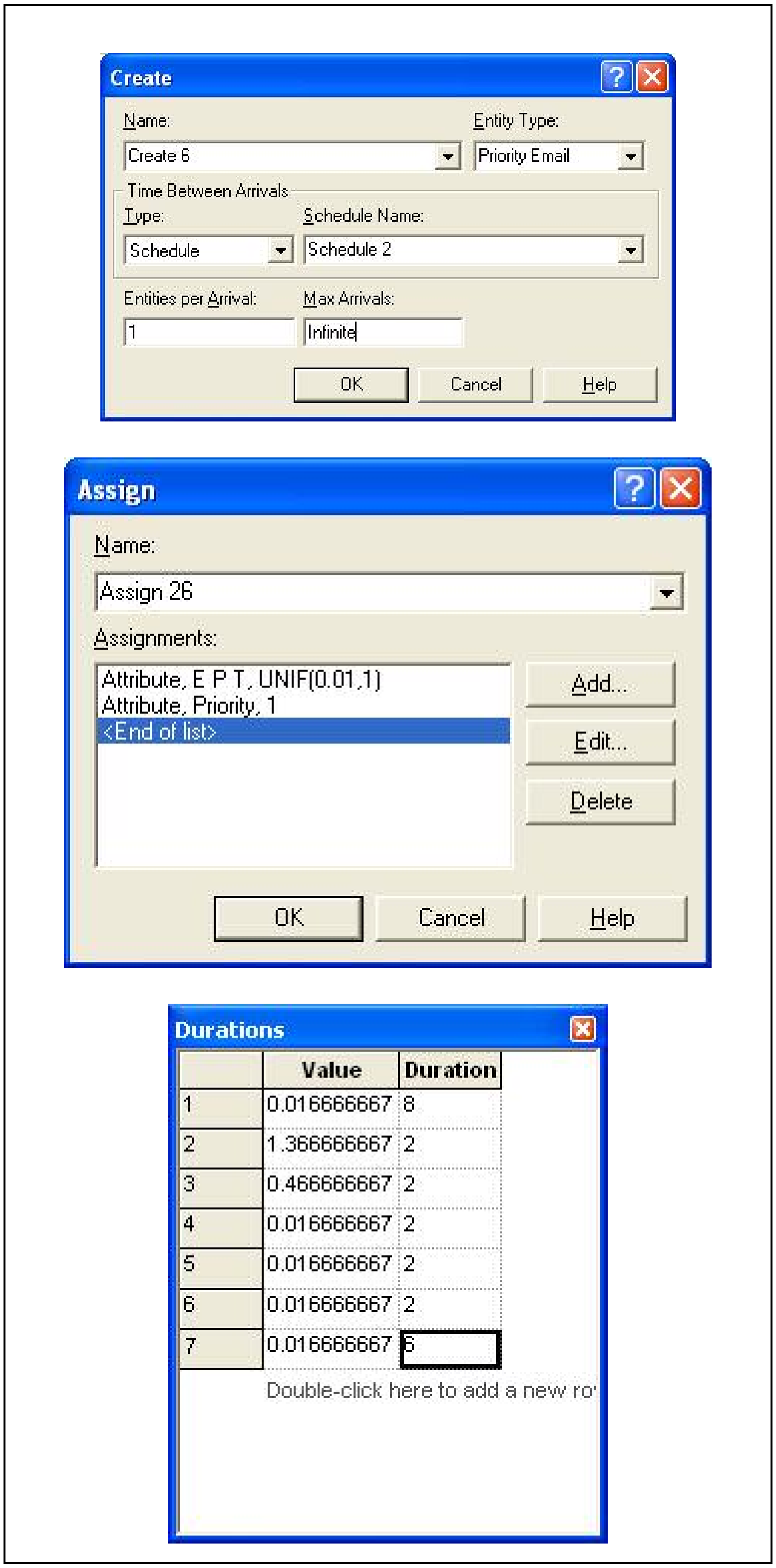


Figure 6.16. The Creation and Assignment of Email Messges Following the Schedule-2 Arrival Pattern

The time needed to process email messages was implemented as follows. All email fell into one of three categories (< 1 MINUTE, 1 – 10 MINUTES, or > 10 MINUTES). The < 1 MINUTE processing time ($P_{k=1ds}$) was implemented using a uniform distribution from 0.01 to 1 minute, as implemented in the assign module, Figure 6.17.

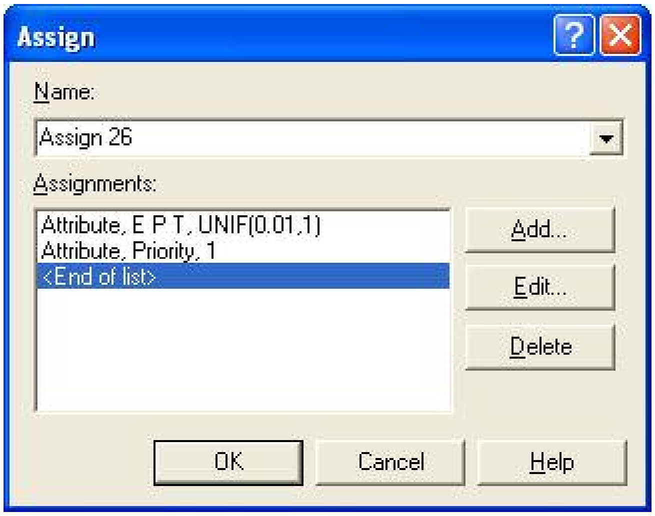


Figure 6.17. The Assignment of Email Processing Time (EPT), Messages Requiring 0.01 to 1 minute and having a Priority of 1

The 1 – 10 MINUTE processing time ($P_{k=2ds}$) was similarly implemented using the uniform distribution from 1 to 10 (Figure 6.18).

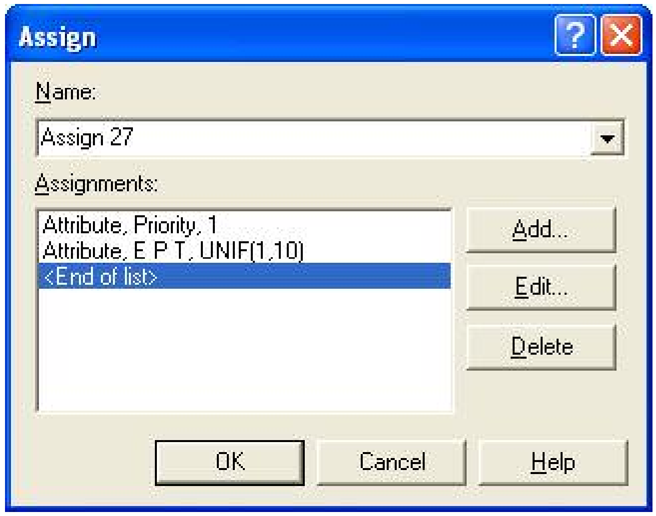


Figure 6.18. The Assignment of Email Processing Time (EPT), Messages requiring from 1 to 10 Minutes and having a Priority of 1

Finally, the > 10 MINUTES processing time ($P_{k=3ds}$) was implemented by taking the maximum of: an exponential processing time with a mean of 15 minutes, or 10 minutes (Figure 6.19).

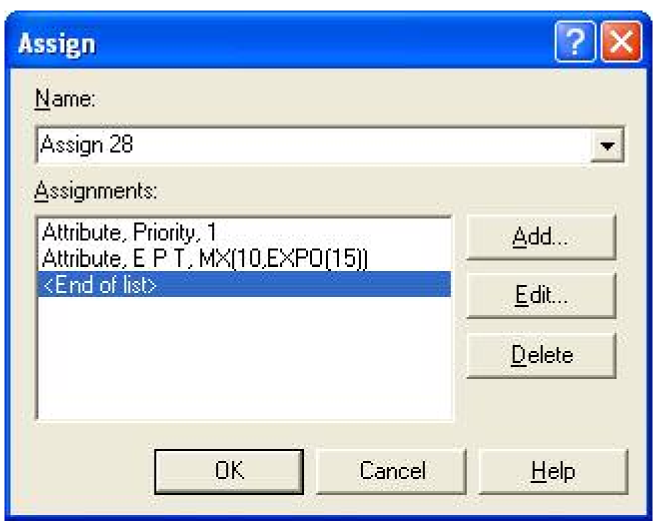


Figure 6.19 Assignment of Email Processing Time (EPT), Messages Requiring More than 10 Minutes and having a Priority of 1

Taking the maximum ensures that the categories of email processing time (EPT) do not overlap. By choosing the exponential distribution, the model allows for the possibility of lengthy email processing times.

The “Email Flow Statistics & Disposal” submodel is seen in Figure 6.20 below. The first module holds the email until the second module is empty and the Focus variable equals 1, corresponding to email processing. Holding all email until the second module is empty ensures that the Attention entity is only applied to one email at a time in the second module. The second module holds an individual email message until the processing of the email is complete (E Time >= E P T). The third module assigns or resets the E Time variable to zero. The E time variable is used to capture the amount of processing time that has been applied to the current email, and it is reset after each email is processed. The fourth module directs the email to one of four modules, based on the email’s priority. Modules 5 through 8 capture statistical information about each individual email of the four priorities and write the data to a Microsoft Excel file. Figure 6.21 illustrates the data that is captured for each email message. For each email message, the simulation repetition (NREP), the priority of the email message, the email’s arrival time (Entity.CreateTime), and the time of resolution for the email (TNOW). TNOW – EntityCreateTime = the Email Resolution Time or Ws_{js}.

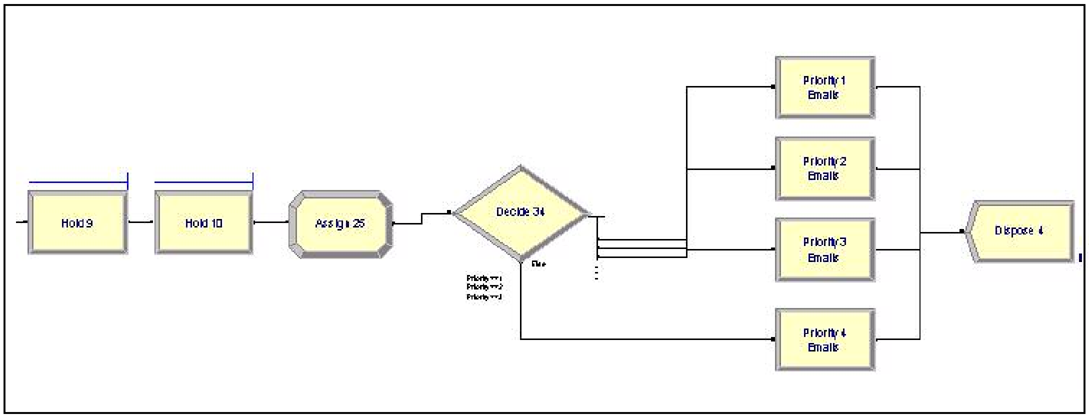


Figure 6.20. The Email Flow Statistics & Disposal submodel

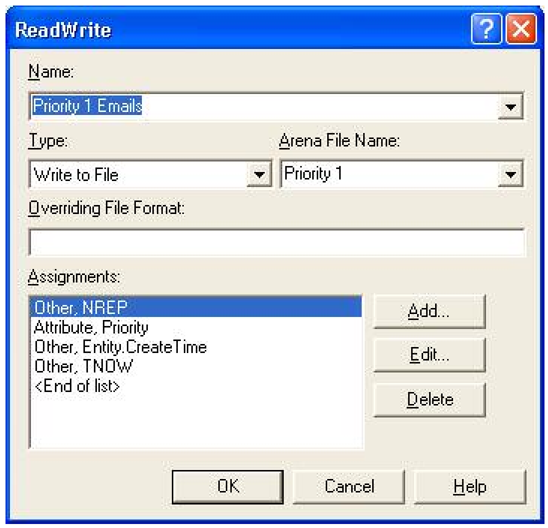


Figure 6.21. Write Module for Priority-1 Email Messages

6.4 Determination of Simulation Warm Up and Run Length Times

Initially, the knowledge work environment that is simulated does not accurately reflect reality. For example, email queues do not exist initially, because email have not had an opportunity to arrive or accumulate. The simulation's clock begins at midnight, so any email that would have arrived the evening before did not have an opportunity to do so. Also, if an email strategy cannot adequately handle a particular email processing load, then this may not be apparent initially, as it may take several days or more before enough email accumulate to cause noticeable differences in performance measures. For these reasons, performance information is not collected until the simulation has run for some period of time (the warm up period). In determining an appropriate warm up period, the goal is to determine the point in time of a simulation run that performance measures begin to "level out." This study used the Welch's method (Welch, 1983) in determining an appropriate warm up period. The results of the Welch's method appear in Figure 6.22.

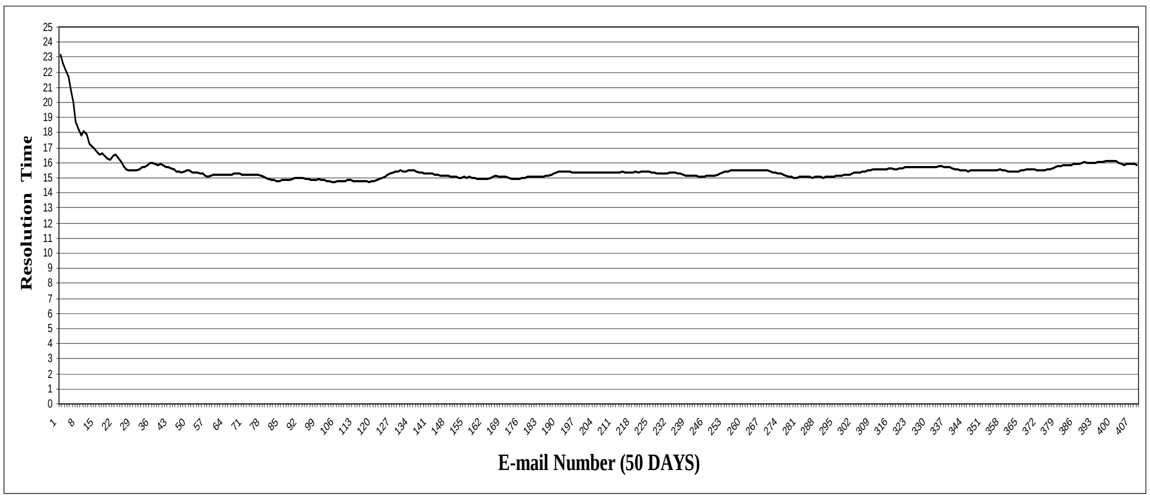


Figure 6.22. Results of the Welch's Method for the Batch Attention-1 Email Processing Strategy & Priority-3 Email Resolution Time

The Welch's method was performed using the Batch Attention-1 email processing strategy, while considering the priority-3 Email Resolution Time performance measure. The processing strategy and the performance measure were chosen, because they have the greatest potential for variability and therefore should lead to the most conservative simulation warm up period. The graph indicates that the Email Resolution Time performance measure has stabilized by the 160th email observation. The 160th observation roughly corresponds to day 20 in the simulation. In order to be even more conservative, 50% of this period was added back to the 20 day period, resulting in a warm up period of 30 days. The simulations were run for 90 days beyond the warm up period. Forty replications of each simulation were performed. When the means of performance measures were compared across the 40 replications, very little variance was seen. The grand mean of all 40 replications with respect to priority-3 email resolution time was 15.0133 hours. The standard deviation of the replication means was 0.6808 hours, or less than 5% of the mean performance measures. This indicated that 90 days was a reasonable period of time to obtain an accurate picture of the performance of the model. As further evidence of the appropriateness of the 90 day simulation run, the simulation was repeated for 5 replications of 720 days. As can be seen in Table 5.5 below, there was little difference in the mean and the standard deviation improved only slightly. Also, it is recommended that in order to successfully perform a MANOVA, a *minimum* of 20 observations are necessary.

Table 6.5. Differences in Run Length / Replication Choices

Run Length / Replications	**Mean Priority-3 Email Resolution Time (Hrs)**	**Standard Deviation Priority 3 Email Resolution Time (Hrs)**
90 days / 40 Replications	15.0133	0.6808
720 days / 5 Replications	14.8935	0.4849

Having described the simulation model, chapter 7 next discusses the results of the simulations as they apply to the earlier stated research questions, propositions, and hypotheses.

7. ANALYSIS AND RESULTS

Although only certain email processing strategies were specifically investigated within the study's hypotheses, data collected from all 13 email processing strategies were included in the model and its analysis. Simulations of each processing strategy were performed and performance measures were collected. The collected data included six performance measures: Efficiency, Hours-Worked, and the Email-Resolution-Time for each of the four priorities of email message. Because we are comparing multiple performance measures across groups (one group corresponding to each email processing strategy), a multivariate analysis of variance (MANOVA) was performed. Table 7.1, below, summarizes the results of the MANOVA model.

Table 7.1. Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	1.000	87739879.955(a)	6.000	502.000	.000
	Wilks' Lambda	.000	87739879.953(a)	6.000	502.000	.000
	Hotelling's Trace	1048683.824	87739879.953(a)	6.000	502.000	.000
	Roy's Largest Root	1048683.824	87739879.953(a)	6.000	502.000	.000
Strategy	Pillai's Trace	4.591	137.677	72.000	3042.000	.000
	Wilks' Lambda	.000	744.819	72.000	2736.980	.000
	Hotelling's Trace	507.821	3528.889	72.000	3002.000	.000
	Roy's Largest Root	426.365	18013.910(b)	12.000	507.000	.000
a Exact statistic						
b The statistic is an upper bound on F that yields a lower bound on the significance level.						
c Design: Intercept+Strategy						

The email processing strategy was found to have a significant effect ($\alpha = 0.001$). All of the email processing strategies were compared across multiple performance measures. Tests for differences between groups (email processing strategies) were performed using the Bonferroni approach for adjusting alpha to account for inflation of the overall type I error rate resulting from multiple performance measures. Results for the hypotheses outlined earlier were mixed. The results of each hypothesis are described below.

7.1 Analysis of Proposition 1

Proposition 1(a) was supported.

> ***Proposition 1(a):*** *Dividing non-priority email work into two specific time frames (holding email hours twice daily – Scheduled Attention-2) will allow for successfully replying to all email within the 24 hour appropriate time frame.*

When employing the Scheduled Attention-2 processing strategy, the mean resolution time for priority-1 email messages was 0.4993 hours. Considering all individual observations of priority-1 email resolution times, the maximum resolution time was 16.4128 hours. This seems quite a long period of time for an email that has been given first priority, however, it is easily explained by an arrival occurring shortly after the knowledge worker leaves for the day. The email is then not processed until the following morning. The priority-1 results are not surprising; we would expect similar results from any of the processing strategies, because all processing strategies give priority-1 email messages first priority.

From all individual observations across all simulation replications, the maximum resolution time for priority-2 email was 22.5887 hours, and the maximum resolution time for priority-3 email was 23.8542 hours. This indicates that all email were in fact processed within 24 hours, as was hypothesized. More than 75% of the observed priority-2 email were completed within 5 hours, and more than 2/3 of priority-3 email were completed within 6 hours, indicating that most email messages were processed well within the 24 hour time frame.

The results of proposition 1(a) suggest an alternative to the Continuous mode of monitoring email messages. By giving priority only to those messages in need of priority ("urgent" messages), the knowledge worker is able to process other email work in bulk, avoid interruptions, and still resolve all email within an acceptable time frame.

Mixed results for proposition 1(b) were found.

> ***Proposition 1(b):*** *Processing non-priority email in batches corresponding to ½ of an average daily email processing load will allow for successfully resolving all email within the 24 hour appropriate time frame.*

All email were not resolved within the 24 hour time period. From all replications, the average resolution time for priority-1 email messages was 0.6908 hours, and the maximum resolution time from any individual observation for priority-1 email messages was 15.3264 hours. All priority-1 email messages were easily processed within the 24 hour time frame. From all individual observations, the maximum resolution time for priority-2 email was 33.2636 hours, and the maximum resolution time for priority-3 email was 40.4466 hours, indicating a lack of support for proposition 1(b). However, of the 63,835 observations of priority-2 email messages occurring among the 40 simulation repetitions (90 days of activity per replication each), only 8 observations or 0.0125 % required more than 24 hours for resolution. Of the 32,230 observations of priority-3 email messages, only 69 or 0.2141 % were not resolved within the 24 hour time frame. Because the arrival patterns of email messages are stochastic, the possibility exists that email will not accumulate into a batch for an extended period of time. However, the overwhelming majority of email messages were resolved within the 24 hour time frame, as indicated in Figure 7.1 below. The mean and median resolution times for priority-2 email were 5.7816 and 3.0742 hours, respectively, and the mean and median resolution times for priority-3 email were 7.5934 and 4.4340 hours, respectively. This also indicates that most email messages are resolved well within the 24 hour time frame. The Batch Attention-2 email processing strategy does not completely eliminate the possibility of a slow response, but it does come close. As with the Scheduled Attention-2 processing strategy, the Batch Attention-2 strategy may also be seen as an alternative to processing email continuously.

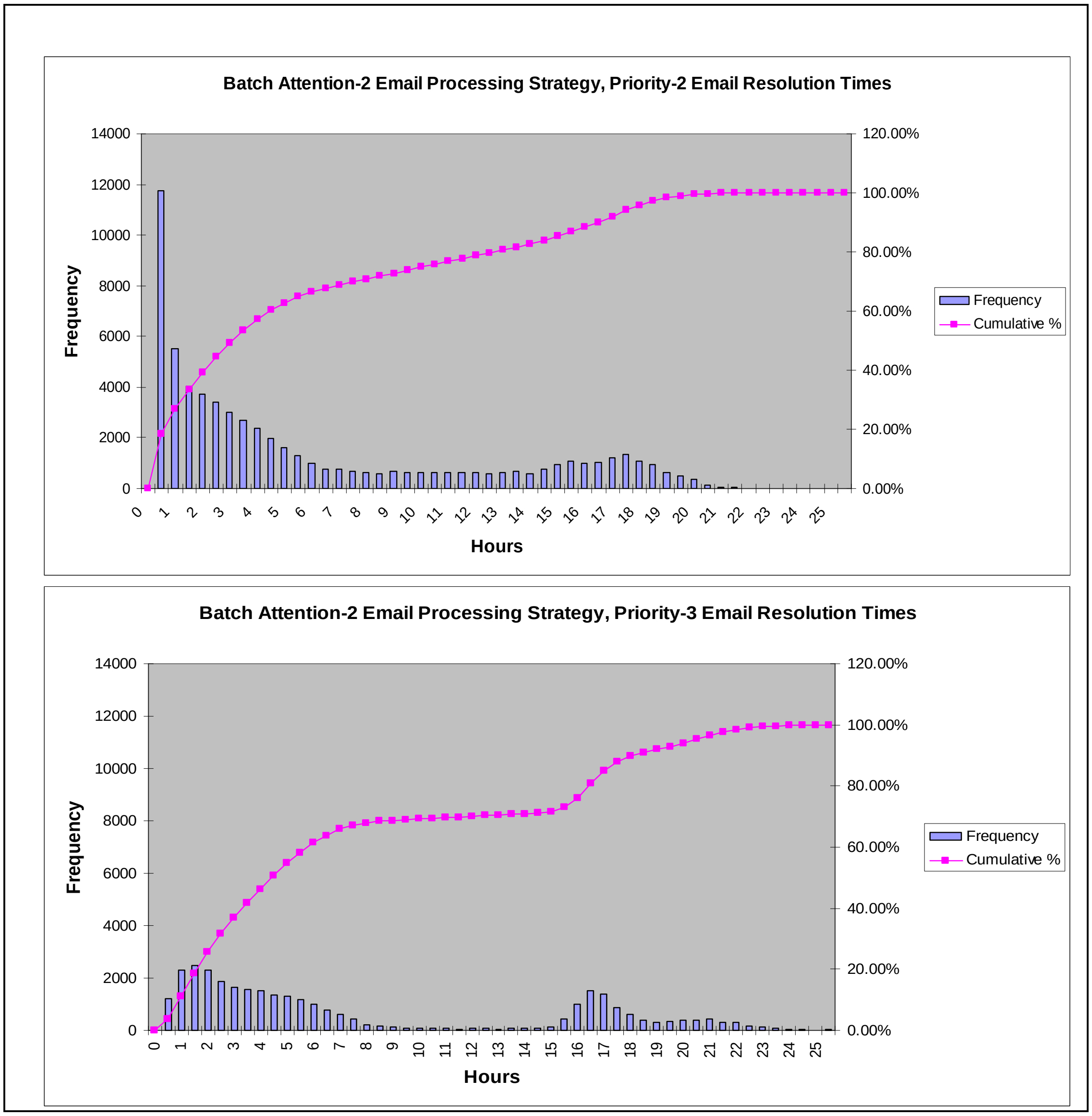


Figure 7.1. The Batch Attention-2 Email Processing Strategy: Priority 2 and Priority 3 Email Resolution Times

7.2 Analysis of Hypothesis 2

Hypothesis 2(a) was supported. The expected gains in efficiency were found to be statistically significant ($\alpha = 0.001$).

> *Hypothesis 2(a): Dividing non-priority email work into two specific time frames will result in significantly greater efficiency when compared to processing email continuously.*

The efficiency that resulted from the Scheduled Attention-2 processing strategy was 97.35%, indicating that less than 3% of the knowledge worker's work day was wasted on interruption and resumption lags. The Continuous email processing strategy resulted in efficiency of 94.34%, a mean difference of roughly 3%. What can a knowledge worker do with 3% of their time back? 3% of a 9 hour day corresponds to roughly 16 minutes per day. 16 minutes per day corresponds to an hour and 20 minutes per week, or around 69 hours per year. Consider the knowledge workers used in this case study who are billed out at $300 to $400 per hour. Considering an organization with dozens or hundreds of knowledge workers, the cost of email interruptions adds up! But it need not. Choosing the Scheduled Attention-2 processing strategy achieved efficiency without adversely affecting the successful resolution of email messages.

Similarly, support for hypothesis 2(b) was found.

> *Hypothesis 2(b): Processing email in batches corresponding to ½ of an average daily email processing load will result in significantly greater efficiency when compared to processing email continuously.*

The Batch Attention-2 email processing strategy resulted in a statistically significant (α = 0.001) gain in efficiency when compared to the Continuous email processing strategy. The Batch Attention-2 email processing strategy resulted in an efficiency of 97.90%, compared to the 94.34% efficiency corresponding to the Continuous email processing strategy. Again, as was discussed regarding hypothesis 1(b), the gain in efficiency did not adversely affect the successful resolution of the vast majority of email messages.

7.3 Analysis of Hypothesis 3

Hypothesis 3(a) was not supported. The Scheduled Attention-2 email processing strategy resulted in an average daily total hours worked of 10.5524, while the Continuous email processing strategy resulted in an average daily total hours worked of 10.0095. The difference was statistically significant ($\alpha = 0.001$), however the direction of the difference was not as expected. The explanation is of interest, however.

> ***Hypothesis 3(a):*** *Holding email hours twice daily will result in significantly fewer total hours worked daily when compared to processing email continuously.*

In light of efficiency, considerably more work is being accomplished with the Scheduled Attention-2 email processing strategy. The Scheduled Attention-2 email processing strategy results in an average of 10.2728 productive hours daily (10.5524 * 97.35%). The Continuous email processing strategy results in an average of 9.4430 productive hours daily (10.0095 * 94.34%). Consider a project requiring 160 hours of work. Using the Continuous email processing strategy, the project could be completed in approximately 17 work days. If the knowledge worker instead employed the Scheduled Attention-2 processing strategy, the project could be completed within roughly 15.5 work days. With the Scheduled Attention-2 processing strategy, email has a tendency to hold the knowledge worker at work for longer hours. With Continuous processing, you are more or less always caught up. With the Scheduled Attention-2 email processing strategy, the "email hours" are scheduled in the morning and at the end of the day. The knowledge worker will often stay late catching up on the day's email processing needs. Scheduled Attention-2 might be especially effective for the knowledge worker who is facing a deadline or who is more concerned with getting things done than going home at a particular time. Alternatively, Scheduled Attention-2 could be tweaked to process email a bit earlier in the day in hopes of always being caught up by the end of the day.

Hypothesis 3(b) was supported. A statistically significant difference between the hours worked resulting from the Batch Attention-2 email processing strategy and the hours worked resulting from the Continuous email processing strategy was found (α = 0.001).

> ***Hypothesis 3(b):*** *Processing email in batches corresponding to ½ of an average daily email processing load will result in significantly fewer total hours worked daily when compared to processing email continuously.*

Unlike the Scheduled Attention-2 email processing strategy, the Batch Attention-2 strategy did not result in the end-of-day "catch up periods" for the knowledge worker. When compared to the Continuous email processing strategy, the efficiency gained by the knowledge worker results in finishing earlier each day, rather than accomplishing more work each day. The average total hours worked daily resulting from the Batch Attention-2 email processing strategy was 9.8130, while the average total hours worked daily using the Continuous email processing strategy was 10.0095. The drawback to Batch processing is the inability to always predict when the batches will occur.

7.4 Analysis of Proposition 4

As indicted in Table 7.2 below, the mean resolution times for priority-2 email messages do not support proposition 4(a). The difference between 3.5226 hours (Scheduled Attention-2 – with pattern) and 3.6419 hours (Scheduled Attention-2 – no pattern) is not statistically significant.

> ***Proposition 4(a)****: Email hours scheduled during peaks in arrival patterns will have significantly shorter resolution times when compared to email hours not scheduled during peaks in arrival patterns.*

Table 7.2. Scheduled Attention-2 (Pattern and No Pattern), Email Resolution Times for Both Priority-2 and Priority-3 Email Messages

	Scheduled Attention 2 Pattern		Scheduled Attention 2 No Pattern	
Priority 2 Email	**Mean**	3.5226	**Mean**	3.6419
	Median	2.2690	**Median**	3.1322
	Min	.0012	**Min**	.0007
	Max	22.3474	**Max**	22.5887
Priority 3 Email	**Mean**	2.3879	**Mean**	4.0288
	Median	1.6391	**Median**	3.2893
	Min	.0010	**Min**	.0086
	Max	23.2022	**Max**	23.8542

However, the mean resolution times for priority-3 email do support this hypothesis (2.3879 hours is a statistically significant shorter resolution time than 4.028 hours (α = 0.001)). The schedule for processing email according to arrival patterns is based on the *total* arrivals of email of both priority-2 and priority-3. Priority-3 email messages more closely matches the scheduled email hours, causing the mean resolution time to be shorter with priority-3 emails than the priority-2 email messages. An analysis of frequency distributions, Figure 7.2, indicates that with respect to priority-3 email, scheduling email hours during peaks in arrival patterns prevents a bimodal distribution of resolution times. If the knowledge worker were to adopt two specific "email hours" during his or her day, selecting email hours that coincide with email arrivals can improve the resolution time of a good many of the priority-3 email that are processed. Priority 3 emails are those email that do not require a particularly prompt response (within one week), so the result may be seen as less important. However, all things being equal, faster resolutions are desirable.

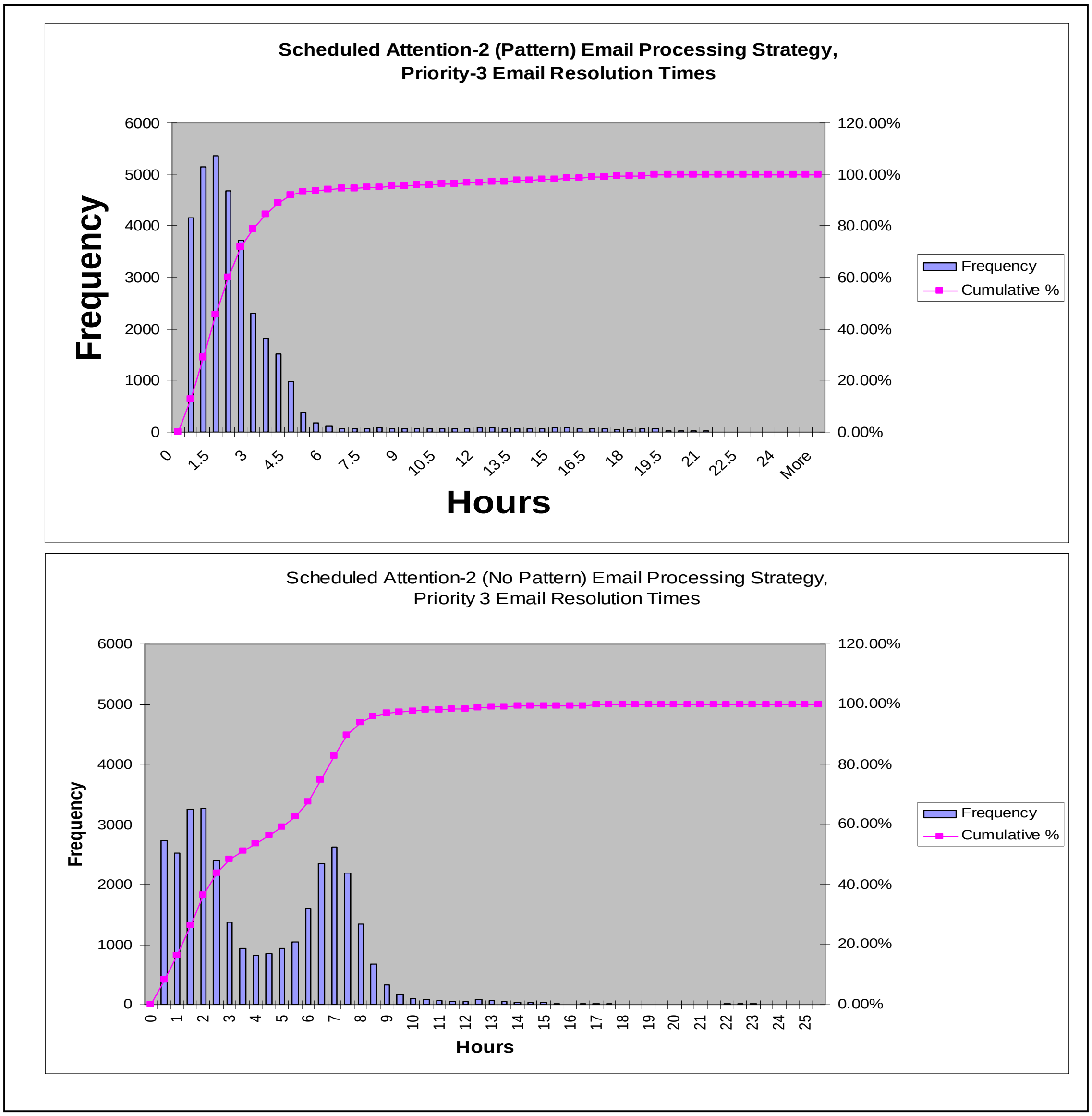


Figure 7.2. Scheduled Attention-2 (Pattern and No Pattern), Email Resolution Times for Priority-3 Email Messages

Proposition 4(a) also considers the mean resolution times of priority-2 and priority-3 email messages resulting from the Scheduled Attention-4 (no pattern) and the Scheduled Attention-4 (with pattern) email processing strategies described in Table 7.3 below.

Table 7.3. Scheduled Attention-4 (Pattern and No Pattern), Email Resolution Times for Priority-2 and Priority-3 Email Messages

	Scheduled Attention-4 Pattern		Scheduled Attention-4 No Pattern	
Priority 2 Email	**Mean**	2.7862	**Mean**	2.5445
	Median	0.9759	**Median**	1.4184
	Min	0.0009	**Min**	0.0010
	Max	21.1193	**Max**	17.7263
Priority 3 Email	**Mean**	1.9202	**Mean**	1.9236
	Median	1.3045	**Median**	1.3236
	Min	0.0014	**Min**	0.0023
	Max	21.1648	**Max**	17.9526

The mean resolution times for priority-2 email do not support this proposition (2.7862 and 2.5445 hours are not different statistically). The mean resolution times for priority-3 email do notsupport the proposition either (1.9202 hours is not statistically different from 1.9236 hours). An analysis of frequency distributions, Figures 7.3 and 7.4 below, reveals little difference in the two alternative email processing strategies. The email processing strategies are only slightly different in terms of their schedules (see Appendix E). In an effort to match the email processing schedule with the email arrival schedule, Scheduled Attention-4P begins its first email processing at 10:00 a.m. each day, contrasting with the Scheduled Attention-4 processing strategy which starts processing at 8:00 a.m. This explains the slightly longer mean processing times corresponding to priority-2 email messages: those email having arrived the night before all must wait an additional 2 hours.

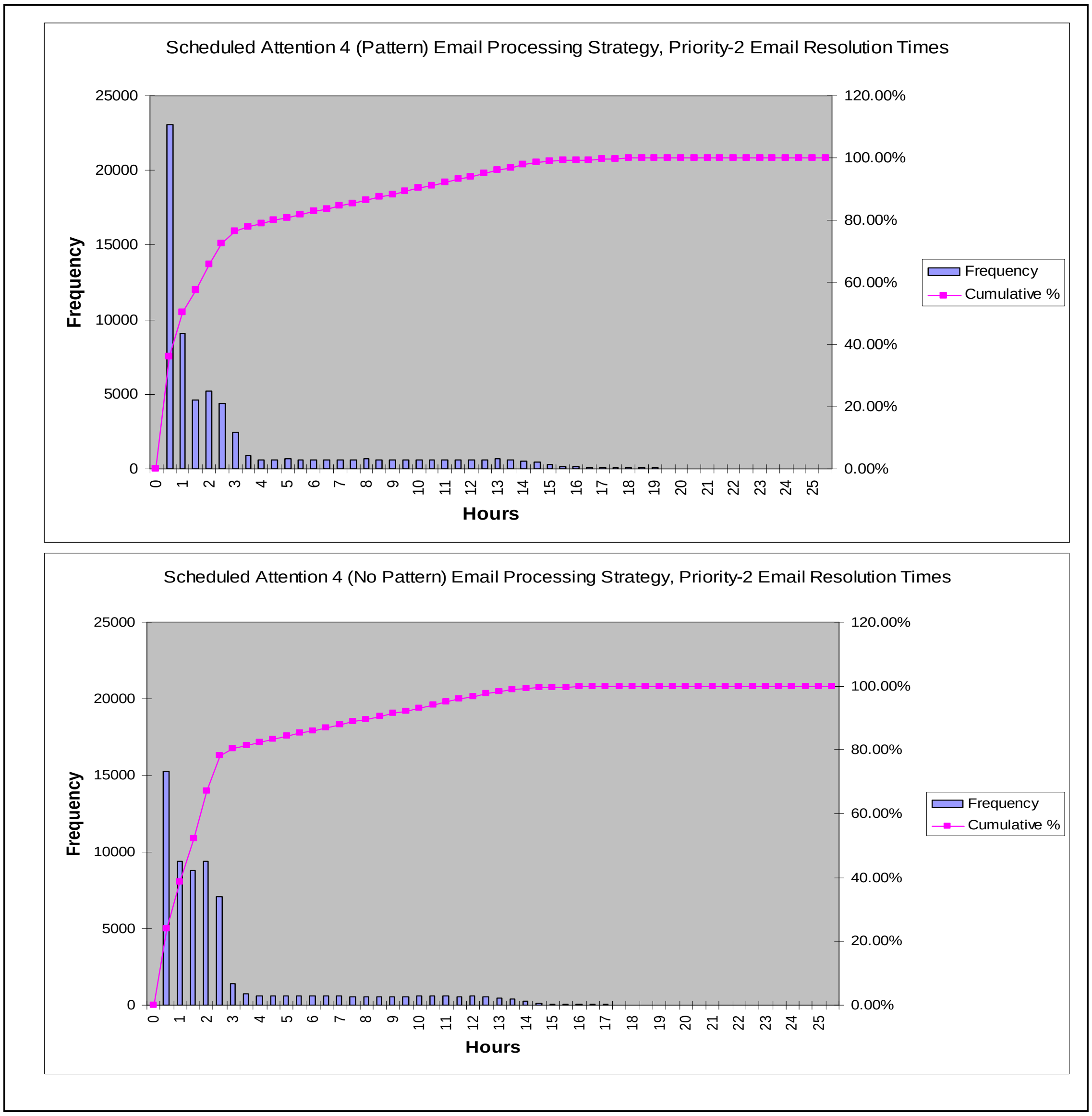


Figure 7.3. Scheduled Attention-4 (Pattern and No Pattern), Email Resolution Times for Priority-2

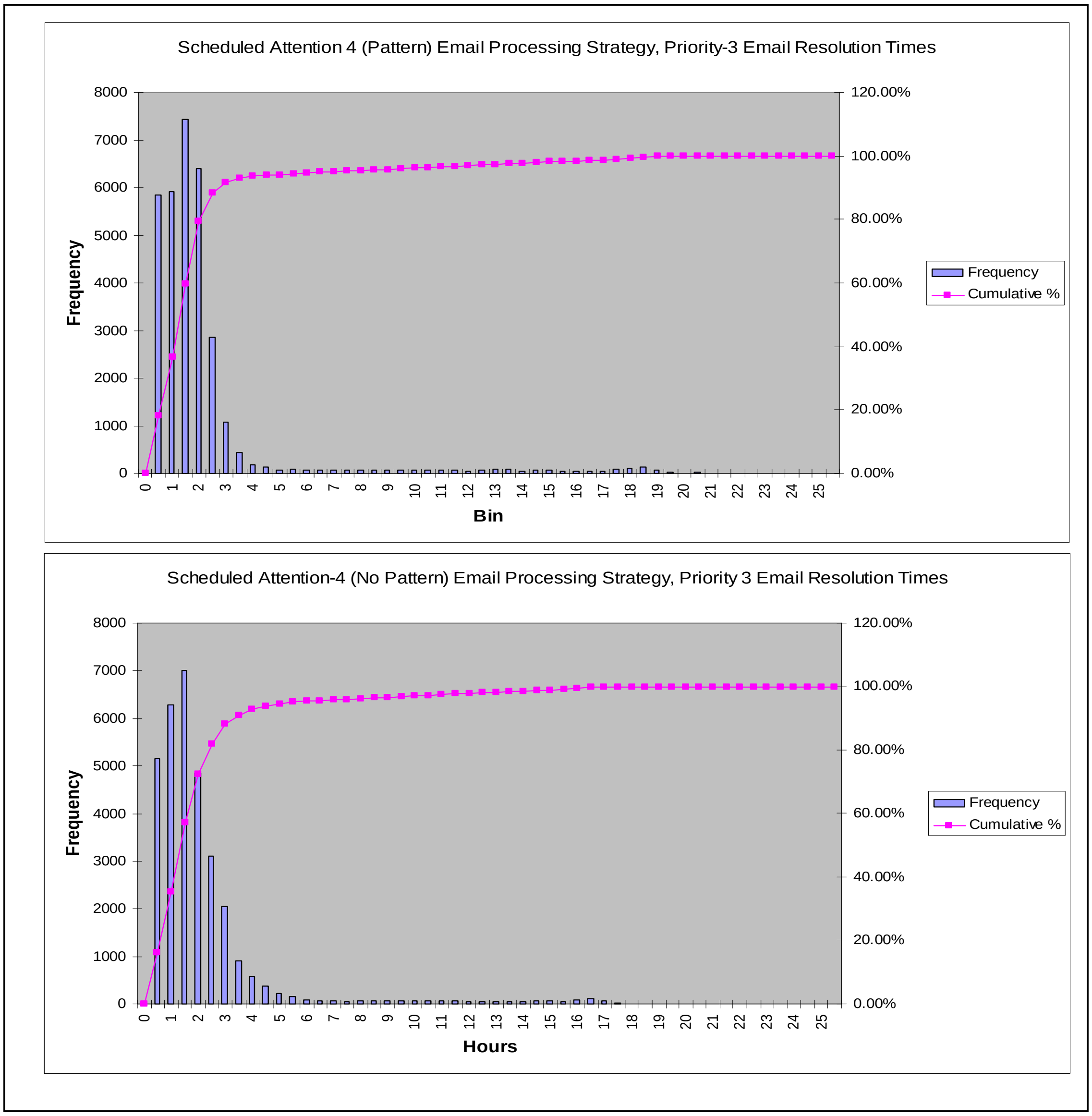


Figure 7.4. Scheduled Attention-4 (Pattern and No Pattern), Email Resolution Times for Priority-3

As indicated in Table 7.4 and described below, proposition 4(b) was not supported.

> ***Proposition 4(b)***: *Email processed in batches will have significantly shorter resolution times when compared to email hours not scheduled during peaks in arrival patterns.*

Table 7.4. Batch Attention-2 and Scheduled Attention-2 (No Pattern) Email Resolution Times for Priority-2 and Priority-3 Email Messages

	Batch Attention-2		Scheduled Attention-2 No Pattern
Priority 2 Email	Mean	5.7816	3.6419
	Median	3.0742	3.1322
	Min	0.0013	.0007
	Max	33.2636	22.5887
Priority 3 Email	Mean	7.5934	4.0288
	Median	4.4340	3.2893
	Min	0.0032	.0086
	Max	40.4466	23.8542
	Batch Attention-4		Scheduled Attention-4 No Pattern
Priority 2 Email	Mean	3.4176	2.5445
	Median	1.4602	1.4184
	Min	0.0017	0.0010
	Max	20.0852	17.7263
Priority 3 Email	Mean	4.0307	1.9236
	Median	1.7851	1.3236
	Min	0.0056	0.0023
	Max	21.5475	17.9526
	Batch Attention-6		Scheduled Attention-6 No Pattern
Priority 2 Email	Mean	2.6515	2.1683
	Median	0.8696	0.6542
	Min	0.0011	1.0012
	Max	19.1460	15.9153
Priority 3 Email	Mean	2.7134	1.7231
	Median	1.1199	1.1243
	Min	0.0032	0.0012
	Max	18.7722	18.0148

When comparing Batch Attention-2 to Scheduled Attention-2 (no pattern), the mean resolution time for priority-2 email reveals the opposite of what hypothesis 4(b) suggests

(α= 0.001). Occasionally, emails can get "stuck" waiting for a batch to accumulate. This does not happen with predefined or "scheduled" email hours. Priority-3 email results are similar. Batching may not be a good idea: an email can get stuck waiting for a batch of email messages to accumulate, resulting in less than optimal yet satisfactory resolution times.

Proposition 4(b) also considers the mean resolution times of priority-2 and priority-3 email messages resulting from the Scheduled Attention-4 (no pattern) and the Batch Attention-4 email processing strategies. Results for proposition 4(b) with respect to four sets of email hours are consistent with those results with respect to two sets of email hours. As indicated in Table 7.4 above, the Batch Attention-4 email processing strategy actually resulted in longer resolution times for both priority-2 and priority-3 email messages (3.4176 hours versus 2.5445 hours for priority-2 and 4.0307 hours versus 1.9236 hours for priority-3). The differences for each priority of email was statistically significant (α=0.001). With respect to priority-3 email, graphical analysis, Figure 7.5 below, indicates that scheduled email can prevent a bimodal distribution resulting from email "waiting for a batch." This may have little relevance, however, because both strategies perform relatively well with respect to the needed resolution times of priority-3 email messages.

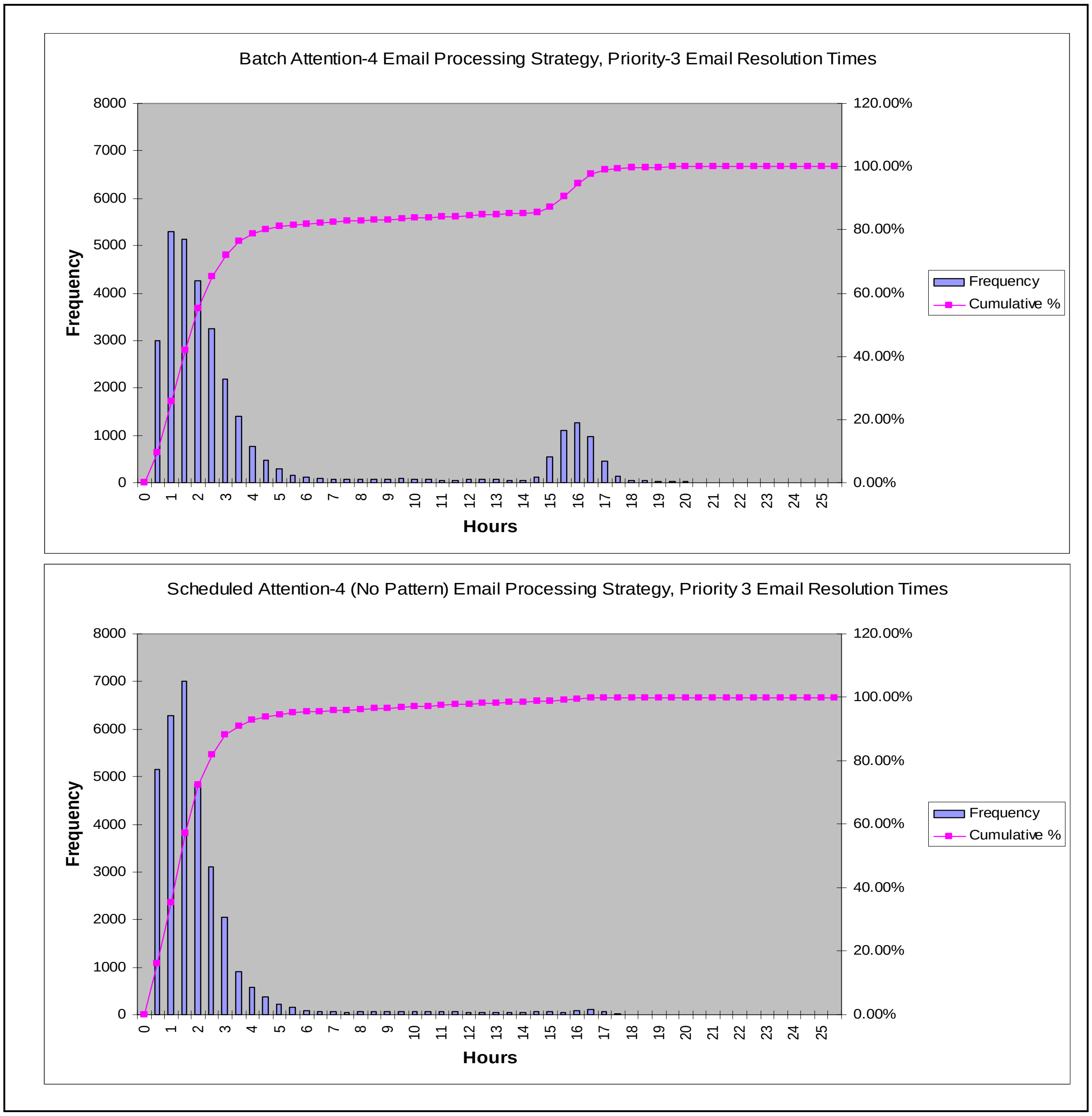


Figure 7.5. Batch Attention-4 and Scheduled Attention-4 (No Pattern) Email Resolution Times for Priority-3 Email Messages

Similarly, Table 7.4 reveals that Scheduled Attention-6 outperforms Batch Attention-6 with respect to email resolution times for both priority-2 and priority-3 email messages. Although the difference is statistically significant (α=0.001), the difference may not be practically significant, as both priority-2 and priority-3 email are processed well within their appropriate time frames (1 day and 1 week, respectively).

Proposition 4(c) was also not supported.

> ***Proposition 4(c):*** *Email processed in batches will not have significantly different resolution times when compared to email hours scheduled during peaks in arrival patterns.*

As indicated in Table 7.5 below, the Batch Attention-2 email processing strategy required more time to resolve email messages of both priority-2 and priority-3, than did the Scheduled Attention-2 (with pattern) email processing strategy (statistically significant differences of 5.7816 hours versus 3.5226 hours and 7.5934 hours versus 2.3879 hours for priority-2 and priority-3 emails respectively ($\alpha = 0.001$)). Again, batch processing appears to create bimodal distributions of resolution times, as is illustrated in Figures 7.6 and 7.7 below.

Table 7.5. Batch Attention-2 and Scheduled Attention-4 (with pattern) Email Resolution Times for Priority-2 and Priority-3 Email Messages

	Batch Attention 2		**Scheduled Attention 2 Pattern**	
Priority 2 Email	**Mean**	5.7816	**Mean**	3.5226
	Median	3.0742	**Median**	2.2690
	Min	0.0013	**Min**	.0012
	Max	33.2636	**Max**	22.3474
Priority 3 Email	**Mean**	7.5934	**Mean**	2.3879
	Median	4.4340	**Median**	1.6391
	Min	0.0032	**Min**	.0010
	Max	40.4466	**Max**	23.2022

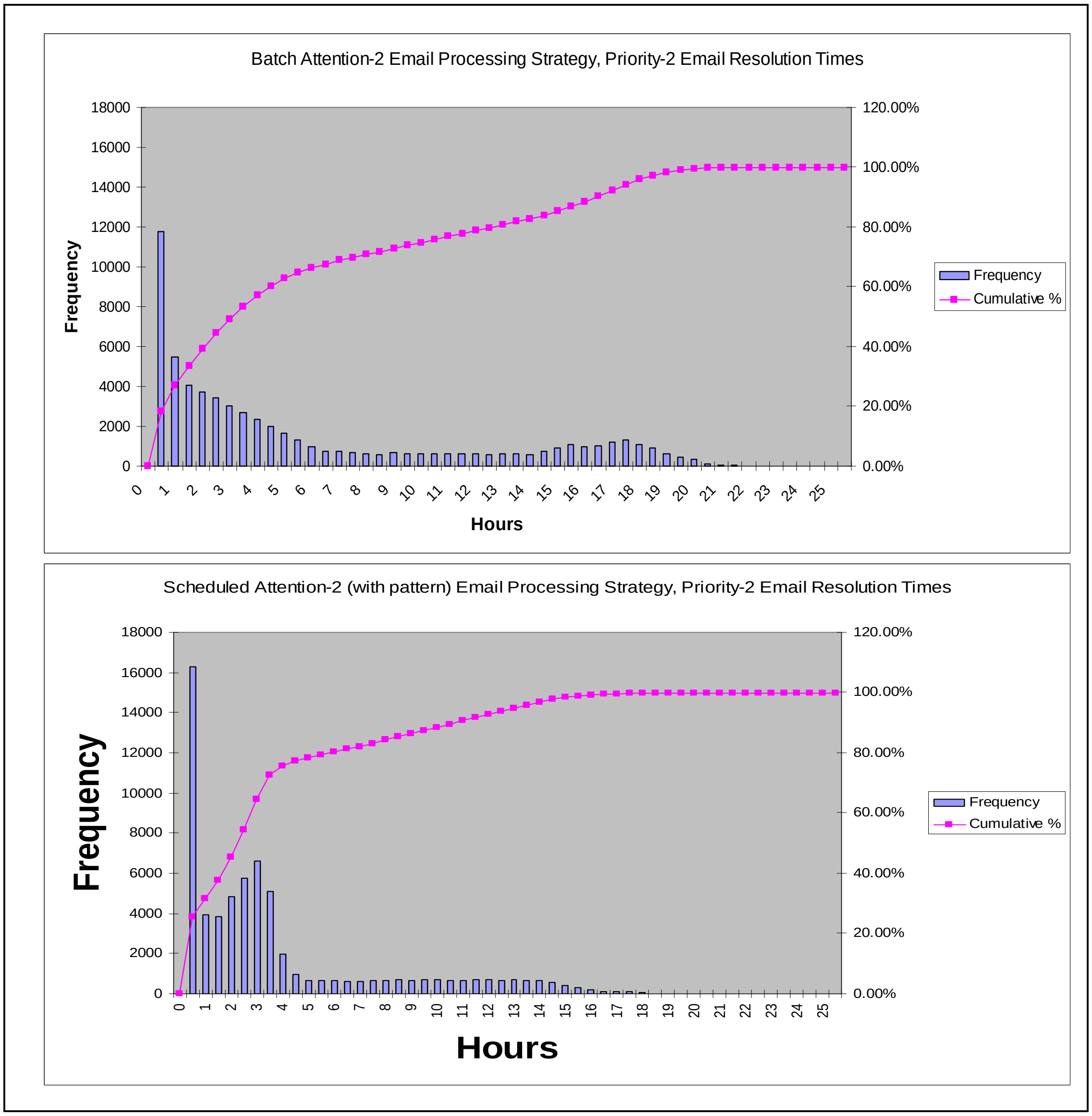


Figure 7.6. Batch Attention-2 and Scheduled Attention-2 (with pattern) Email Resolution Times for Priority-2

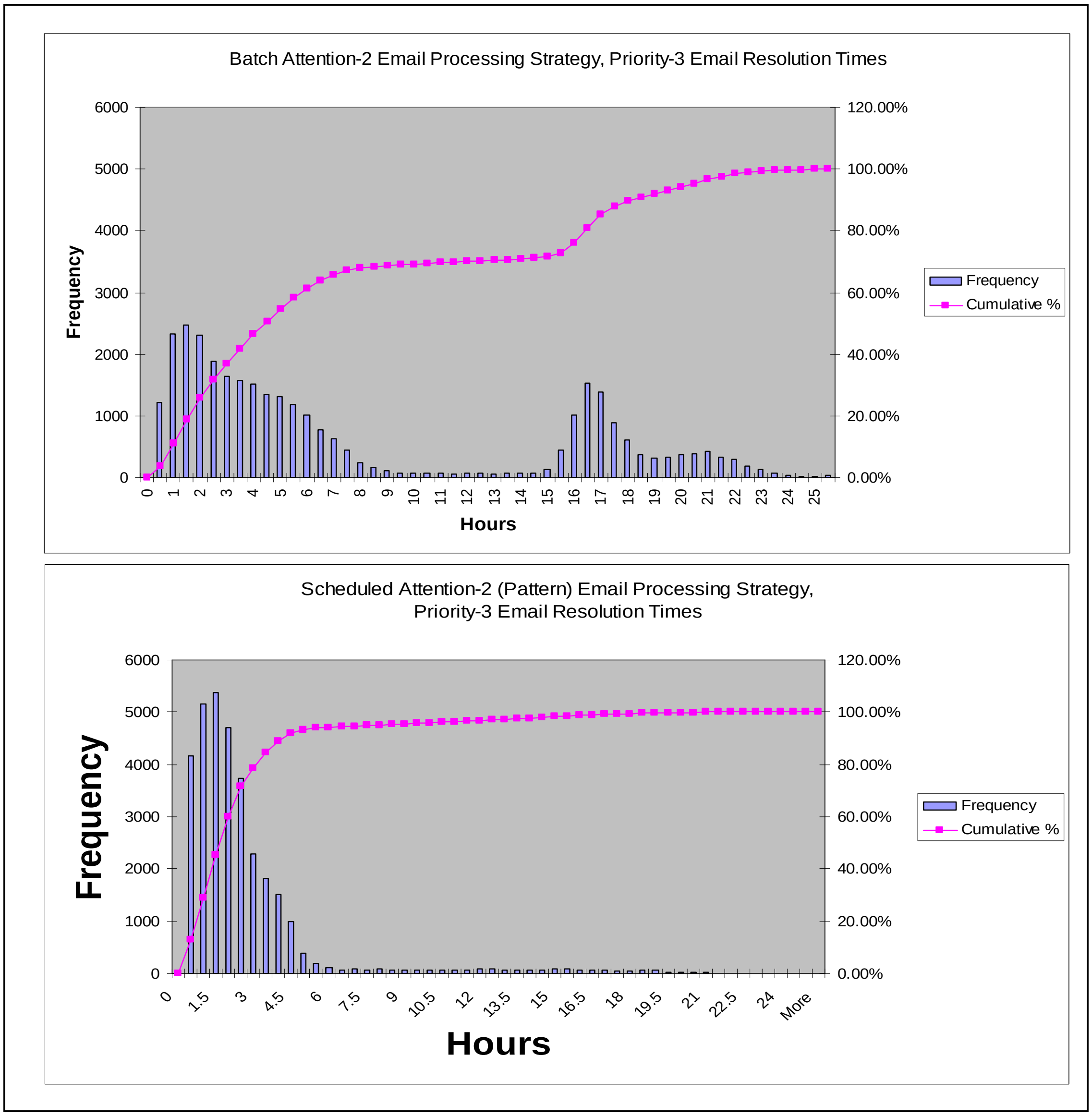


Figure 7.7. Batch Attention-2 and Scheduled Attention-2 (with pattern) Email Resolution Times for Priority-3

Results are similar when comparing Batch Attention-4 and Scheduled Attention-4 (Pattern). Table 7.6 and Figures 7.8 and 7.9 depict similar results.

To summarize, the Scheduled email processing strategies offer slight advantages over Batch email processing strategies. Batching email messages may cause unnecessarily long resolution times, and the knowledge worker loses the advantage of knowing when email processing will need to occur (when a batch will accumulate). Section 7.5 next gives an overview of the performance of all email processing strategies.

Table 7.6. Batch Attention-4 and Scheduled Attention-4 (with pattern) Email Resolution Times for Priority-2 and Priority-3 Email Messages

	Batch Attention 4		Scheduled Attention 4 Pattern	
Priority 2 Email	**Mean**	3.4176	**Mean**	2.7862
	Median	1.4602	**Median**	0.9759
	Min	0.0017	**Min**	0.0009
	Max	20.0852	**Max**	21.1193
Priority 3 Email	**Mean**	4.0307	**Mean**	1.9202
	Median	1.7851	**Median**	1.3045
	Min	0.0056	**Min**	0.0014
	Max	21.5475	**Max**	21.1648

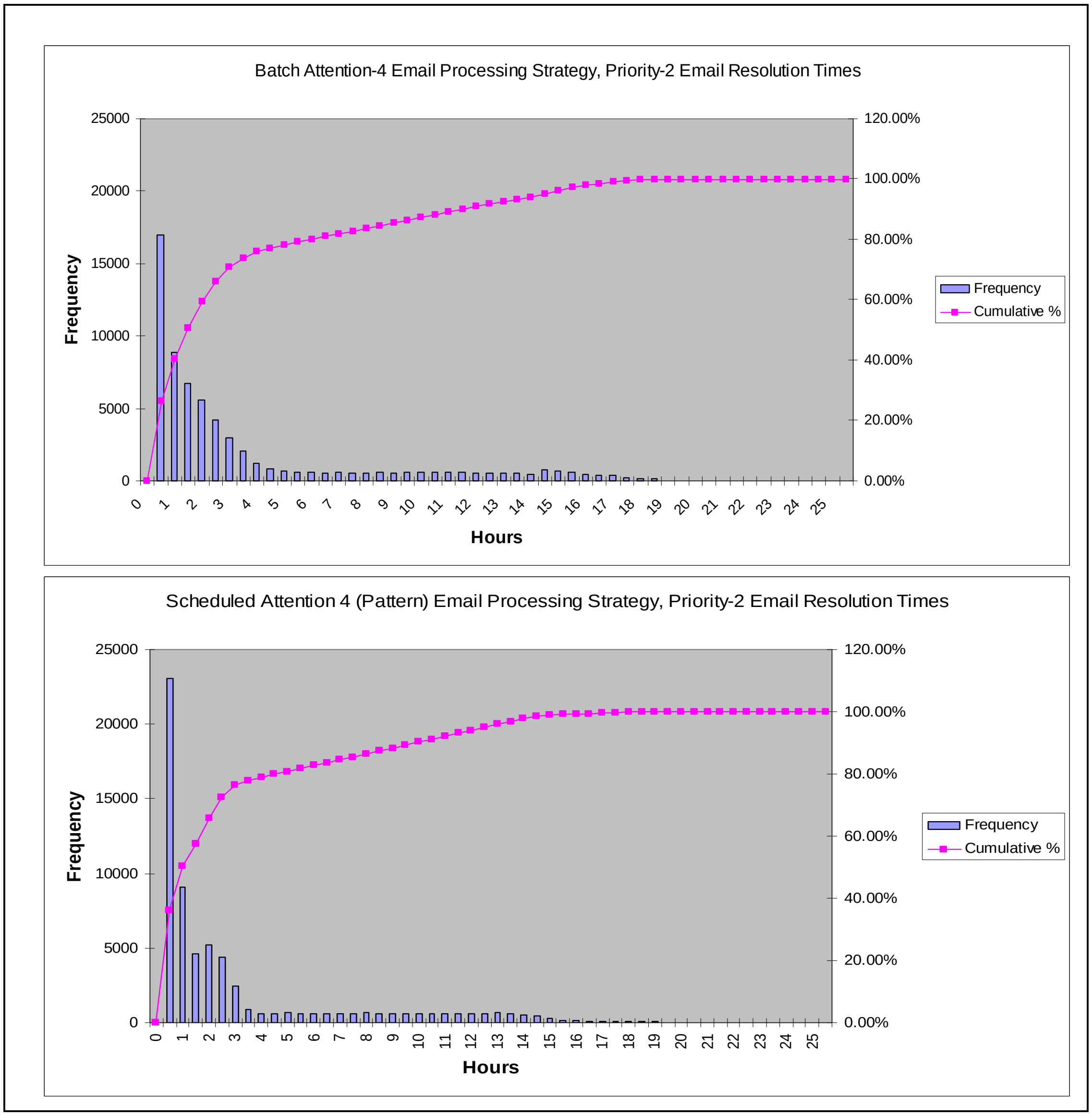


Figure 7.8. Batch Attention-4 and Scheduled Attention-4 (with pattern) Email Resolution Times for Priority-2

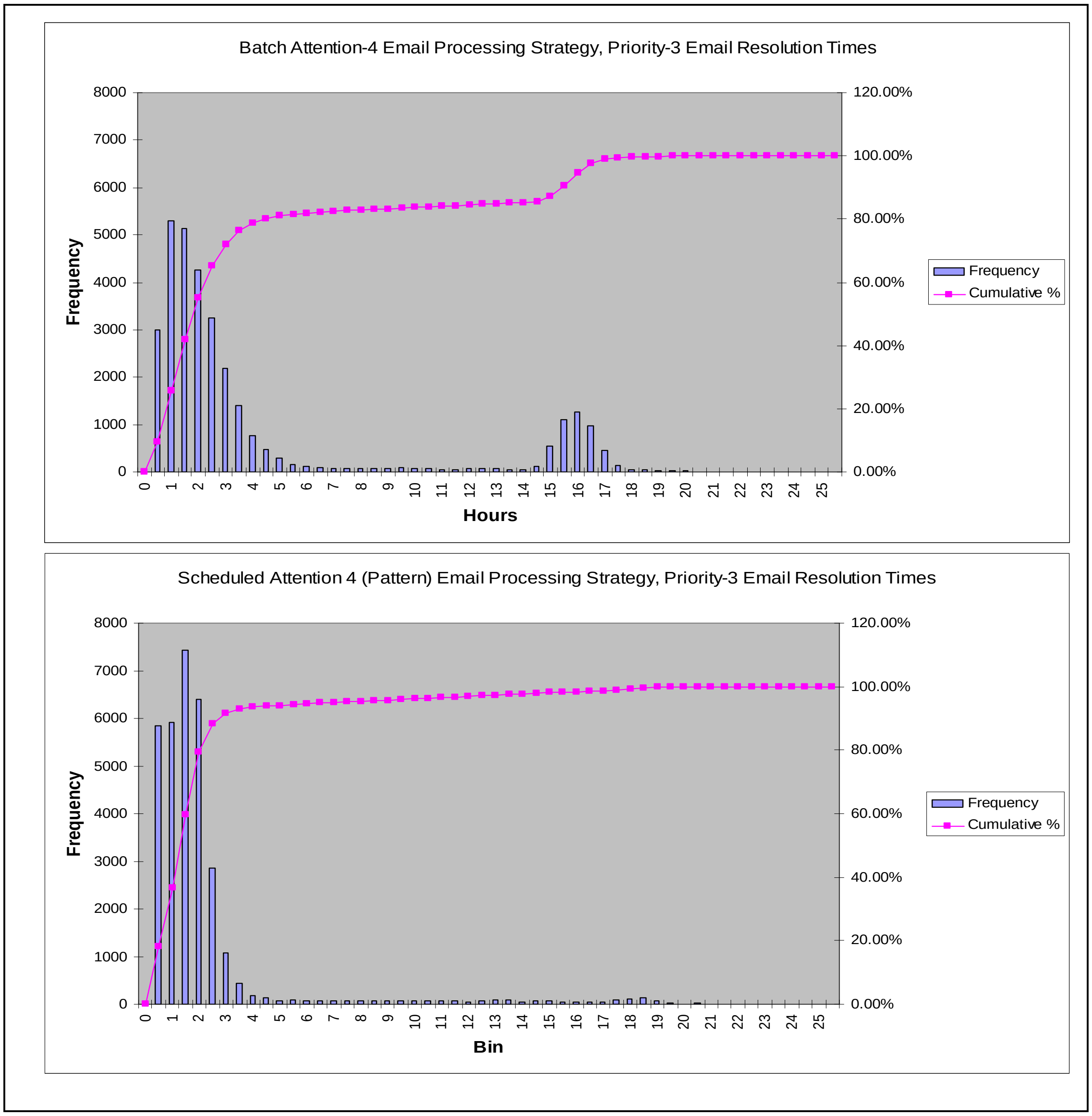


Figure 7.9. Batch Attention-4 and Scheduled Attention-4 (with pattern) Email Resolution Times for Priority-3

7.5 Summary of Results from All Email Processing Strategies

Figure 7.10 below charts the performance of all of the email processing strategies along two performance dimensions, Efficiency and the Resolution Time for Priority-2 email messages. Priority-1 messages are processed outside of the rules governing how all other email messages are processed, and therefore have comparable resolution times across all email processing strategies. Priority-3 messages are those messages that must be processed within one business week. Priority-4 messages are those email messages that are irrelevant or SPAM messages. This leaves priority-2 messages, those messages that must be processed within one business day. Priority-2 messages do not share the same level of urgency as priority-1 messages, however, prompt replies are still desirable. Figure 7.10 below captures how well each email processing strategy manages the tradeoff between efficiency and prompt email resolution. Specific performance values are also included in Tables 7.7 and 7.8. As discussed in chapter 1, the tradeoff between efficiency and prompt email resolution was the focus of this dissertation. The Continuous email processing strategy (C) stands apart from the rest of the email processing strategies. Although the strategy offers the most prompt resolutions, it also causees the least efficiency. For example, although the difference is statistically significant, the difference between priority-2 email resolution times resulting from the Continuous email processing strategy and those resulting from the Scheduled Attention-1A email processing strategy may not be *practically* significant. 4.4757 hours versus 1.7624 hours pertaining to emails that only need resolution within one business day perhaps is insignificant in light of the possible 3% gain in knowledge worker efficiency (97.67% compared to 94.36%).

Next, section 7.6 describes the successful use of Optquest optimization software in choosing optimal email processing strategies.

Figure 7.10. Performance of Email Processing Strategies

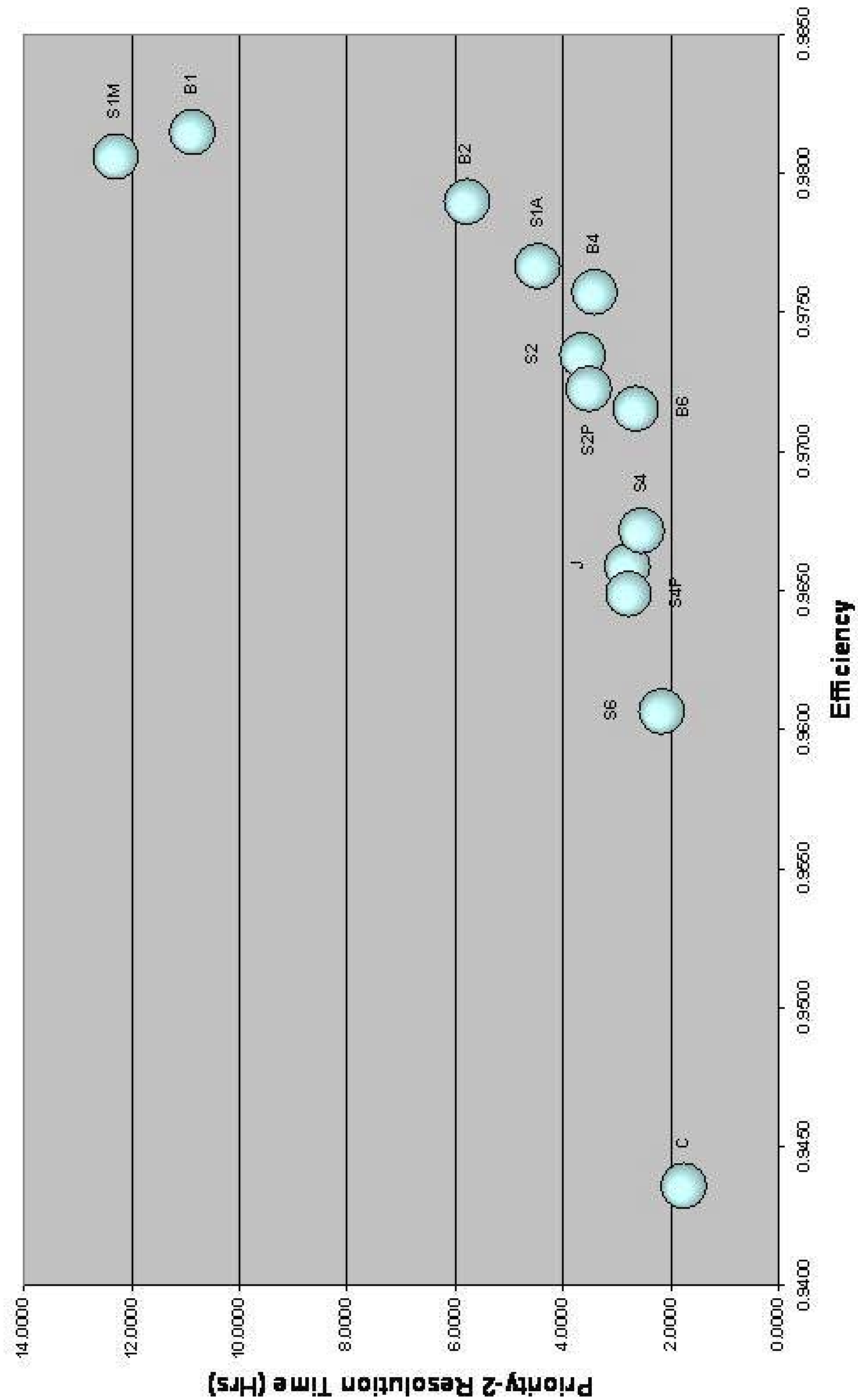


Table 7.7. Rankings of Email Processing Strategies' Efficiencies

	Email Processing Strategy	Efficiency	Statistically Indifferent (α = 0.001)
BEST	Batch Attention-1	0.9815	}
	Scheduled Attention-1M	0.9806	}
	Batch Attention-2	0.9790	
↑	Scheduled Attention-1A	0.9767	}
	Batch Attention-4	0.9757	}
	Scheduled Attention-2	0.9735	
↓	Scheduled Attention-2P	0.9723	}
	Batch Attention-6	0.9715	}
	Scheduled Attention-4	0.9672	
	Jackson Attention	0.9659	
WORST	Scheduled Attention-4P	0.9649	
	Scheduled Attention-6	0.9607	
	Continuous Attention	0.9436	

Table 7.8. Rankings of Email Processing Strategies' Priority-2 Resolution Times

	Email Processing Strategy	Priority 2 Email Resolution Time	Statistically Indifferent (α = 0.001)
BEST	Continuous Attention	1.7624	
	Scheduled Attention 6	2.1689	
	Scheduled Attention 4	2.5446	}
	Batch Attention 6	2.6517	} }
↑	Scheduled Attention 4P	2.7859	}
	Jackson Attention	2.8099	}
	Batch Attention 4	3.4180	}
↓	Scheduled Attention 2P	3.5229	} }
	Scheduled Attention 2	3.6412	}
	Scheduled Attention 1A	4.4757	
	Batch Attention 2	5.7842	
	Batch Attention 1	10.8782	
WORST	Scheduled Attention 1M	12.3028	

7.6 Optimization through Simulation

The need for simulation stems from the complexity of both the nature of the arriving email and the processing strategies employed by the knowledge worker. Simulation is an analytical technique that offers an opportunity to represent and collect information about an environment. It does not offer optimal solutions to users, but rather provides information that is then used in finding optimal solutions. In this study, optimal solutions correspond to email processing strategies that best achieve a knowledge worker's specific goal or goals. Simulation tools have been coupled with optimization tools in order to manage the analysis of multiple simulations. The coupling of optimization tools with simulation tools allows us to specify those variables that we have control over (in this case, email processing strategies), along with an objective (for example: maximize efficiency). The optimization tool will then search for the best processing strategy, given a defined objective. In this study, the variable that is under the control of the optimization tool is the processing strategy. The optimization tool (Optquest) will search among the processing strategies for the strategy that optimizes a defined performance objective. The performance objectives of the study are outlined in Table 7.9, below.

Table 7.9. Performance Objectives

Performance Objective	Description
Maximize Efficiency	This finds the Email Processing Strategy(s) that maximizes efficiency. No consideration for email resolution time is given.
Minimize the Resolution Time of Priority-2 Email Messages	This finds the Email Processing Strategy(s) that minimizes resolution time for those email messges needing to be resolved within a business day. No consideration for efficiency is given.
Minimize Priority-2 Email Resolution time, Efficiency > 97%	This minimizes the resolution time of Priority-2 email, while setting limitations on efficiency.
Maximize Efficiency, Email Resolution Time < 3 Hours	This maximizes efficiency, while specifying limitations regarding the timely resolution of email messages.

In addition to defining an objective, simulation/optimization tools allow for inclusion of constraints. This ability will allow for forcing balance between two objectives. As the last two performance objectives outline, resolution times can be minimized while controlling efficiency, and efficiency can be maximized while controlling resolution times. A screenshot of Optquest is seen in Figure 7.11 below.

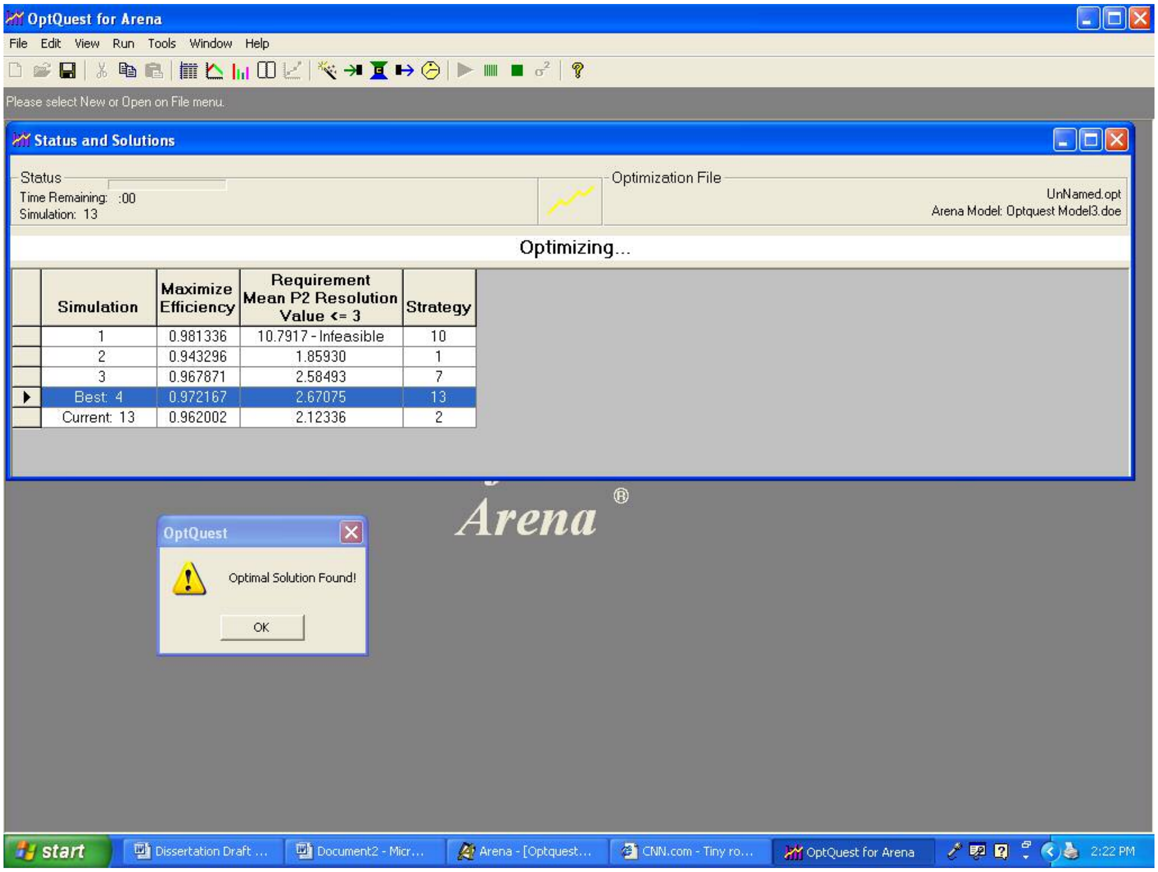


Figure 7.11. Screenshot of Optquest Maximizing Efficiency while Controlling for Priority-2 Email Resolution Time

Optquest manipulates the "Strategy" variable; values from 1 to 13 correspond to the 13 email processing strategies. The value of the variable controls the email processing stategy implemented by the model. Optquest is searching for the optimal value of the Strategy variable, which corresponds to a particular email processing strategy. An example of specific performance goals and results provided by Optquest for this study's knowledge worker is seen in Table 7.10 below.

Table 7.10. Optquest Results for Objectives and Constraints

Performance Objective & Constraint	**Strategy**	**Performance Measure**
Maximize Efficiency	Batch Attention-1	98.13%
Minimize the Resolution Time of Priority-2 Email Messages	Continuous Attention	1.8593 Hrs
Minimize Priority-2 Email Resolution time, Efficiency > 97%	Batch Attention-6	97.22% & 2.6708 Hrs
Maximize Efficiency, Mean Email Resolution Time < 3 hours	Batch Attention-6	97.22% & 2.6708 Hrs

The results were validated against the results indicated in Figure7.10 and Tables 7.7 and 7.8. The results are consistent with those obtained through the earlier analysis. Used as a Decision Support System, a knowledge worker could specify his or her individual knowledge work environment and define his or her own performance objectives. Optquest coupled with Arena could then find the email processing strategy that best manages his or her individual goal(s).

7.7 Limitations of the Study

This study considered the effects of email processing strategies on one particular type of email processing environment. The email environment studied, although considered to be typical of knowledge workers, does not represent the broad range of possible email environments faced by a broad range of knowledge workers. Further studies will need to expand on this one, and include similar analyses with other types of email environments. Also, an actual long term implementation of the specific email processing strategies that were simulated in this study would be the only way to truly know the exact effects of the email processing strategies. Despite these limitations, the simulation and analysis of the knowledge work environment has allowed us to gain valuable insights into the effects of email processing strategies on both email outcomes and performance with respect to the knowledge worker's primary work. Chapter 8 follows with a summary and conclusions.

8. SUMMARY AND CONCLUSIONS

8.1 Summary

This study began with the recognition that email represents a significant proportion of the time spent by knowledge workers, and that email overload is a very real problem. The problem of email overload represents enormous opportunity for improvements. Because of the volume of email received by most if not all knowledge workers, even small gains in the efficient management of email can have big impacts on organizations. High level knowledge workers who were dependent on email for their work lives were interviewed, and interesting insights into how and why email is processed were gained. The reasons for processing email in a particular manner often had little to do with the most efficient ways of processing email messages, but rather were dictated by political reasons. Email response times were associated with the knowledge worker's level of commitment, work ethic, and dependability. Instead of attempting to use email applications to prompt users only for emails of an urgent nature, knowledge workers instead adopted habits of continuously monitoring all incoming email. Yet email is by its nature an asynchronous communication tool. The asynchronous nature of email is what should make it powerful – the ability to *plan* the time spent on electronic communication, rather than *react* to communication needs. All email should not be treated equally. All email triggers a reaction (and therefore an interruption) when knowledge workers continuously monitor their email. This study proposed that a) knowledge workers should separate urgent from non-urgent email messages, and b) the non-urgent email should be treated differently – primarily it should not be allowed to interrupt the knowledge worker's primary activities. The study next explored what type of impact various alternatives to the continuous email processing strategy might have on the knowledge worker's performance. Simulation was used as a means of creating the environment faced by a knowledge worker. The email processing strategies were then manipulated and the performance measures were collected and compared across various email processing strategies. Depending on the email processing strategy employed, gains in efficiency of up to 3% were seen. These gains imply hours of time that could be saved by individual knowledge workers after only weeks of time. Furthermore, these gains were not made at the expense of the appropriate resolution of email. Considered in light of the number of knowledge workers using email, these results are of practical significance. The information gained from the case study together with these results from the simulations point out the need for removing the political reasons for continuous monitoring of email messages. If, for example, the subject line of each email message sent within an organization began with a key work indicating the email's expected resolution time, then the ambiguity of the email's urgency is removed. The *sender* has expressed explicitly his or her response time expectations, and therefore the need to respond quickly only to "keep up appearances" is removed. The simple key word at the beginning of the subject line would also allow the knowledge worker to only be prompted for email denoted as "urgent." The study's primary contribution to knowledge is the demonstration and analysis through simulation of the benefits to be gained from alternative email processing strategies, specifically gains in efficiency without loss of effectiveness (appropriate email resolution times).

8.2 Future Research

Future research will involve expanding both aspects of the simulation model. The simulation model can easily accommodate additional alternative email processing strategies. These additional strategies can be studied in the same manner as has been described. Second, the simulation model can easily accommodate different email environments, and the effects of the environments have on the success or failure of particular email processing strategies needs to be explored.

Also, Arena coupled with Optquest allows for automation of the process of determining the ideal email processing strategy for a given knowledge worker's individual email processing goal or goals and individual email processing environment. Arena coupled with Optquest could be used for an email processing strategy decision support system. An Email Strategy DSS (ESDSS) is seen as a future outcome of this study. Knowledge workers will provide two inputs to the DSS. First, the knowledge worker's email environment is captured within a table like the one described in Figure 4.2. These inputs will be of interest for research purposes in and of themselves. Second, the user will specify a particular email processing goal or goals, such as those outlined in Table 7.9. Optquest will then find the most appropriate email processing strategy, and provide specific performance measures to the knowledge worker.

In summary, the aim of future research is to continue what we have begun, tackling an increasingly prevalent problem for knowledge workers – email overload. Through modeling, we will continue to propose and analyze new strategies, and gain insights that will lead to better solutions.

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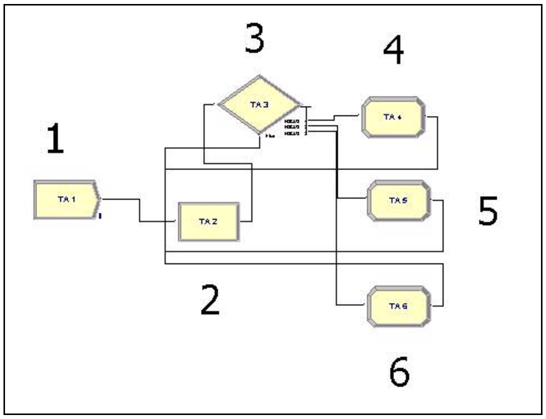
APPENDIX A
TIME ALLOCATION SUBMODEL
MODULE PARAMETERS MODULES TA 1 THROUGH TA 6



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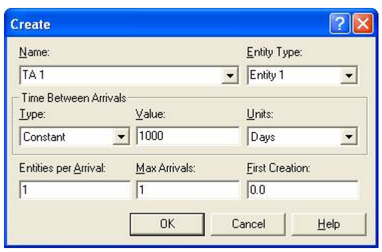

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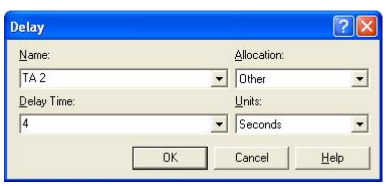

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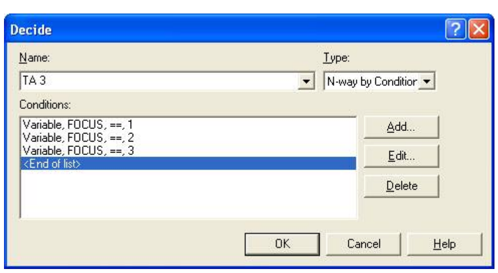

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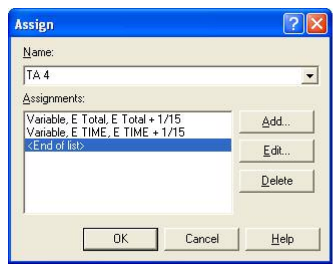

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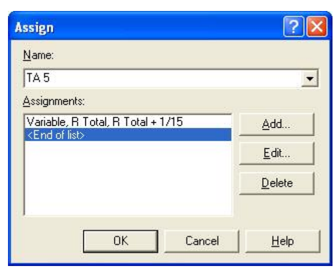

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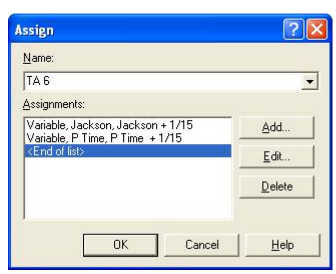
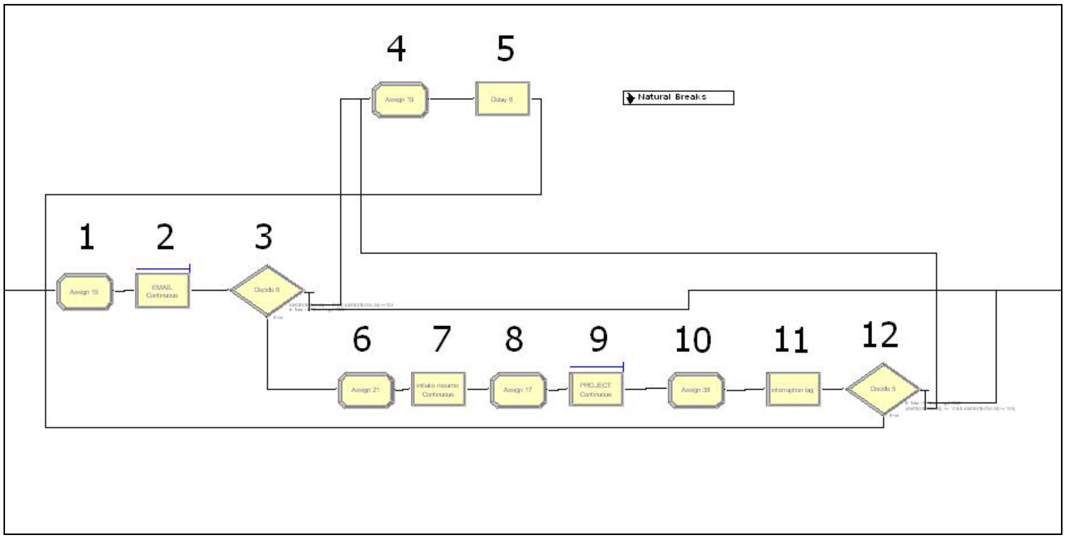


APPENDIX B
THE CONTINUOUS ATTENTION SUBMODEL
MODULE PARAMETERS FOR MODULES 1 THROUGH 12



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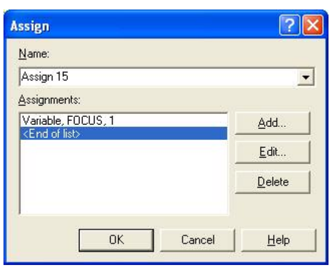

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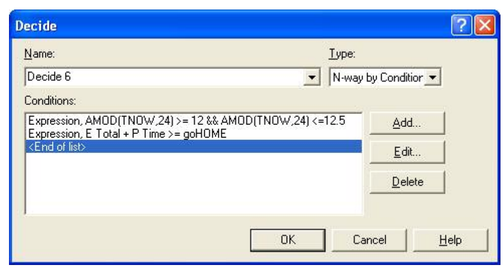

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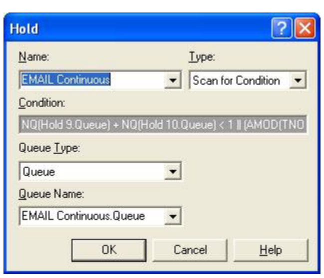

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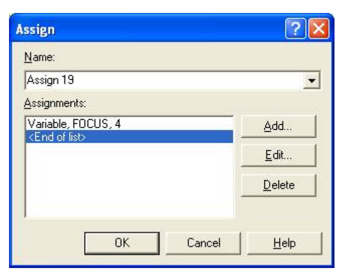

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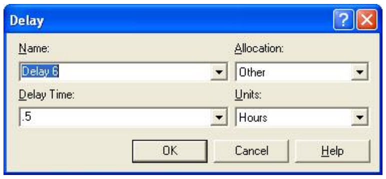

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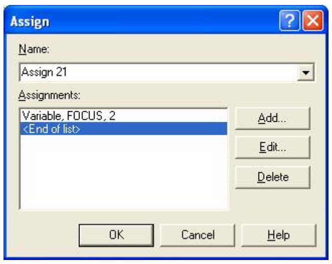

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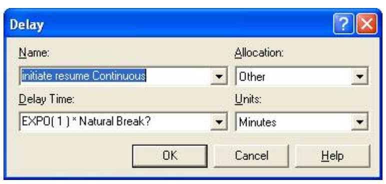

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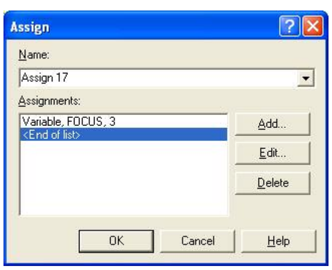

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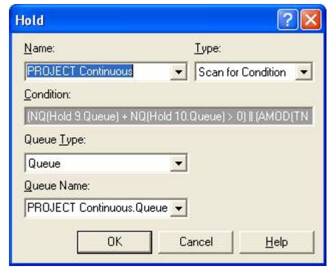

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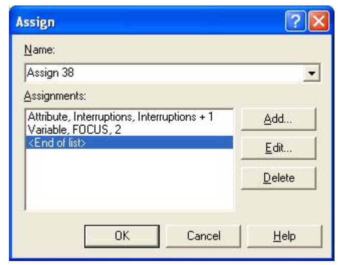

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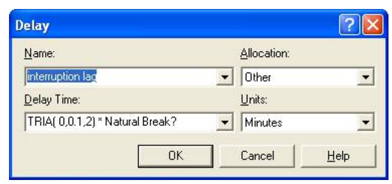

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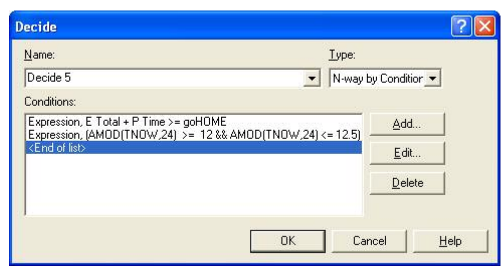
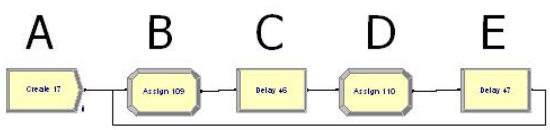


APPENDIX C
THE NATURAL BREAKS SUBMODEL
MODULE PARAMETERS FOR MODULES A THROUGH E



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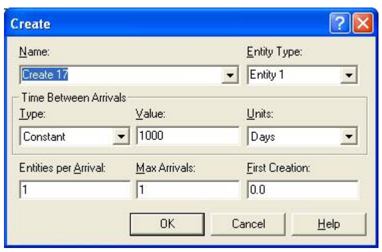

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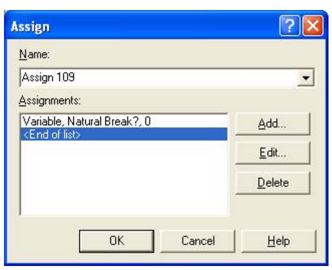

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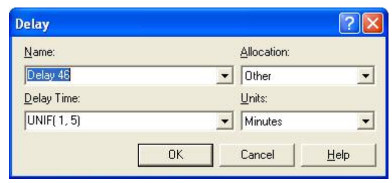

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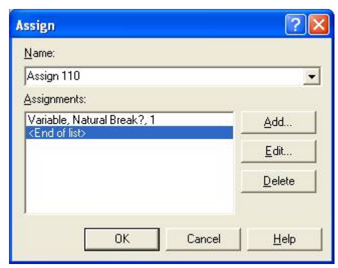

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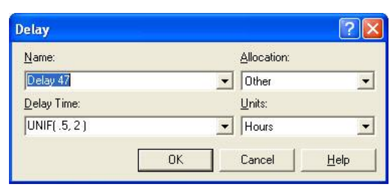
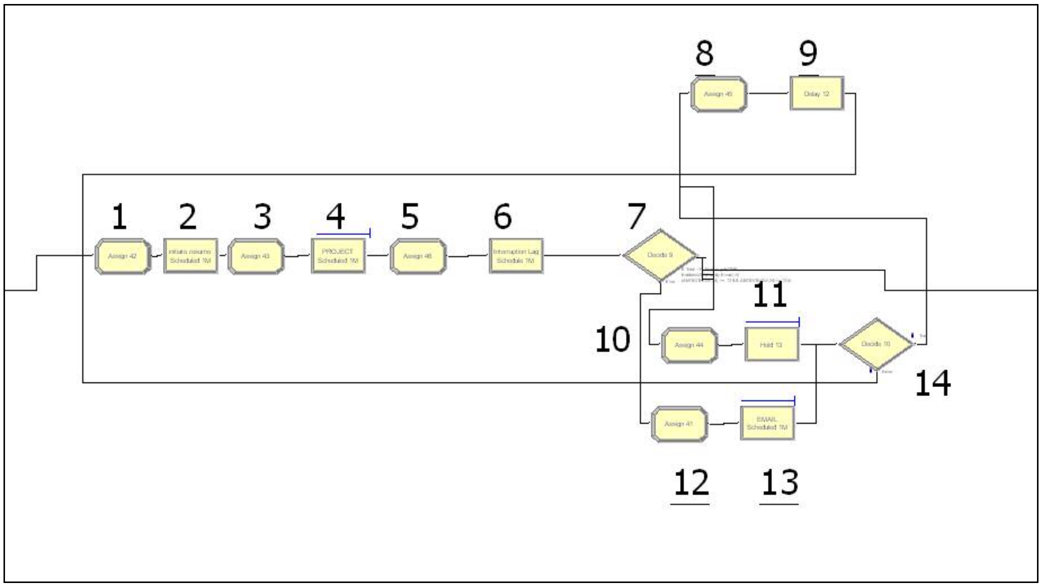


APPENDIX D
SCHEDULED ATTENTION PROCESSING STRATEGIES SUBMODEL MODULE PARAMETERS FOR MODULES 1 THROUGH 14



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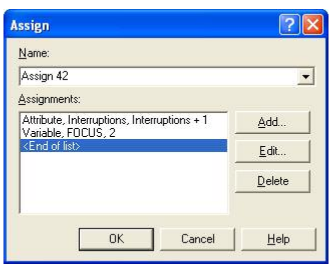

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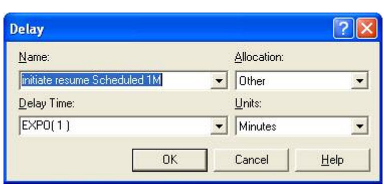

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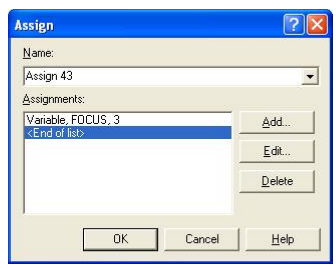

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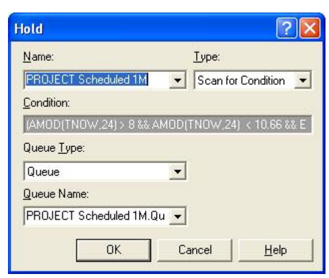

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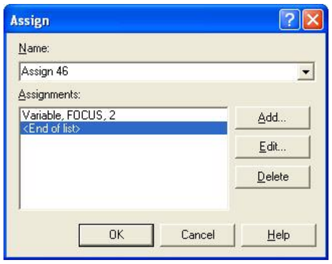

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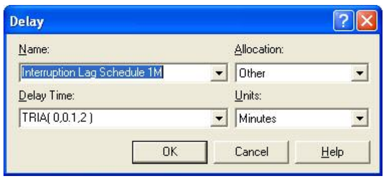

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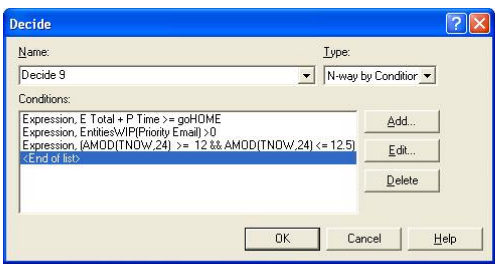

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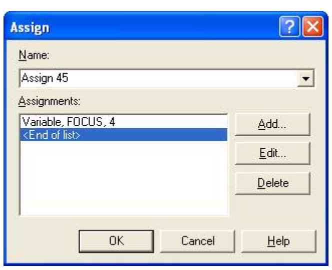

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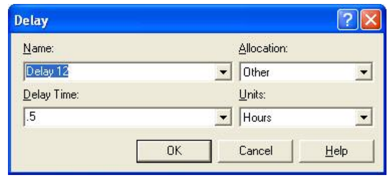

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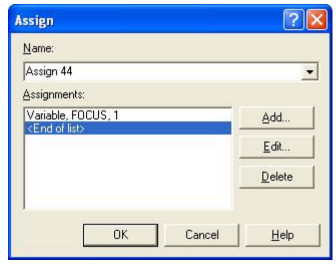

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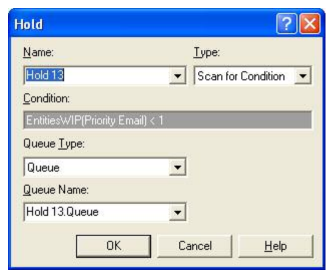

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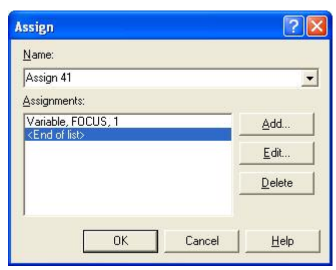

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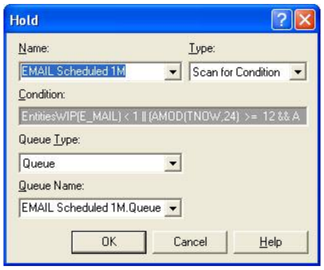
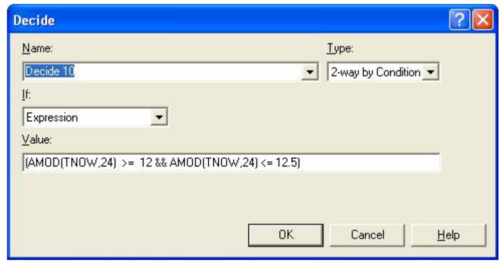

Hold
Name:
EMAIL Scheduled 1M
Type:
Scan for Condition
Condition:
EntitiesWIP(E_MAIL) < 1 || (AMOD(TNOW,24) >= 12 && A
Queue Type:
Queue
Queue Name:
EMAIL Scheduled 1M.Queue
OK
Cancel
Help

14


Decide
Name:
Decide 10
Type:
2-way by Condition
If:
Expression
Value:
(AMOD(TNOW,24) >= 12 && AMOD(TNOW,24) <= 12.5)
OK
Cancel
Help

APPENDIX E
PROCESSING STRATEGY
AND MODULE LOGIC
MODULE 4

<table>
<tr><th>Processing Strategy</th><th>Hold Logic</th></tr>
<tr><td>Scheduled Attention 1A</td><td>(AMOD(TNOW,24) > 15.33 && AMOD(TNOW,24) < 18 && EntitiesWIP(E_MAIL) > 0) ||
(P TIME + E Total >= goHOME) ||
(EntitiesWIP(Priority Email) > 0) ||
(AMOD(TNOW,24) >= 12 && AMOD(TNOW,24) <= 12.5)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Scheduled Attention 1M</td><td>(AMOD(TNOW,24) > 8 && AMOD(TNOW,24) < 10.66 && EntitiesWIP(E_MAIL) > 0) ||
(P TIME + E Total >= goHOME) ||
(EntitiesWIP(Priority Email) > 0) ||
(AMOD(TNOW,24) >= 12 && AMOD(TNOW,24) <= 12.5)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Scheduled Attention 2</td><td>(AMOD(TNOW,24) > 16.66 && AMOD(TNOW,24) < 18 && EntitiesWIP(E_MAIL) > 0) ||
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(P TIME + E Total >= goHOME) ||
(EntitiesWIP(Priority Email) > 0) ||
(AMOD(TNOW,24) >= 12 && AMOD(TNOW,24) <= 12.5)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Scheduled Attention 2P</td><td>(AMOD(TNOW,24) > 12 && AMOD(TNOW,24) < 13.33 && EntitiesWIP(E_MAIL) > 0) ||
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(P TIME + E Total >= goHOME) ||
(EntitiesWIP(Priority Email) > 0) ||
(AMOD(TNOW,24) >= 11.5 && AMOD(TNOW,24) <= 12)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Scheduled Attention 4</td><td>(AMOD(TNOW,24) > 8 && AMOD(TNOW,24) < 8.67 && EntitiesWIP(E_MAIL) > 0) ||
(AMOD(TNOW,24) > 11.1133 && AMOD(TNOW,24) < 11.7833 && EntitiesWIP(E_MAIL) > 0) ||
(AMOD(TNOW,24) > 14.22667 && AMOD(TNOW,24) < 14.89667 && EntitiesWIP(E_MAIL) > 0) ||
(AMOD(TNOW,24) > 17.33 && AMOD(TNOW,24) < 18 && EntitiesWIP(E_MAIL) > 0) ||
(P TIME + E Total >= goHOME) ||
(EntitiesWIP(Priority Email) > 0) ||
(AMOD(TNOW,24) >= 12 && AMOD(TNOW,24) <= 12.5)</td></tr>
<tr><td></td><td></td></tr>
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(AMOD(TNOW,24) > 12.5 && AMOD(TNOW,24) < 13.17 && EntitiesWIP(E_MAIL) > 0) ||
(AMOD(TNOW,24) > 14 && AMOD(TNOW,24) < 14.67 && EntitiesWIP(E_MAIL) > 0) ||
(AMOD(TNOW,24) > 17.33 && AMOD(TNOW,24) < 18 && EntitiesWIP(E_MAIL) > 0) ||
(P TIME + E Total >= goHOME) ||
(EntitiesWIP(Priority Email) > 0) ||
(AMOD(TNOW,24) >= 12 && AMOD(TNOW,24) <= 12.5)</td></tr>
<tr><td></td><td></td></tr>
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(AMOD(TNOW,24) > 12.5 && AMOD(TNOW,24) < 12.9444 && EntitiesWIP(E_MAIL) > 0) ||
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(P TIME + E Total >= goHOME) ||
(EntitiesWIP(Priority Email) > 0) ||
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<table>
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(E Total + P TIME >= goHOME) ||
(EntitiesWIP(Priority Email) > 0) ||
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<tr><td></td><td></td></tr>
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(E Total + P TIME >= goHOME) ||
(EntitiesWIP(Priority Email) > 0) ||
(AMOD(TNOW,24) >= 12 && AMOD(TNOW,24) <= 12.5)</td></tr>
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(EntitiesWIP(Priority Email) > 0) ||
(AMOD(TNOW,24) >= 12 && AMOD(TNOW,24) <= 12.5)</td></tr>
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<tr><td>Batch Attention 6</td><td>(EntitiesWIP(E_MAIL) > 4) ||
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(P TIME + E Total >= goHOME) ||
(EntitiesWIP(Priority Email) > 0) ||
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Oklahoma State University Institutional Review Board

Date: Monday, September 13, 2004

IRB Application No BU055

Proposal Title: Modeling and Simulation of Knowledge Worker Attention for Evaluation of Email Processing Strategies

Reviewed and Processed as: Exempt

Approval Status Recommended by Reviewer(s): Approved **Protocol Expires: 9/12/2005**

Principal Investigator(s):

Robert A. Greve
8829 NW 121st Terrace
Oklahoma City, OK 73162

Ramesh Sharda
320 CBA
Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☒ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact me in 415 Whitehurst (phone: 405-744-1676, colson@okstate.edu).

Sincerely,

Carol Olson, Chair
Institutional Review Board

VITA

Robert Allen Greve

Candidate for the Degree of

Doctor of Philosophy

Thesis: MODELING AND SIMULATION OF KNOWLEDGE WORKER ATTENTION FOR EVALUATION OF EMAIL PROCESSING STRATEGIES

Major Field: Business Administration

Biographical:

Education:

Bachelor of Business Administration from the University of Central Oklahoma in 1994. Master of Business Administration from the University of Central Oklahoma in 1998. Completed the requirements of a Doctor of Philosophy, Oklahoma State University, Stillwater, OK, May, 2005.

Experience:

Graduate Teaching Assistant at Oklahoma State University from 1998 until 2002
Visiting Assistant Professor at Oklahoma State University-Tulsa from 2002 until 2004
Assistant Professor at Oklahoma City University from 2004 until present

Name: Robert Allen Greve Date of Degree: May, 2005

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: MODELING AND SIMULATION OF KNOWLEDGE WORKER ATTENTION FOR EVALUATION OF EMAIL PROCESSING STRATEGIES

Pages in Study: 126 Candidate for the Degree of Doctor of Philosophy

Major Field: Business Administration

Scope and Method of Study: Even small gains in the efficient management of email can have big impacts on organizations because of the volume of email received by most knowledge workers. This study proposed that 1) knowledge workers should use available means to separate urgent from non-urgent email messages, and 2) the non-urgent email should be treated differently – primarily it should not be allowed to interrupt the knowledge worker's primary activities. The study compares the effects of various email processing strategies on various knowledge worker performance outcomes including email resolution time, knowledge worker efficiency and total hours spent working daily. High level knowledge workers who were dependent on email for their work lives were interviewed, and interesting insights into how and why email is processed were gained. The study then explored what type of impact various alternatives to continuously monitoring email might have on the knowledge worker's performance. Simulation was used to create the email environment faced by a knowledge worker. The various email processing strategies were then simulated and the performance measures were collected and compared across various email processing strategies. A Multivariate Analysis of Variance (MANOVA) was performed comparing performance measures (knowledge worker efficiency, email resolution time, and total hours worked daily) across groups, each group corresponding to an alternative email processing strategy. Next, optimization software (Optquest) was used to find optimal email processing strategies, given constraints on performance. Finally, the results of the optimization were compared against those obtained through brute force analysis.

Findings and Contributions: Processing all non-urgent email messages only twice daily or processing all non-urgent email in batches corresponding to ½ of one day's email processing load allowed for statistically significant (α = 0.001) gains in knowledge worker efficiency of 3%, when compared to continuously monitoring email messages. These gains imply hours of time that could be saved by individual knowledge workers after only weeks of time. Furthermore, these gains were not made at the expense of the appropriate resolution of email. The optimization software, Optquest, also was successful at finding optimal email processing strategies, given constraints on performance. The results of the Optquest software were consistent with those results obtained through brute force analysis.