# Improving Goal Completion: Tagging Locations and Tasks

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## ABSTRACT

A conceptual framework was devised to unify competing considerations in Personal Information Management , Activity Analysis, and Mobile ICT research. With an emphasis on task and goal completion, these attributes were examined with twin goals of reducing travel and improving goal completion. A simulation model sought to assess the value of managing time, task, and location data while avoiding the pitfalls of developing, deploying, and evaluating a Mobile PIM tool. Using existing survey data, the daily activities of a thousand student commuters were synthesized and simulated over the course of a college semester. Though enhanced information provided comparatively little impact on travel reduction, task completion and goal achievement was found to have improved significantly.

## Categories and Subject Descriptors

H.3.3 [**Information Storage and Retrieval**]: Information Search and Retrieval.

I.6.6 [**Simulation Output Analysis**]: Simulation and Modeling.

## General Terms

Algorithms, Design, Human Factors, Theory, Experimentation

## Keywords

Personal Information Management, Activity Analysis, Task Management, Time, Personal Workflow management

## 1. INTRODUCTION

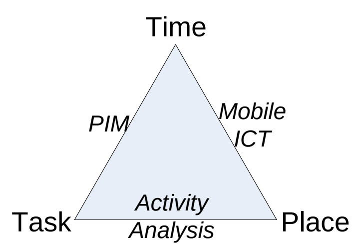
This project builds on a proposed framework emerging from research in Personal Information Management (PIM), Mobile Computing (Mobile ICT), and transportation Activity Analysis [1]. Development work drew from varying data structures and processing operators to act on task, time, and location-based information in a consistent way [2–4]. A simulation was developed to assess the varying impacts of these factors on task completion and cost reduction.

The primary goal of this simulation was is to evaluate its expressiveness over the domain in question. The explanatory power of this framework to address problems cited within Personal Information Management, Activity Analysis, and Mobile Computing will determine its value. Its ability to resolve these issues will be the measure of its expressiveness, and suggest additional directions for future research.

Central to the test of this framework is the development of a simulation to model impacts of improved information processing capabilities over a population. This simulation relies on two major developments: the conversion of population demographics into individual "synthetic actors", and a processing framework to test the population behaviors between combinations of information processing capabilities.

The simulation followed the travels of 1000 synthesized student profiles as they traveled between home, campus, and work, while conducting various errands and appointments. System constraints created time budgets that limited the number of hours per day that the simulated person could travel, perform school work, employment and other needed tasks, in accordance with established time use literature. The creation of a simulation modeling the use of PIM among a synthetic population led to insights regarding the value of explicitly managing the PIM user's State Information (SIM), and the duality of public and private Location Information Management (LIM).

**Figure 1: Conceptual Framework of data managed within research streams used for simulation** [1]




## 2. PROCESSING FRAMEWORK

Tasks and schedule activities were consolidated into a single data structure, with time and date boundaries classified as estimated or actual starting times or ending times. This became the single table Tasks, containing both schedules and unscheduled tasks. Effectively, this simulated both the traditional Calendar and the To-Do list.

A significant attribute is the assignment of a task into a single task class- the nature of the task would help categorize it, and work in conjunction with a location class to determine a place where that task could be performed. For example, a task class of "study" would correspond to a number of places where one could study, including a library, school, or home. It would be the task of the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Location Information Management system to retrieve a suitable location to perform that activity.

The Task table works in combination with the junction table TaskDependency, which connects a given task to its dependent tasks. With this mechanism, a task will only be available to be completed when its prior tasks are completed. Retrieval of pending tasks would depend on the completion of these prior tasks and ensuring that these tasks had been completed already, releasing a given task into a list of eligible tasks to be completed.

## 2.1 Schedules and Time

Though schedules share a data table with tasks, the time attributes largely distinguish the two. Separate values for scheduled start and end times, starting and ending dates, and duration are used in combination to capture the time use types discussed in the Implementation Plans chapter: namely that scheduled activities may have a rigid start time, but either a definite end time or an estimated duration.

In contrast, there may be an estimated duration and a due date, as is more the case with tasks, or an estimated duration and a definite ending time, which may represent activities such as errands at a facility with a closing time. For the purposes of the simulation, these variations provided adequate representation of the range of activities for the population in aggregate.

## 2.2 Workflows

Extensions of this model included the need to associate these tasks and schedules into a concept borrowed from Computer Supported Collaborative Work: the notion of workflow. The workflow concept provided adequate structure to model the interdependence of tasks. Furthermore, the measurement of workflow completion created a useful means to measure the success of the simulated individual in conducting various activities.

In creating a workflow construct, the grouping of tasks into a short term objective paralleled the weekly orientation of academic class work, while permitting the accumulation of costs and achievements across varying activities into a common measure spanning the user's week. Successive weeks of accomplishments are reviewed on a monthly basis to evaluate plans and determine whether to prioritize or abandon these efforts.

All tasks are defined as belonging to a workflow which is defined as having a single terminal task, though there may be more than one initial task. Workflow tasks are structured with a series of dependencies. The terminal task has one or more direct dependencies, and only initial tasks lack dependencies. These dependencies are managed through the TaskDependency table structure.

The optimization of workflows can prove to be a complex problem as discussed in operations research literature. The simplified nature of personal workflows will be treated using a more rudimentary algorithm. In this simulation, workflows represent typical work over a span of a week, often consisting of a large share of scheduled appointments (such as attending class) and unscheduled tasks (class readings, lab assignments, or homework) which must be completed over the span of the week.

The idea of workflow expresses the relationships between discrete tasks. By monitoring their completion, understanding their interconnections, and prioritizing them as necessary, a series of actions and appointments can be arranged to effectively reach some greater purpose. Workflow balancing within the context of weekly activity planning seeks to monitor the ongoing completion of tasks across overlapping workflows. By prioritizing tasks which have fallen behind schedule, special adjustments can be made to attempt completion. These actions likely will result in additional trips, generating higher costs in terms of mileage and time.

## 2.3 Task Processing System

The processing system combined processing constraints and optimization mechanisms on pairs of attributes to compare the findings from these streams of research: optimizations on task and location to simulate activity analysis optimizations, time and place to simulate the impacts of Mobile ICT technology, and Time and Task optimization to simulate the impacts of PIM / TIM efforts. These in turn will be compared to the processing outcomes of Time, Task, and Location optimizations.

Figure 1 suggests that the use of Mobile ICT optimizations enables task optimizations through its focus on enabling the completion of tasks via the reduction of restrictions on the time and location of the user. Likewise, PIM technologies focus on the optimization of task completion by helping the user sequence tasks in time.

Though some research has been conducted in the design of data storage mechanisms for Personal Information Management applications, and user interface features have been proposed in applications, little work has been done in simulating the individual's use of information in these contexts. How could the use of PIM data be simulated effectively? Given optimum information, what is the best case for the use of these tools? And what intermediate stages of improvement are likely given tools addressing specific deficiencies in human-optimized use of personal information: what is the Human Default strategy for information use?

A combination of Relational Database models, in-memory data structures, Structured Query Language data queries, and procedural code were employed to store, retrieve, and iterate through simulation data to assess the value of varying improvements in information quality. The data structures proposed capture more descriptive attributes and relationships. The data operators, in the form of SQL and procedural code outlined here demonstrate the extraction of these attributes and both the explicit and implicit relationships between data based on sequential relationships or proximity, respectively.

# 3. SIMULATION CONSTRUCTION

Construction became easier by breaking down the problem into one of three separate, but interconnected information systems. Their consolidation into overlapping domains completes the process of transforming a generic Personal Information Management problem into specific domains of Task, Locations, and User State Information Management.

Given that scheduled activities are treated as tasks, these functions synthesize data according to the varying combinations of fixed start time, fixed completion time, fixed duration, and estimated duration. For example, a task item with a fixed start and fixed end time (and resultant fixed duration) would be considered a rigidly-defined appointment as is the case with college class attendance. However, a fixed start time and an estimated duration would require an estimate for ending time. Generic functions for deriving starting times, ending times, durations, and similar measures were designed to operate on these combinations of factors to return the desired outcome.

## 3.1 Location Information Management

Another realization in the development of the simulation was the need to model location information as a separate entity from task information. Location here is treated simply as an external, shared resource, where locations are stored in physical database tables: Location, LocationClass, and UserLocationClass. Processing functions based on location consider that a given location may be public, or open for many or all individuals, as represented in the combination of the Location and LocationClass tables. A location may be private, or certain roles may only available to a specific individual, as represented in the combination of Location and UserLocationClass tables.

A critical aspect of the Location Information Managment framework is the use of the much-maligned "many-to-many" relationship in relational databases. The key premise is that a given task can be classified by type, suggestive of the resources required to complete it. For the purpose of this project and simulation, that task class resource in question is merely based on location, though further research may want to expand the range of resources of include other, non-locational attributes. The TaskClass is identified in the Tasks table within the Task Information Management boundary

The other side of this "many-to-many" relationship is based on the recognition that a given physical location can provide more than one use. Some of these may be relative to the user: not all available uses for a location may be realized by all potential users. Under conditions of perfect information, this would not be the case, but under more conventional circumstances, a probability may exist that the number of potential users will be aware of the availability of a location's utility, further reduced by the probability of recall of that utility when the opportunity presents itself.

These issues in Location Information Management describes the conflict between information owned by individuals versus information experienced by individuals. Though the location of public facilities such as grocery stores and libraries would be "experienced" by individuals, the location of "home" or to a lesser extent "work" would be considered to be "owned" by the individual. Presumably the individual has more control regarding the locations of home or work. A grocery store, or other publicly-accessible service would be "experienced" by the individual during times and circumstances largely out of the control of the individual, but by external actors.

The simulation tracks this distinction between public and private access as between experienced and owned information. Private access resources as represented here are likely available in a location specific to a given individual. Public access resources are represented as location references mapped to the LocationClass table, which in turn references the Location table.

In addition to the storage and retrieval models expected within other types of data driven applications, the need to establish context to improve the use of location was established through time gap analysis functions in FindExistingGaps and corridor functions such as FindTaskClassDistance and FindPlaceCorridor. In FindExistingGaps, opportunistic task completion became realized through queries of eligible tasks and iterative scheduling into available times at a given location. These procedures prioritized tasks and fit in accordance with slack time available, using a shared data structure with time scheduling, aSched.

In summary, the management of the inventory of available public locations, private locations, and the uses to which individuals may put them constitutes an adequately complex process to merit a domain-specific information system of its own. This information domain requires separate data structures and processing methods integral to the functioning of task information management and potentially other domain-specific information systems as well. However, this domain varies from traditional Geographic Information Systems in that the emphasis of use is on the shifting perspectives of public and private uses relative to specific users. In this way, Location Information Management may form an intermediate step between Personal Information Management systems and traditional Geographic Information Management.

## 3.2 State Information Management

Over the course of developing the simulation, the notion of representing the state of the simulated individual became increasingly urgent. Unlike the emphasis of more permanent storage and complex retrieval of accumulated relationships and responsibilities as under Task Information Management, or the dual public / private orientation of the Location Information Management framework discussed previously, the management of the individual's state became apparent as both uniquely solitary and ephemeral.

The user may become aware of tasks, record them, and execute them in turn or not. Locations exist with permanence beyond the scope of the simulation and can be considered effectively fixed. However, user state is in continual flux under a shifting environment of constraints anchored by physical location and mode of travel

Unlike Task Information Management and Location Information Management, the simulated user has a "state" or a current condition that is ephemeral, and yet more complex than a single value returned from a function. State is managed through the interaction of in-memory data structures and the passing of structures between functions. In this simulation, functions manage the conflicts between available resources under constraints (time and location) and needs (tasks and workflows). The changing state of the user simulation involves diminishing windows of time to complete needed tasks, changes in task availability, and the search for locations and construction of trips to complete additional tasks in relation to fixed appointments.

State information exists in this context as the difference between the list of available tasks, and the diminishing pool of time to complete them. In this manner, the function FindExistingGaps examines a schedule to determine time and place corridors to which pending tasks may be matched. These tasks are executed in turn, with the assumption that time estimates may not always match reality, using a probability distribution to determine actual completion times relative to the available window of time available. Remaining time is allocated subsequently.

This tension between diminishing windows of time is expressed relative to intervals between appointments, and actual time, as aforementioned intervals also include projected travel times. In-memory representations of the schedule as in aSched interact with the pending task list in aTasks through the creation of the intermediate structure in FindExistingGaps. Inferring connections between differing scheduled appointments based on proximity in time and location is based on the state of the user and the user's perceptions of the multiple roles a location may play. Interactions with Location Information Management through the FindTaskClassDistance function help determine which tasks may be performed from a starting location with minimal travel, using a minimization function to simulate trip chaining with an effective travel distance of zero.

FindExistingGaps infers connections between scheduled appointments into which available tasks are inserted, subject to limitations. These connections are subjective and transient, existing only in the window in which they occur. Once that window of time has passed, they cease to exist. As such, they have no physical representation and do not become part of the physical data store as do elements of Task and Location information management frameworks.

List comparison operations manage the process of identifying the so-called "To Do" tasks that the user intends to complete, versus the ones that the user's schedule and resources of available time permit. The function ListDifferenceCompare accomplishes a simple task of retrieving either the union of a pair of lists, or the differences between them. This simple mechanism allows the simulation to modify state between the tasks that have been completed within the day's available time windows, and the list of available and pending tasks. At the end of the day (literally) the user removes completed tasks from this "To Do" list, with urgent tasks receiving higher priority the next day.

The course of the simulation relies extensively on the monitoring of state as will be discussed in the Simulation Outputs chapter. The simulation iterates through the months of the semester, evaluating plan progress per month, making a determination as to the success of a plan and deciding whether to continue. Per month, the simulation iterates between weeks, monitoring the completion of workflows, accumulating measures regarding accumulated costs and the success of each workflow. Per week, the simulation iterates between days, where workflows are monitored, with higher priority tasks assigned to the daily execution plan. These higher priority tasks are then grouped by location and executed as separate trips where prior opportunistic task execution had failed to accomplish them. The flow of the simulation relies entirely on the accumulation of costs and the monitoring of results in changing the user state, and the direction of the user's proposed efforts.

By separating the management of user state information, the interaction between the user, user tasks and schedules, and the user's environment can be expressed more explicitly with the goal of better modeling the user in either domain or in combination with both. The notion of user state rises above merely tracking To Do lists and schedules, acting instead to carry forward the running costs of accomplishing higher level workflows and plans, making periodic decisions as to whether to continue a plan or to abandon it.

To evaluate this location and state-aware Task Information Management framework, the generation of plausible tasks and schedules for the simulated individuals to perform. This simulation used survey data and aggregate population statistics to infer a variety of activities for a population of 1000 students. A series of database queries and supporting code were used to generate this data in a Population Synthesizer.

The Population Synthesizer matched survey data to a variety of templates for tasks and schedules. Relationships between these activities were created via a number of generic templates to represent typical weekly workflows. Workflows permitted the structuring of activities over the course of the week to show interdependencies and as a measure of success in achieving overall goals. These workflow patterns were selected to represent likely scenarios representing various student schedules that would create a representative mix of activities to perform the simulation.

These tasks and relationships represent the structure of activities the simulated user will need to perform during the course of the week. Over the course of the simulation, available tasks and appointments are extracted in the form of lists to be completed over the course of each simulated day. The simulation then examines these lists to build daily execution plans to complete schedule and task events as discussed in the Processing Framework and Simulation Outputs chapters.

The separation of task roles from location further permits the creation of generic tasks and schedules. This separation between specific physical locations and the services they provide, and the range of locations where a given activity may be performed not only makes the creation of generic activities possible, but plays an important role in this model. This separation is the basis of the interface between separate Task Information Management and Location Information Management aspects of the simulation.

### 3.3 Simulation Data

The test site represents a commuting community college serving approximately 10,000 students per semester. Of these, more than 6,000 students are recorded as full-time status, with the remaining are considered part-time students. The survey data collected represents traditional on-campus students registered for up to 24 credit hours, though the typical full time student carries between 15 and 18 credit hours for timely completion of their degrees.

The test school supplied anonymous survey data regarding time use statistics developed in accordance with State data reporting requirements. This survey data represented categorized time ranges. These values were matched to a number of templates containing variations of schedules and tasks.

These time ranges were translated into credit hours that represented their workloads. Scheduled attendance represented one hour of on-campus class time per week per credit hour taken. Equivalent tasks for reading, homework, or other assessments were generated as well using templates that represented these tasks

General task relationships were created to simulate the need to attend class before starting assignments, to go to the library before writing a term paper, and similar kinds of dependencies. These dependencies were deemed important to demonstrate the mix of locations that the student may have to travel to in the course of completing a series of actions within a given workflow.

## 4. SIMULATION PROCESSING

Within the semester cycle, a monthly planning event loops through four weeks. Each week a series of workflows must be completed. Each workflow contains the tasks and task dependencies for a given semester plan as broken up into each week. At the end of the week, the monthly plan event examines the results of each week's activities in terms of travel costs and the percentage completion of each of the assigned workflows.

After a month, the plan workflows are evaluated. Plans for which the constituent workflows fail to average a minimum threshold of completion rates are terminated. In future monthly, weekly, and daily event loops, those plans will no longer be executed and those constituent tasks and appointments are removed from daily execution plans.

With the weekly event loops, a daily operation plan is formulated. Subsequently, that daily plan is executed, subject to varying probabilities of actual task and appointment completion. Fixed appointments missed are marked as incomplete. Tasks not completed are inserted into a pending task queue, and returned to the week planning event, to be rescheduled the following day as a priority task.

### 4.1 Daily activities

At the start of each simulated day, a list of scheduled meetings was retrieved, with travel plans build around them. Subsequently, a list of tasks which could be clustered around these meeting locations were retrieved. These task lists were processed as a queue. Those that were subsequently considered complete were added to a completion queue, while those which were not completed were added to a priority queue to be executed the following day.

The CreateDayPlan event loop built around fixed scheduled events, and attempted to fill tasks around these activities. FindAvailableTasks was used to identify the needed activities for the day. FindExistingGaps was used to identify opportunities for trip chaining, as well as FindTaskClassDistance for time boundaries within gap analysis.

### 4.2 Task scheduling and sequencing

Tasks were also prioritized based on impending deadlines- as workflow deadlines approach, the priority for the dependent tasks increases. These deadlines are further analyzed using traditional workflow measures for early and late start, early and late completion times to ensure that the deadlines for subsequent tasks take into account all subsequent activities needed to ensure that the workflow can be completed on time. This permits a greater likelihood that the overall workflow can still be completed on time. Note that workflows have rigid deadlines: once the due date has passed, no subsequent task work can be permitted.

Tasks that could not take advantage of existing scheduled trips required the creation of separate trips. This consisted of two options. First, travel corridors were examined to determine if enough slack time were available "trip chain" or stop en route to perform errands on the way. For example, stopping at a grocery store on the way home from school would be a typical "trip chain" where a stop to complete some errands is done on the way to a higher-priority destination. The novelty of this approach lies in the incorporation of travel time and task completion times to help determine whether enough time is available to perform one or more activities at this chained stop.

Among the perceived benefits of managed task scheduling are the likelihood that task transitions would be shorter. Less time spent in recalling tasks to perform and switching between tasks would improve the quality of life by reducing time spent in transitions. Consolidating tasks by location would reduce the overall costs of travel. By increasing the flexibility of task scheduling, completion rates are expected to improve, in turn improving the success rate of overall goals for the semester.

### 4.3 Task Completion

That these tasks are often not completed by students does not nullify their existence- it merely verifies that available tasks all too often do not complete for any number of reasons. These tasks sequences were obtained from a fixed pool of sample workflows to establish patterns of task dependencies. During simulation, the pool of "available tasks" are selected, based in part on the starting and ending dates of the workflow, and whether prior tasks had been already completed.

### 4.4 Task and Schedule Feedback

At the end of the simulated day, a list of completed tasks is returned to the weekly event procedure. This procedure examines the pending and completed tasks to determine priority scheduling for the following day.

At the end of the simulated week, tasks completed are compared to workflows needed, to determine an aggregate score per workflow. At the monthly level, these workflow scores are compared to minimum thresholds. When workflow completion rates drop below this threshold, the semester-length plan will be dropped, reallocating time and resources to be available for tasks from other plans. This mechanism would improve the success rate of other plans which may have been lagging due to over-scheduling.

### 4.5 Simulation Constraints

The simulation used both constraints and probabilities to better reflect the scope of individual behavior over the course of successive days in the simulation. System constants were created to represent likely constraints in behavior. On the individual, the constraint may consist of factors such as travel time budgets, or total time budget for work and school-related tasks. Probabilities were also used to simulate variability in human behavior not readily addressed in simulation.

### 4.6 Fixed constraints

Overall constraints on the number of constructively available hours per day and constructive hours per week were represented as an overall time budget. Though some days may represent a greater number of working hours than others, the overall weekly time budget remains relatively fixed. One can argue that individual factors and motivation may change the number of hours per week of constructive work, but such behavioral assessments lie outside the scope of this project and would be better addressed in separate research.

The simulation runs use a base constraint of a 16-hour day to form the pool of time from which all possible tasks could occur. Though the final pool of time would remain constant regardless of the optimization method chosen, the process of finding additional real-world constraints in future research will aid in the development of tools that are more effective in meeting real world demands. This first constraint essentially precludes any constructive tasks being performed during an 8-hour period. This pool of time is further reduced in the course of adding other constraints.

ConvDistanceToTime used 1.25 minutes per mile + 9.5 minutes overhead due to parking and urban driving effects: shorter distances and greater congestion. An Internal Revenue Service standard of $0.55 per mile provided the financial cost factor for driving. Over the population base, this cost factor accounts for maintenance and other amortized costs. Though the student population famously drives vehicles provided by parents or cheaper, less reliable vehicles, and may often calculate driving costs purely in terms of fuel prices, it was felt necessary to provide these full costs. The differential in behavior between perceived driving costs and actual costs should be left to separate research.

### 4.7 Budgets

Budgets provided another constraint to limit the range of activities per day and per week. A likely time budget for the simulation was determined to be 50 hours per week as a total for all activities and travel. This was represented in the Public Constant BudgetWeekTime as 50 * 60 minutes per week. This placed an upper bound on a daily time budget of 9 hours per day, to represent that some days were likely to have reduced numbers of activities. This was represented in the Public Constant BudgetDayTime as 9 * 60 minutes per week.

### 4.8 Probabilistic variables

Proposed probabilities were designed to better reflect various uncertainties in conducting everyday life. A global probability of departing home in a given day appeared in the Public Constant ProbAbleDepart value of 0.95. This value reflected the likelihood that regardless of reason, an average student may not be able to attend work or class at least one time out of twenty, for external reasons such as transportation difficulties or illness, regardless of all other factors regarding optimization.

An independent probability of completing a task once started was represented in a Public Constant ProbTaskCompleted value of 0.8. This value reflected a catch-all ability to complete tasks. One time out of five, a task planned may not be executable at the moment due to external factors: missing information, resources, or misjudged time estimates.

### 4.9 Simulation Constraints

Simulation Optimizations interact with the Simulation Constraints in amplifying the effects of these constraints. In restricting both the number and range of hours available for work, changes in the probability of task completion will result in changes in task completion. Otherwise, alterations in task performance would simply result in rescheduling the task rather than the likelihood of abandoning it as is more likely in real life.

The constants were adjusted according to the "human default" case and left constant afterward. This would help ensure that the full benefit of the optimization would be comparable to this default case. Effects on the simulation improvements in changing these constraints (increasing the number of hours of work or somehow lengthening the work day) were left for future research.

### 4.10 Simulation Optimizations

Model behavior tracing to one of three possible attributes were determined and subject to changes in a probability function. These behaviors were traced to key leverage points in the simulation. A probability function was used to represent the impact of that change in optimization to reflect realistic behavior. Some model behaviors could be impacted by more than one kind of optimization. The accuracy in determining departure time for an appointment combines the ability to estimate travel time and ability to incorporate these estimates into departure times sufficiently early to keep scheduled appointments.

### 4.11 Single Factor Optimizations

Behaviors impacted by time estimation were subjected to a TimeOptimization factor where the role of information retrieval seemed essential. This effort focused on the ability to accurately estimate the differences between time available for tasks and the time to complete a task, which are known shortcomings in human estimations. Time Management is typically represented through a number of calendar and other schedule systems.

The LocationOptimization factor focuses on the ability to match optimum locations for a pending task, and the ability to match an available task to the user's current location. Recalling locations and the roles they play in helping to accomplish tasks is expected to be relatively limited, given the limited tool support available to users at present.

Location management may be best represented by the use of a map or geographic service such as GPS navigation tools. The usage scenario pictured here is the ability to select from one of several locations as recorded, with moderately effective location selection.

The TaskOptimization factor focused on the ability to accurately manage and prioritize available tasks. Common task management tools are often limited to simple to-do lists, which do support simple prioritization when used. Improvements would take the form of a range of enhanced task managers, though more advanced tools proposed such as personal workflow tools would be represented here. Two major factors in task completion consist of the likelihood of recalling a pending task, and subsequently completing it.

### 4.12 Human Default case

The Human Default optimization consisted of a simulation run with the parameter settings for TimeOptimization, LocationOptimization, and TaskOptimization set to their base levels. The results from this run became the standard against which all subsequent results were compared. These default optimization levels represent the unaided user in contrast to proposed information system improvements.

The characteristics of this default case consist of moderately reliable scheduling, moderate to-do list capabilities though lacking workflow, and some location optimization. These factors are taken as bounded by human memory constraints, taken as roughly 5 +/- 2 items remembered in the course of completing tasks.

### 4.13 Dual Factor Optimizations

#### *4.13.1 LocationTaskOptimization*

As the name suggests, LocationTaskOptimization combines both TaskOptimization and LocationOptimization. This is a dual factor optimization to combine both the impacts of improved task management and improved use of location. The real-world implication would be an improvement in the ability to match tasks with locations to improve overall task completion rates. Such improvements would reduce overall costs in completing more tasks with fewer trips.

#### *4.13.2 TaskTimeOptimization*

Combining TaskOptimization and TimeOptimization as the name would imply would further join these attributes, enabling tasks to have better time encoding and time (appointments) to become more task aware. The mechanism envisioned here would consist of unified workflows to group tasks and scheduled appointments into overall processes.

The ability to sequence tasks around appointments, and to better manage their relationships is represented both enhancements in time management and task management. This is considered the goal of many of the Personal Information Management tools currently in use via a number of web, desktop, and mobile computing applications, though the systems represented in this simulation are single user and lacking spatial awareness for incorporating user travel.

#### 4.13.3 LocationTimeOptimization

The combination of LocationOptimization and TimeOptimization is taken as improved awareness of places and improved time management capabilities. In the context of this simulation, this type of optimization is represented by improvements in Mobile ICT. Mobile ICT represents a variety of portable computing applications including handheld Personal Digital Assistant devices, and advanced cellular telephones, or "smart phones," though the capability represented here is theoretical rather than tied to specific implementations.

#### 4.13.4 Full Optimization

The fully optimized case represents what is considered likely in the presence of ideal information, or the "best case" optimization. Human behavior and other constraints remain in effect, in that the simulation subjects will still adhere to a limited number of working hours per day and week. However, the goal is to best utilize the use of location and time availability to reduce overall travel.

### 4.14 Simulation Comparisons

In the initial view of the data, it would appear that the human default case results in the same general costs in terms of time and distance as the optimizations. However, when examining the success rate, the costs per finished task is lower between the higher levels of optimizations. One likely explanation is that partial failures, such as dropping or failing a college course, do not reduce overall costs significantly.

**Table 1: Z-score output from simulation**

| prob Time | prob Place | prob Task | Hypothetical Improvements .AvgOfPlanAvg | Hypothetical Improvements .StDevOfPlanAvg | ZScore (from Human Default) |
|---|---|---|---|---|---|
| 75 | 50 | 75 | 0.69 | 0.43 | -8.77 |
| 50 | 50 | 75 | 0.65 | 0.42 | -6.41 |
| 50 | 75 | 75 | 0.63 | 0.42 | -5.65 |
| 50 | 95 | 75 | 0.62 | 0.42 | -5.18 |
| 75 | 50 | 50 | 0.60 | 0.39 | -4.06 |
| 75 | 75 | 50 | 0.57 | 0.39 | -2.34 |
| 50 | 75 | 50 | 0.51 | 0.36 | 1.11 |
| 50 | 50 | 50 | 0.53 | 0.37 | — |

The primary optimization factor proved to be task management. This is likely due in part to the orientation of the simulation, which focuses on task completion. Task management included the shifting and prioritization of tasks to improve their likelihood of completion. Higher levels of optimization increased the probability of available task recall, and the effectiveness of task rescheduling.

All optimizations that included tasks improved above the threshold for significance, the combination with Time yielded greater yields than for Location. One aspect of time management with task management is the ability to retrieve additional tasks that may be performed at the user's current location. In this way, location optimization is entangled with time and task optimization by eliminating additional trips.

LocationOptimization alone yielded improvements below the threshold for statistical significance. Interpreting this in real-world terms, it would likely parallel the use of the automotive GPS navigation unit, which provides benefits in directing users to unfamiliar locations, but less clear benefits in familiar areas.

LocationOptimization as modeled here represents the ability to find the closest suitable location to perform needed tasks. However, that optimization focuses on the retrieval of external locations.

The conclusion this suggests is that finding the optimum location within a travel corridor, or as a distinct destination provides little benefit over sub optimum locations. That is, slight increases in travel costs and times by themselves have a nominal impact on the overall travel and time costs. However, the ability to cluster additional activities around schedules and other tasks provides the greatest benefit.

What would be considered time and task management implicitly combines location management in that the maximum utility of a physical location is used in task completion. In this way, the computational burden of finding the "perfect" routing strategies may prove inefficient in comparison to even modest improvements in time estimation and improved task management. In summary, the implication of this finding in the context of this simulation is not the accuracy of the location calculation commonly used in GPS technologies, and the complexity of the mapping between address and coordinates. The more important task is the determination of various roles that a given location may play, and the categorization of locations and appointments into the roles played by location.

## 4.15 Results

Travel productivity improved using factors that improved the recall and performance of needed tasks. Through task consolidation at a given location, more tasks could be performed at that location, reducing the need for additional travel. The simulation demonstrated that even under various types of optimizations, the overall volume of travel time and distances did not change significantly.

The goal of trip reduction under the varying constraints was overshadowed by significant increases in productivity. When factoring completion rates with trip costs, a different picture emerged. With various optimization strategies, the efficiency of travel improved significantly, in that more tasks could be completed per trip, lowering the average cost of each task completed.

A critical aspect is theorized to be improved location matching to tasks. By shifting the focus from absolute location to the roles of locations in supporting tasks and activities, time and task management tools permit greater task consolidation, permitting more tasks to be completed in each location traveled to. This factor appears to be far more important than precise optimization in selecting locations for excursions or trip chaining. In other words, location and route selection merely has to be "good enough" with a greater focus on improving the understanding of what each location offers.

A number of contributions are expected as a result of developing this simulation. Unlike conventional end-user applications, the simulation modeled the state of each of the simulated users. The simulation anticipated a measure of their actions, under the assumption of reasonable diligence in performing various activities to accomplish various life goals. Absent in the current state of PIM and Mobile ICT systems are an awareness of the user's context. By accounting for the user's location, pending travel times, pending tasks, and destination, these tools would reduce the cognitive burden of matching current context to the user's overall desired outcomes.

Within the context of the simulation, benefits were realized through explicitly managing the task workflow. The ability to implicitly connect tasks across workflows enabled significantly greater benefits by improving the retrieval of available tasks bounded by available time at a given location. This combination provided the greatest improvements in plan completion rates.

## 5. Conclusion

The construction of this simulation yielded some observations. Travel costs under optimal conditions ("perfect information") changed comparatively little by adding more locations or increasing availability for completing tasks (i.e. additional nodes) as information quality improved. Adding location classes or the range of tasks that could be completed at a given location proved more effective than merely adding additional locations.

Plan completion rates rose most significantly under improved task and time management. This finding is qualified with the understanding that these improvements represent improved retrieval rates. A better understanding of the range of tasks that could be accomplished at the user's location lead to a greater overall number of tasks accomplished per trip. This realized savings through fewer trips to accomplish needed tasks. Under less ideal information availability, the ratio of travel costs to completion rates increased, in that lower completion rates lead to higher overall costs per task completed. Conversely, average travel costs per task decreased with improved information quality.

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## 7. REFERENCES

[1] S. Lackey, “Integrating Place and Time with Tasks: Adding Transportation to PIM,” in *Proceedings of the ASIS&T Workshop: Personal Information Management*, Vancouver, BC, Canada, 2009.

[2] K. M. Vaughn, M. A. Abdel-Aty, and R. Kitamura, “A framework for developing a daily activity and multimodal travel planner,” *International Transactions in Operational Research*, vol. 6, no. 1, pp. 107-121, 1999.

[3] E. Falke, “The associative pda 2.0,” in *CHI ’08 extended abstracts on Human factors in computing systems*, Florence, Italy, 2008, pp. 3807-3812.

[4] S.-Y. Hwang and Y.-F. Chen, “Personal Workflows: Modeling and Management,” in *Mobile Data Management*, 2003, pp. 141-152.