A MOBILE FLEXIBLE BUSINESS PROCESS MANAGEMENT SYSTEM SUPPORTING DAILY LIFE PROCESSES AND DECISIONS

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ABSTRACT

A MOBILE FLEXIBLE BUSINESS PROCESS MANAGEMENT SYSTEM SUPPORTING DAILY LIFE PROCESSES AND DECISIONS

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Within the Business Process Management domain, only a few studies focus on personal processes. Personal processes are looser and more context- and person-dependent compared to business processes. So, flexibility is a significant concern in Personal Process Management (PPM). In this study, we first conduct semi-structured interviews with a diverse population. Using the collected data, we develop a personal process taxonomy with four classes and twenty-two subclasses. Then, we create a reference model for context-aware mobile decision support systems for PPM. Finally, with the guidance of the reference model, we build a constraint programming (CP) model and a prototype context-aware-mobile application employing this CP model. We conduct experiments with 50 participants to evaluate the application and the CP model via two scenarios. We compare the participants' performances with and without the PPM system with quantitative metrics such as planning times and values. System Usability Scale (SUS) questionnaires and open-ended questions supply qualitative evaluation results. Throughout the study, we apply the Design Science Research methodology to rigorously conduct research activities. The empirical results show that our proposed CP model for PPM is effective with positive comments and a high SUS score. Overall, the prototype PPM application leads to fast and better (re)planning, which is invaluable in dynamically changing daily activities.

Keywords: Business Process Management, Personal Process Management, Decision Support Systems, Personal Assistant, Process Flexibility

ÖZ

GÜNLÜK SÜREÇ VE KARARLARI DESTEKLEYEN MOBİL VE ESNEK SÜREÇ YÖNETİM SİSTEMİ

Oruç, Sercan
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İş Süreçleri Yönetimi alanında, sadece birkaç çalışma kişisel süreçlere odaklanmaktadır. Kişisel süreçler, iş süreçlerine kıyasla bağlam ve kişi bağımlılığı yüksek, daha değişken süreçlerdir. Dolayısıyla, Kişisel Süreç Yönetiminde (KSY) esneklik önemli bir konudur. Bu çalışmada, önce çeşitliliği yüksek bir popülasyonla yarı yapılandırılmış görüşmeler yaptık. Toplanan verileri kullanarak, dört sınıf ve yirmi iki alt sınıf içeren bir kişisel süreç taksonomisi geliştirdik. Ardından, KSY için bağlama duyarlı mobil karar destek sistemleri için bir referans model oluşturduk. Son olarak, referans modelin rehberliğinde, bir kısıt programlama (KP) modeli ve bu KP modelini kullanan bir bağlama duyarlı mobil prototip uygulama oluşturduk. Uygulamayı ve KP modelini iki senaryo üzerinden değerlendirmek için 50 katılımcı ile deneyler yaptık. Katılımcıların performanslarını, KSY sistemi olan ve olmayan, planlama süreleri ve değerleri gibi nicel metriklerle karşılaştırdık. Sistem Kullanılabilirlik Ölçeği (SKÖ) anketleri ve açık uçlu sorular nitel değerlendirme sonuçları sağladı. Çalışma boyunca, araştırma faaliyetlerini titizlikle yürütmek için Tasarım Bilimi Araştırma metodolojisini uyguladık. Ampirik sonuçlar, KSY için önerilen KP modelimizin olumlu yorumlar ve yüksek bir SKÖ puanı ürettiğini göstermektedir. Genel olarak, prototip KSY uygulamasının, dinamik olarak değişen günlük aktivitelerde çok değerli olan hızlı ve daha iyi (yeniden) planlamayı sağladığı görülmektedir.

Anahtar Sözcükler: İş Süreçleri Yönetimi, Kişisel Süreçlerin Yönetimi, Karar Destek Sistemleri, Kişisel Asistan, Süreç Esnekliği

To my cheerful and creative companion Burcu

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LIST OF ABBREVIATIONS

ADL	Activities of Daily Living
BADL	Basic Activities of Daily Living
BPM	Business Process Management
CP	Constraint Programming
CP-SAT	Constraint Programming – Boolean Satisfiability
DSR	Design Science Research
DSRM	Design Science Research Methodology
DSS	Decision Support Systems
IADL	Instrumental Activities of Daily Living
IS	Information Systems
PPM	Personal Process Management
RCPSP	Resource Constraint Project Scheduling Problem
SME	Small and Medium-sized Enterprise
SUS	System Usability Scale

CHAPTER 1

INTRODUCTION

1.1. Problem Definition

In everyday life, people make various decisions regarding the processes that they manage. Personal process management (PPM) is the management of daily activities within the limits of some contextual and executional constraints. Personal processes may be complicated, as in the example of moving to a new country, or procedurally straightforward as in brewing coffee. Some other personal process examples could be relocating a house, making a cake, or choosing and registering for a sports club. In most cases, how these processes are handled depends on the context and the people involved, i.e., how to execute a process may differ by the time of day and location, or two different people who are going through the same process may have many separate requirements compared to each other.

Within the business process management (BPM) domain, only a limited number of studies are conducted on personal processes. Personal processes are looser and more person- and context-dependent in comparison with the precisely defined business processes. This makes it more challenging to provide solutions in the PPM domain. A well-known and widely used method for managing personal processes is creating to-do lists and prioritizing and completing the items within these lists. In most cases, these lists are made with some goals in mind. For some processes, the list of activities is predefined, i.e., submitting a paper to a journal. Yet, for some other processes, it is not that clear. What to do becomes more explicit for the individuals who have more experience with the processes they want to perform. Yet again, whether the list is clear or not, the person managing this list of activities makes decisions considering the contextual conditions. This person also tries to find answers to questions such as when or in which order the activities should be performed, which activities should be delegated, or for each activity, what the value, importance, or urgency levels are. Answering the broader question of how to carry out a process becomes more challenging when knowledge or experience levels decrease, or the numbers of activities, constraints, or conditions increase.

1.2. Motivation

We provide some motivational scenarios in this section to better explain personal processes and the issues which emerge in PPM. First, we explain two scenarios, “A Week in London” and “Planning a Day,” that we developed. Then, we share the scenarios found in the literature in the “Other Scenarios in the Literature” subsection.

1.2.1 A Week in London

Selin will have a trip to London for a week. She makes a list of restaurants, iconic buildings, museums, and attractions with their locations, importance levels, and values for her. She mentally divides these activities in two clusters as mandatory or optional. For example, she thinks that visiting British museum to see Rosetta Stone is a must for this trip or having a quality time in Hyde Park too. Yet, visiting Kensington Palace would be nice only if some additional time will remain from other activities. Indeed, she has some other concerns as well. Some attractions are ticketed. In addition to this, as in the example of the Harry Potter Experience, for some of these ticketed attractions, the tickets are sold out sometimes weeks before the event date. So, which activities should Selin choose to perform within this one week? On which day or in which order should she perform these activities? If the weather changes unexpectedly, what should her decision be? Would it be better to arrange a house to stay in Zone 1 with short travel distances yet with a higher cost or in Zone 3 with a higher distance yet a lower cost?

1.2.2 Planning a Day

Mete is a sophomore at METU. Recently, he moved to a new house. He would like to register the utilities, i.e., natural gas (process 1), water (process 2), and electricity (process 3). Separate parties provide these utilities. As a result of this, registration processes are performed in different locations. Also, Mete needs to collect his transcript from the student registrar’s office of METU (process 4). Lastly, he agreed to meet with his mother at 12:30 for lunch (process 5). Within a day, he is willing to complete these personal processes. Except for the lunch meeting, all these processes have some predefined definitions, i.e., corresponding companies and METU have given lists of ordered activities to be performed.

In Figure 1, Mete starts the day at point A where he lives. Points B and C are for natural gas and electricity registrations, respectively, which are geographically close to each other. It would take 15 minutes to walk from one to another. Point D is for water registration. METU is located at point E. Finally, point F is the location of restaurant where Mete will have lunch with his mother. All five processes have some time constraints. For example, electricity registration needs to be done between 9 am and 4 pm. For processes one to four, some particular prerequisites should be met too, e.g., photocopying ID cards, gathering some other certain documents like earthquake insurance for natural gas registration. For registration processes in points B, C, and D, Mete will need to wait in queues with different lengths, depending on the demand for these services on this day. Traffic is another consideration. Traffic in Ankara may significantly affect travel time depending on the time of the day. This would eventually affect the process execution. As METU is the closest point to his house, he may prefer to go there first. Alternatively, considering the short queue in the morning, he may choose to start with electricity registration at point C. So, how should Mete plans his day so that he will complete these processes within minimum time, distance, effort, or cost?

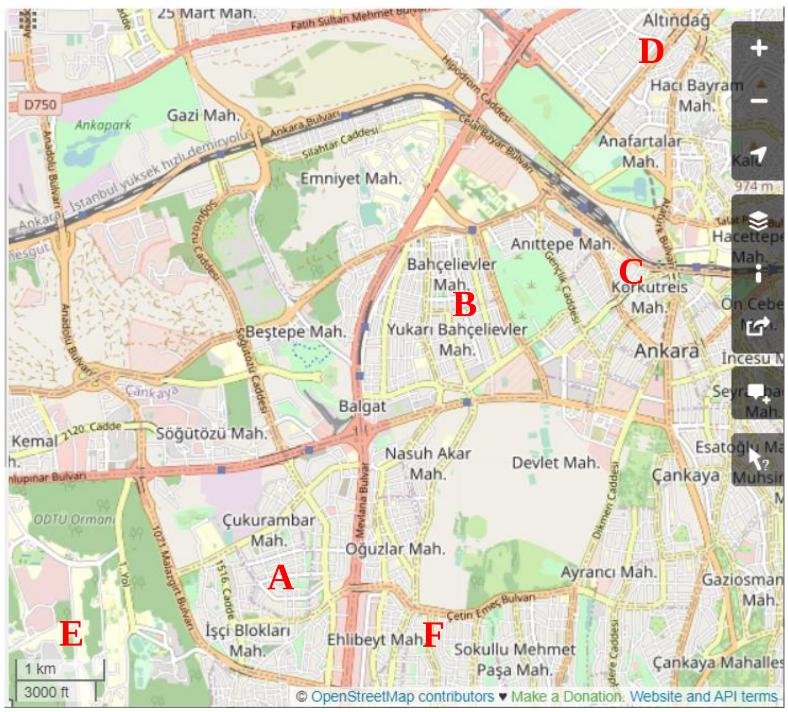

Figure 1 Map showing the task locations [1]

1.3. Research Questions

The main question and the subsequent underlying questions that motivated this study are as follows:

- How to increase productivity in daily life activities via a mobile PPM system?
    - How can personal processes be classified so that it would help the researchers to understand and analyze them and lead to an improvement in the PPM domain?
    - How can we develop a reference model which would create a vision for a complete PPM system?
    - What algorithm could be used to merge different processes, considering the context information like the locations of the performer and the activities, the current time and the time windows for activities, the importance, urgency, and activity value?
    - What algorithm or method could be used to make predictions and recommendations based on the user-defined criteria like time, distance, effort, and convenience?
    - What technique could be used to integrate the context (real-world information) with the process management system so that the managed process can be adapted seamlessly to the changes in the environment?

1.4. Research Methodology

In this study, we use Design Science Research (DSR) as the research methodology. The DSR is accepted as the consistent way of conducting Information Systems (IS) research [2]–[6]. It constructs the research activities to precisely develop and validate the artifacts through proof of concept, use, and value [4]. To be more explicit, we follow Hevner's guidelines [5], Peffer et al.'s DSR Methodology [6], and Gregor and Hevner's DSR Publication Schema [4] in this study.

1.5. Justification of the Research and Contributions

In this section we briefly describe the research justification and the contributions of the study. We support these brief descriptions with a deeper analysis in the literature review section. The four main contributions of the research are personal process taxonomy, a reference model for PPM systems, a constraint programming (CP) model for process recommendation, and the prototype implementation and evaluation.

1.5.1. Contribution *1: Personal Process Taxonomy*

The first contribution is a taxonomy for personal processes. After collecting data by conducting semi-structured interviews with a diverse population, we build the taxonomy. There are four classes and twenty-two subclasses in the taxonomy. Further, it is organized by six characteristics and three dimensions. The intention of creating a personal process taxonomy is to guide practitioners and researchers by describing the variety of processes, by perceiving the relationship among process types, and by structuring the knowledge within the PPM domain. In essence, the taxonomy would promote the creation of new methods, tools, and approaches for increased effectiveness in PPM. We used the method suggested by Nickerson et al. [7] in creating the personal process taxonomy.

1.5.2. Contribution *2: A Reference Model for PPM Systems*

The second contribution is a reference model for mobile context-aware applications that are developed for PPM with the aim of being a decision support system (DSS) and a personal assistant. We developed the reference model to support the solutions for the problems that emerge in PPM, such as “how can personal processes be defined and shared”, “how would personal processes be executed effectively and efficiently”, and “how should the cognitive workload on the person in PPM be decreased”.

1.5.3. Contribution *3: A CP Model for Process Recommendation*

After defining a reference model for PPM systems, in this research, we also realized a part of the reference model. This part, which consists of a CP model, has the role of making recommendations to the user in managing personal processes. The CP model to be used in PPM systems takes various information as input and creates an execution plan for personal processes.

1.5.4. Contribution *4: Prototype Implementation and the Evaluation*

We developed a prototype mobile application with the core capabilities like defining processes, activities, constraints, and making recommendations for execution plan. This prototype helps to demonstrate the applicability of both proposed models: the reference model and the CP model. We conducted experiments with 50 participants. Then we compared and analyzed the performance results of the participants and prototype system.

For validation and justification, we also collected the comments and assessments of the participants for the prototype PPM system.

1.6.Thesis Structure

As it is mentioned earlier, we follow the DSR Publication Schema [4] to shape the thesis, and the DSR Process Model [6] to conduct the research. In accordance with these, the rest of the thesis is organized as follows:

Chapter 2 contains the literature review. For this research, this chapter provides the corresponding knowledge base. Notably, this chapter covers related studies in BPM, merging processes, and flexibility in BPM, PPM, process taxonomies, DSS, and CP.

Chapter 3 introduces the innovative research paradigm DSR and explains how it is used in this research.

Chapter 4 presents how the semi-structured interviews are conducted, how the results are used in creating a personal process taxonomy, and what the results of this part of the study are.

Chapter 5 provides the components of the developed reference model for PPM systems, the interactions among these components, and how they could be used in creating PPM systems.

Chapter 6 describes the CP model details, implemented prototype application with CP, and the test results.

Chapter 7 discusses the evaluation of the artifacts.

Chapter 8 gives a discussion of the research contribution as well as highlights the broad implications of the results.

Chapter 9 concludes the report with some remarks and suggestions for future research.

CHAPTER 2

LITERATURE REVIEW

2.1. Business Process Management

The process studies in history defined a significant portion of how people work today by providing new profit margins. According to report [8], which summarizes BPM evolution, after the industrial age, the second half of the 18th century, the focus was on the division of labor and productivity in workpieces till the information age, which significantly decreased costs. Scientific management, mechanization, and standardization were the fundamental techniques used. At the end of the 1970s and 1980s, by the start of the information age, computerization became effective in process management. The focus was on process continuity and quality. Methodologies and techniques like Total Quality Management, Six Sigma, and Statistical Process Control were born in these years. In the 1990s, the adoption of the Internet skyrocketed, which triggered the stream of process innovations. Business Process Reengineering and Redesign methods were the hot topics of these years. On top of Manufacturing Resource Planning tools of the 1980s, end-to-end process management systems like Enterprise Resource Planning, Supply Chain Management, Customer Relationship Management systems rose in the 1990s. Then, in the new millennium, Business Process Management took its center place on the stage. [8]

A *Business Process* ([9] and [10]) consists of an activity or a set of activities performed by relevant roles in a specific sequence to reach some particular (business) goals. Weske [9] defines *Business Process Management (BPM)* as "... concepts, methods, and techniques to support the design, administration, configuration, enactment, and analysis of business processes." His definition implies how BPM is seen as a holistic tool to create efficiency in processes. The book "Business Process Management, The Third Wave" [11] defines the BPM evolution in three waves. Milestones mentioned previously in this introduction are in parallel with the three waves in the information age. The third wave starting in the early 2000s, perceives BPM as a comprehensive effort that provides efficiency and flexibility in operations so that intelligent exception handling, rapid business change, and business analytics can be done effectively. *(Business) Process*

Management System is the name given to the software to design and execute business processes. Although traditional Work Flow Management Systems promote process design, deployment, enactment, and administration, BPMSs additionally support process diagnosis activities facilitation [12]. *Business Process Models* include a set of activity models and interrelated constraints, and these models sustain as the “blueprint” of the *Business Process Instances* [9].

Van der Aalst [13] defines six key BPM concerns as “*process modeling languages, process enactment infrastructures, process model analysis, process mining, process flexibility, and process reuse.*” Aalst interrogated 289 BPM papers written between the years 2000 and 2011. According to the analysis of sample papers, process flexibility seems to be the least popular, almost neglected topic. Aalst comments that modern processes and information systems should have the capability to manage both foreseen and unforeseen changes. Aalst also defines the process quality in terms of flexibility as the “*ability to deal with such changes, by varying or adapting those parts of the business process that are affected by them, whilst retaining the essential format of those parts that are not impacted by the variations.*” In his paper, Aalst lists the weaknesses of the papers. Listed weaknesses are remarkable. He comments that although the need for new languages is not clear, many papers introduce a new language that is not used again. Although rapid and flexible adaptation is one of the considerable motivations in BPM systems’ development, there are not enough studies to fill the gaps. The papers mostly have little concern for real-life use cases. He also adds that case studies are primarily artificial, so the studies’ core contributions are not evaluated. [13]

2.2. Merging Processes in BPM

Rosa et al. [14] propose an algorithm that produces a process model to combine given two or more process models. They mention three requirements for the merged model:

- Behavior-Preservation: The resulting configurable process should encompass the given input models.
- Traceability: Given an activity within the resulting (merged) model, the user could understand which original model that activity belongs to.
- Reversibility: Users can derive the original models from the merged model. The algorithm first extracts the common parts of the given processes then appends the different parts of the given processes to these common parts, resulting in a more compact process while keeping the input processes’ behavior.

The paper [14] focuses on merging variants of a process. Making changes on a merged process can automatically be reflected on these variants, eventually reducing the time that the analysts waste on doing these changes. The algorithm uses the similarities in activities to define commonalities among input processes. It does not consider any other contextual attributes like time window or the activity's location.

Gottschalk et al. [15] propose a technique to be used for merging Event-Driven Process Chain (EPC)s. The technique first constructs a function graph that abstracts each EPC. In this functional graph, all connectors are removed and replaced with annotations attached to the edges. By using means of set unions, these graphs are merged. Then the annotations attached in the previous step are used to relocate the connectors. Two nodes are connected only if they have identical labels. They do not use contextual properties in matching activities among different models.

Li et al. [16] study merging variant models and creating a generic model so that the change distance between each original model to the merged model is minimal. Change distance is the minimum number of operations that transform a model into another. In this approach, the combined model does not necessarily subsume the original models.

Küster et al. [17] define tool requirements for merging processes. It lets the modelers find the differences among different models. The procedure given in the study does not automatically provide some merged processes.

Ryndina et al. [18] study a method for merging state machines. The study is on merging partial views of a process model, and it does not consider merging similar yet not identical activities.

Sun et al. [19] propose an approach in merging workflow nets. First, they map the activities in two process models to be merged. These mapped activities are directly copied to the merged model, and the remaining activities are added to the merged model by merge patterns. Their mapping technique merges two models combining activities that are seen as necessary for the new model. The approach needs information from the modeler. It does not consider location, time, or other contextual properties automatically yet takes into account somewhat indirectly through the modeler.

2.3. Flexibility in BPM

There is a vast number of studies conducted in process flexibility. In 2012, Reichert and Weber [20] had written a comprehensive book on process flexibility in process-aware information systems. Reichert and Weber [20] list four open challenges: End-User Assistance, Mobile Process Support, Real-World Aware Processes, and Flexibility

Support for Cross-Organizational Processes. Additionally, the book gives precious information like flexibility taxonomy, the evolution of process flexibility studies, recent studies, and flexibility classifications. According to Reichert and Weber [20], existing BPM flexibility studies mostly are about five challenges a process-aware information system should tackle with:

1. Variability in business processes (variants) should be made known to the process management system.

2. Preplanned routines should be integrated well for handling known exceptions during run-time.

3. Authorized users should be able to deviate from the predefined process in unplanned situations.

4. Processes may evolve due to environmental changes. Robustness, compliance, and correct execution of processes should be protected.

5. Some processes can be data- or user-centric rather than process-centric. In this type of processes, which are called knowledge-intensive processes, process model specifications can be done loosely in built-time and refined in run-time.

Stoitsev et al. [21] propose a system that lets the end-users collaboratively model the analysts' processes. This study's motivation is that the end-users know the actual processes better and take place in process modeling. In this study, a system using webservice-based activity tracking generates weakly structured process models and captures data on personal task management. Then, the developed model can be "adapted and reused for ad-hoc process support". The authors comment that this property results in enhanced process flexibility and complements formal workflows through deviations at runtime.

Liu et al. [22] use computer-based simulation techniques to model and analyze business processes. With their approach, they can "model business processes using event graphs and simulate the processes for common operational decision support".

Schonenberg [23] provides a taxonomy for process flexibility. It defines four flexibility types, namely: flexibility by definition, flexibility by deviation, flexibility by underspecification, and flexibility by change. Figure 2 shows the taxonomy provided by Schonenberg.

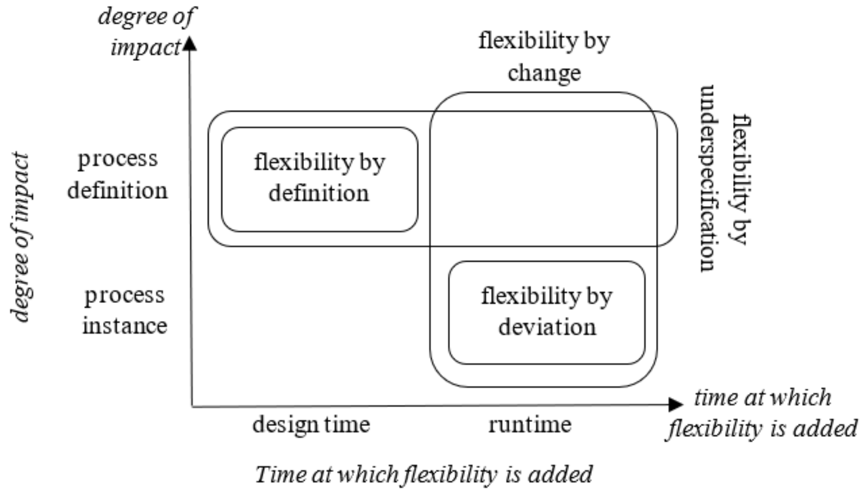

Figure 2 Taxonomy of process flexibility identifying four main flexibility types [23]

There are also other works ([24], [25], [26], [27], [28], [29], [30], [31]) around process flexibility which shows the importance of the topic.

Weber et al. [32] offer a language for personal process modeling. Their study focuses on the form-based processes and reduces redundant data entry required for these processes. Their future work will be on including other services like WSDL/SOAP, RESTful Web services, etc., and on having more "*flexible execution, so that users can roll-back process instances, e.g., to change some input values, and re-execute selected steps.*" Even though the study contributes to process flexibility in personal process modeling, it also does not fill the gap in the mobile process support area.

Adaptive Process Management Systems (APMS) create flexibility to some extent by supporting manual changes in the exception handling cases ([33], [34], and [35]), yet making frequent changes via APMS is time-consuming. So, parallel to Müller et al.'s [33] comment that traditional process management systems are rigid and support only predefined hard-to-alter processes, new approaches are needed to manage more complex and erratic processes.

2.4. Personal Process Management

Wang et al. [36] point out that new solutions are needed for the changeable and varied nature of personal processes. They narrow down the scope to scientific research processes. They aim to provide a personal workflow system for e-science that would improve scientific productivity. So, they develop a tool that shows local and web resources to the user and proposes business services representing domain activities. By applying this approach via web services, the user is kept away from different resources' complexity.

The user may automatically execute a process or select the underlying services individually. Their study shows that a tool would improve scientific productivity by providing flexible management and improving programming efficiency and quality.

Bova et al. [37] aim at providing a solution for keeping and sharing experience in conducting activities for a given task. So, they propose a framework that they have developed to be used in sharing personal processes. The framework consists of three layers: user, agent, and service layers. These layers work cooperatively to create process model (task) repositories, share or subscribe to these repositories, and query within these repositories. The framework also includes a function used to keep the historical information of user behavior, more precisely, how the user chooses a task to be used in a process. This function is called "task memory" which is used for making better recommendations to the user. The framework uses a declarative language.

Brambilla [38] focuses on organizing the interactions, dependencies, or constraints between activities and emphasizes that the language for modeling should be simple so that any person could accept and use it. He also considers the social perspective of process management. In his prototype tool, activities can be assigned to other users, and these users can be notified immediately through social networks.

Cui et al. [39] aim at proposing a method that can be used in building process models dynamically for individuals. This method is seen as a critical problem in managing personal processes because these processes depend heavily on the individuals, so they are not once modeled and often executed. Additionally, these processes must be more flexible in a pervasive computing environment as the context changes frequently. The model uses a semantic process repository. The method which is given in the study consists of "process ontology construction," "process requirement elicitation," and "process automatic building".

Görg and Bergmann [40] and Görg et al. [41] propose a PPM tool, named CAKE, as a part of a social network. They conduct these studies in the context of project WEDA, which aims to create value in private individuals' everyday business with knowledge from traditional workflow management. The tool lets the users construct their processes and keep track of these processes' execution. The process models can be shared with the other users for performing in the future. If needed, activities in process instances can be transferred to be completed by some other participants. One of the reasons why Görg et al. [41] use the social network is that a workflow engine can use existing services for task enactment to execute a personal workflow. They also claim that a network of people with similar interests can share experiences and participate in personal workflows. To reach these goals, Görg et al. [41] provide a new modeling language. Their proposal also includes capabilities to the user for searching processes from repositories and modifying these processes if needed or defining a new process from scratch. Görg and Bergmann [40] use the Delphi method and confirm that

- Individuals already use internet services to reach complex goals by completing a structured flow of activities (processes). These processes may have an association with friends or professionals.

- Social workflow services can create value for individuals in some scenarios.

- Features of discovering new workflows, adapting workflows, inviting new friends as workflow participants, automatically executing a workflow, and sharing relevant workflows.

Görg and Bergmann [40] also research if these applications would be accepted by people who do not process management experts. They try to find out what processes the users would desire to manage. The results show that individuals would use such process management services. Among the alternative scenarios they come up with, the most liked social process is searching for a new apartment, which is followed by organizing a relocation due to the need for moving to a different city or a job; and then finally attending a festival. The study shows that social workflow services would be accepted by individuals and would cover an essential gap in managing personal processes.

Hajimirsadeghi et al. [42] introduce a social network-based framework (named ProcessBook) for managing personal processes. The specific goals of the framework are explained as follows:

- Describing, modifying, and sharing personal process models

- Using the experience of individuals having similar goals

- Providing better approaches or feedback for problems

- Updating the individuals for process changes

The conceptual framework is explained in the paper, showing the modeling process, the knowledge capturing and sharing process, the filtering and querying capabilities, and the notification mechanism. Hajimirsadeghi et al. [43] extend the framework to capture users' experiences and make recommendations for new process executions. The user first creates a ToDoList composed of various tasks. These tasks have some precedence relationships. The system considers previous executions of the task flows for the defined goal. The previously executed task flows have some weights determined by the task's popularity and users' votes.

Hwang and Chen [44] aim to provide a model with related algebraic operations used in specifying and querying personal processes. Their prototype implementations include three components, the storage manager and query processor on the client-side and the process recommendation system on the server-side. A user may specify a personal process or query and use the recommended processes from the server. This study and its prototype implementation show great potential for mobile technologies to manage personal processes.

Lehner [45] points out the divergence between the process design and execution and says that the personal workflows should be flexible enough to be easily improved. So, the activities that are not there in the process model would not be performed manually. Lehner [45] asks how to transfer the benefits of using BPM to individuals of an organization. Then he extends the question for the business process modeling language choice, system flexibility for domain specialists, new feature development process, measuring the productivity change of individual employees for using personal BPM.

Sztyler et al. [46] aim at sharing some ideas on how process mining techniques can be used in self-tracking systems in personal health care. They emphasize the developments in wearable devices, sensor technology, and communication technologies. Data gathered from these technologies can be used to discover processes, monitor personal behaviors, find deviations from the reference model, and make operational support. The preliminary experiments are conducted by gathering data from seven individuals and analyzing these data. These experiments show that frequent patterns tracked could be extracted by collecting data from individuals through wearable devices or sensors. These patterns may change depending on the context, like the day of the week. The gathered data can optimize these patterns, define some reference models, and make some recommendations to the user.

Umuhoze et al. [47] aim to simplify business process modeling languages and make them more suitable for the end-users. They measure the effectiveness of the language variants by extracting qualitative and quantitative data in user modeling sessions. These modeling sessions show the authors that business process modeling languages can be simplified for the end-users, and this can be done objectively by using the proposed simplification process.

Hwang et al. [48] point out mobile personal computers can effectively be used in PPM. They also mention the importance of flexibility and other issues to be tackled like the personal process storage, graphical interface design, the worklist presentation, the triggering system, the temporal and spatial operations design.

Avenoğlu and Eren [49] propose a framework providing help and guidance for organizing daily activities. This framework gives the users the chance to model their daily activities in the form of workflows, which are adaptable at run-time according to context information collected in pervasive environments.

Xu et al. [50] propose a graph-based description language (Personal Process Description Graph - PPDG) to show control and data flows of personal processes. They also propose an approach to make graph queries in a personal process graph repository. The main goal is to provide a platform (named ProcessVidere) to describe, share, query, reuse, and analyze personal processes. The article mainly focuses on the details of the personal process description graphs, query templates, and performance. In a complementary study of Hsu et al. [51], an idea of similarity search over different PPDGs using both features of PPDG nodes and structure. This way, the searching mechanism won't work only depending on the keywords but also consider the structure of the activities and semantic similarity of words. In paper [52], Hsu et al. handle the case when all query constraints are not satisfied by a personal process description. They propose a general framework to be used in conducting aggregated searches over PPDG.

Study [53] is a good example of how a mobile application can support people in daily life in accomplishing daily life activities accurately and properly. In the study [53], a software framework is developed that employs both workflows and context information to model and enrich user activities, build automation, and support the user in managing personal processes.

2.5. Process Taxonomy

Taxonomies reduce confusion and improve understanding [54]. They help the researchers to understand and analyze the domains, which results in an improvement of these domains [55]. They build the knowledge core of research domains [55]. Nickerson et al. [7] list various studies showing the role of taxonomies in the information systems (IS) research literature and state that "classification is a fundamental mechanism for organizing knowledge." Classification creation is seen as necessary for more advanced theories [55].

In the BPM domain, there are many taxonomies proposing studies of different perspectives. [56] shows an ontological model and a BPM systems taxonomy. It also sketches the hierarchy of interface, execution engine, metrics, and subclasses applicable to software industry BPM systems. Shaw et al. [57] propose a BPM system architecture showing core technologies as building blocks similar to taxonomy classes. They classify the full set of levels and core technologies and how they constitute a BPM system. The study [54] depicts a taxonomy of BPM technology purposes.

The study [58] shows a taxonomy of business process and IS modeling techniques. This taxonomy aims to help the decision-makers evaluate and select appropriate modeling techniques considering the project needs. On the other hand, [59] gives a taxonomy of BPM project types, and by using multivariate data analysis techniques, it defines three major and two minor classes.

In the study [60], flow automation and BPM definitions are listed. A set of terms and concepts also supports it to provide clear communication in related industries. For this clarification, five categories are given: Administrative and Task Support (Visual), Application Independent, Application Specific (Preconfigured), Integration-Focused, and Team Process Support Tools (Collaborative).

In the study [61], Arevalo et al. give a time rule taxonomy to provide business temporal rules with the current BPMN standard.

In the study [62], Zhao et al. provide an exception taxonomy to find solutions in supporting exception handling in current business process programming languages for semantic web services.

In the study [63], four main classes in a taxonomy of change are suggested: “origin of change”, “type of change”, “time of change”, and “structural effect of change,” whereas in the study [64] BPM flexibility taxonomy with a focus of change is proposed with three classes which are abstraction level of change, properties of change, and subject of change. On the other hand, the study [65] shares a process flexibility taxonomy with four types: flexibility by change, deviation, design, and underspecification. These classes are chosen as a result of conducting a literature study.

The study [66] proposes an unstructured workflows taxonomy. This taxonomy aims to help in transforming these unstructured workflows into structured equivalents. The taxonomy is created by using control elements’ relationships of the workflows.

A systematic literature review is conducted, and then organizational information-processing theory is used in the study [67] to identify the process differences. The taxonomy is used for understanding the different management requirements for different processes so that wasted efforts would be minimized. The scope of this study covers organizational business processes.

In the medical domain, there are classifications for daily activities as well. Activities of Daily Living (ADL), Basic ADL, or Instrumental ADL are some terms used in the domain. Study [68] is one of these examples.

2.6. Decision Support Systems and Constraint Programming

In 2010 Suduc et al. [69] makes a study on showing the evaluation of the DSS domain. They point out that DSS evolved from stand-alone systems to distributed systems. They mention that in the first generation, DSS is more data-centered. Then, in the second generation providing better user interfaces is the primary concern. The third generation focuses on models, and finally, the fourth generation becomes web-based. They also point out that the number of articles written in this domain increases exponentially. Figure 3 shows the number of materials by decades searched and found on ScienceDirect.

By analyzing 1020 articles published between years 1990 and 2003, in 2005 Arnott and Pervan [70] shows that the DSS research is mainly focused on four areas: personal DSS (35.3%), group support systems (29.2%), intelligent DSS (14.4%) and large data-centered systems (EIS) (7.3%).

Using existing W3C standards, Crowley et al. [68] propose a framework that aggregates and links heterogeneous data from various sources like legacy systems, citizen sensor data, sensor data, open web data, transforming them to Linked Data. They aim to decrease the decision risk by aggregating many data sources to enable comprehensive analysis. This study converges the topics in DSS and Mobile Pervasive Computing domains.

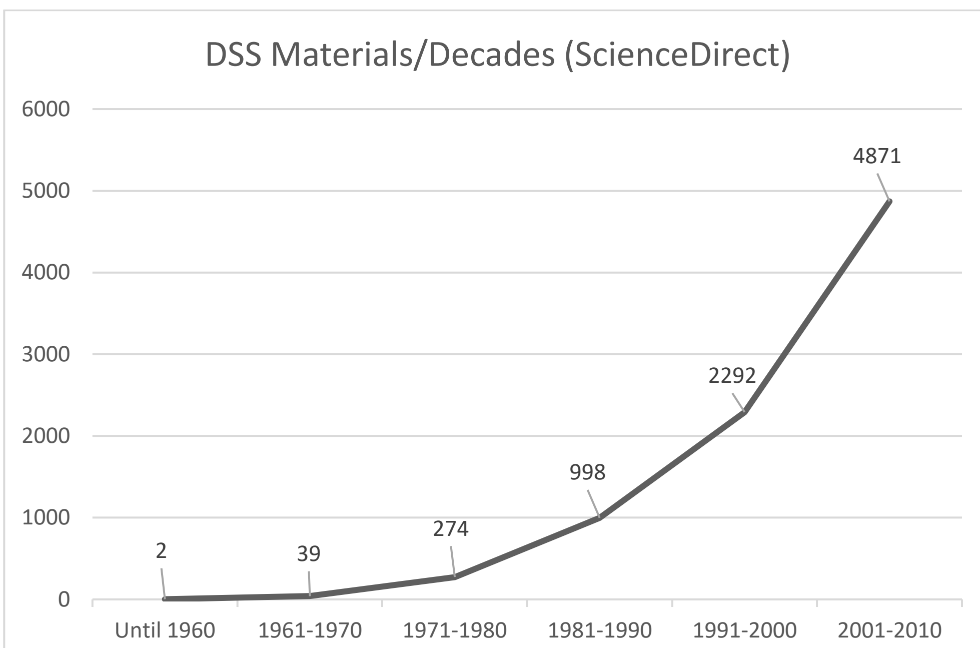

Figure 3 DSS materials by decades [69]

Costanzo and Faro [71] propose a real-time DSS that helps mobile users to reach their destination by considering both the main external conditions and personal constraints. The study only takes location services into account by saying external conditions. Personal constraints cover states like the age or health of the user.

Ivanov et al. [72] prefer using experimental methods for evaluating DSS effectiveness and efficiency. They work on disaster DSS, which requires "real-time responses and performance, more efficient user interfaces and are difficult to evaluate in a realistic environment." A case study is created in this study: evacuation from a town with flood risk. Simulation (agent-based modeling) is used for evaluating the contribution of personal DSS. Karbovskii et al. [73] conduct a similar study with Ivanov et al. [72] that uses agent-based modeling. This time simulation method is used in disaster time in a cloud computing environment. Depending on the results, people (agents) in the evacuation area are informed and directed via messaging.

The study [74] proposes a concept to support SMEs, combining knowledge-based document management and flexible workflow management. The approach consists of constraint satisfaction problem-solving. Imperative models are transformed into declarative constraints, and possible following work items are proposed.

In his book, Van der Aalst [75] mentions about process mining framework and 10 activities within it. Three of these are "detect", "predict", and "recommend". These three actions are used in online support to the user. In making recommendations, the approach taken in the process mining domain starts with using process logs, predicting the future from history. For instance, taking the average time it took to complete an activity is served as the prediction of the service time of that activity. Process mining-based time prediction of Aalst et al. [76] is an example of this type of approach.

Schonenberg et al. [77] suggest a recommendation service for choosing the next best action which can be used during the process execution. The system makes the recommendations based on similar past process executions by considering the specific optimization goals. In this study, some experiments are conducted to evaluate the recommendation system. The study has a similar plan to this current research. However, it does not consider the environmental effects (contextual parameters), and the available historical data bounds the recommendations.

2.7. Chapter Summary

In this chapter, the literature review results are shared starting from the BPM, then a specific topic within BPM: merging processes in BPM as one of the goals of this study is to find an efficient way of managing multiple processes by merging them and improving the execution of these processes. As flexibility is an essential issue in BPM and as in most cases, personal processes need to be managed flexibly, studies on flexibility in BPM are reviewed. Following that section, PPM and then process taxonomy-related studies are introduced. Finally, DSS and CP-related studies are shared because, in this research, a prototype application that could be used as a DSS for PPM using CP is developed.

Although these studies make essential contributions to the literature in various aspects, the focus on context-aware process recommendation is limited. Accordingly, we aim to contribute to the field by proposing a PPM taxonomy and a reference model for PPM systems, a CP model for making process execution plan recommendations without historical information.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. Introduction

A researcher should identify and follow an appropriate research methodology to generate useful outputs and contribute knowledge base of a particular research area [6].

This chapter describes how we carry out the study and presents the sound methodology that we use for the research based on existing literature. It shows the rigor and relevance of the study. Referencing the research pyramid suggested in the study [78], we justify the research paradigm and the methodology, and we describe the research methodology process and the validation. The chapter ends with the concluding remarks.

3.2. Research Pyramid

The study [78] suggests the Research Pyramid be a guiding tool in outlining a proper research methodology. The pyramid can be seen in Figure 4. Jonker and Pennink [78] state that the pyramid's goal is to guide the researcher in consciously structuring his research approach. For this reason, the researcher goes through the four levels of the research pyramid: paradigm, methodology, methods, and techniques.

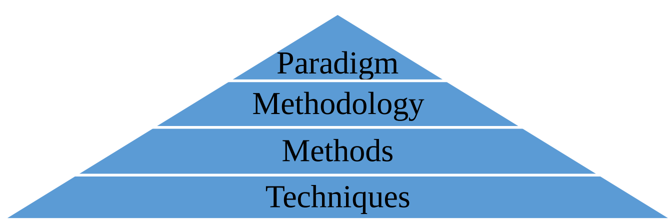

Figure 4 Research Pyramid [78]

3.2.1. Research Paradigm

A research paradigm is described as the base values and rules that shape researchers' thinking and behavior [78]. According to Vaishnavi and Kuechler [79], it is essential that the researcher knows the paradigm and its implications that the researcher uses. This study is conducted using the Design Science Paradigm suggested by [5].

3.2.2. Research Methodology

Research methodology describes the steps that the researcher goes throughout the research process. It starts from the problem definition whereas generally ends with the solution proposal and the insights gathered through the research. In this research, DSR guidelines proposed by Hevner et al. [5] and DSR methodology suggested by Peffers et al. [6] are used.

3.2.3. Research Methods

The research methodology is filled with various methods that give information on how to conduct the specific research. These methods are chosen following the paradigm and the methodology used. Hevner et al. [5] propose many methods to be used in a DSR type of study, which will be described in detail in the next sections.

3.2.4. Research Technique

The most concrete level of the pyramid is the research techniques level. The techniques may include the instruments or the tools used for conducting the research. These instruments or the tools are used following the methods used, supporting them to collect the desired artifacts.

3.3. Design Science Research

DSR is a research paradigm that leads the researcher to present practical relevance via useful artifacts and precise design theory formulations [2]. Within IS domain, DSR is an emerging paradigm, having increased attention year by year ([3], [6], [80]). Hevner et al. [5] suggest a succinct framework defining how to perform DSR in IS to build explicit IS artifacts as examples of methods, models, instantiations, and constructs. The IS research framework given in [5] can be seen in Figure 5.

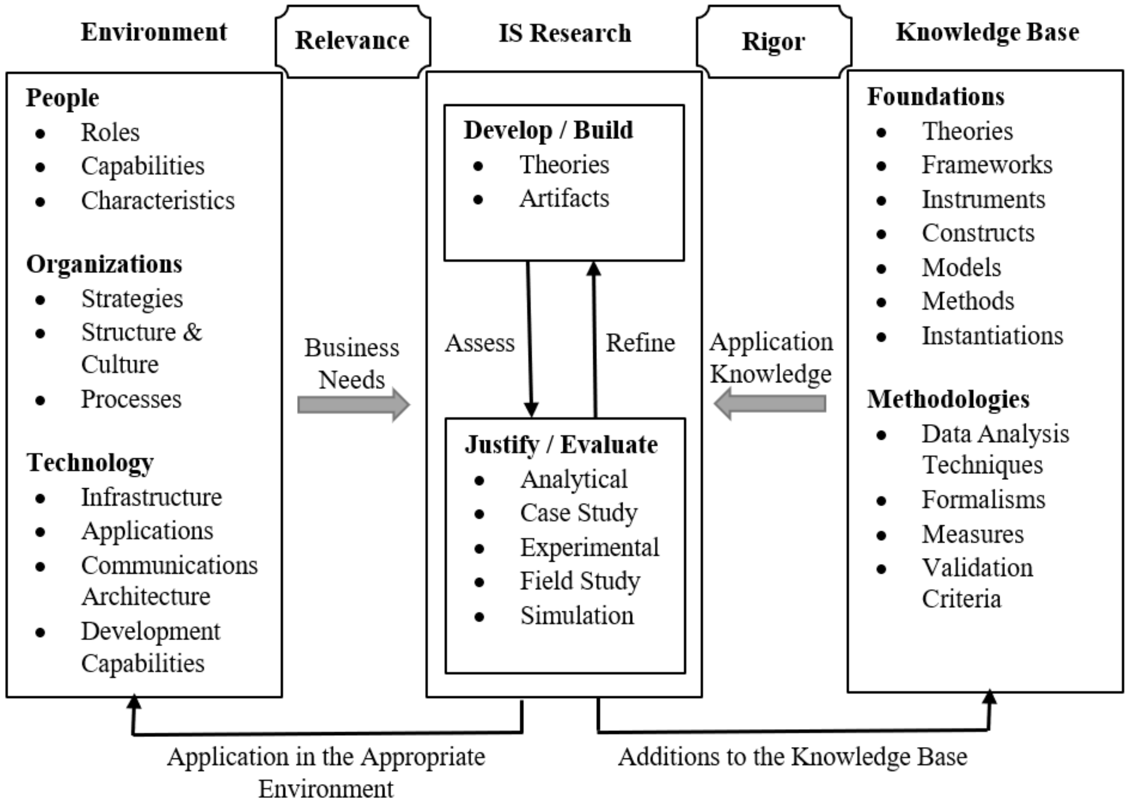

Figure 5 IS research framework [5]

In Hevner's framework (Figure 5), business needs are the primary inputs for an IS research, which points out that the research should be relevant concerning at least one of three environment components; people, organization, or technology. This research's main driving force comes from the people and organizations components as they are the most personal process-related ones. As the research proposes some improvement via filling the gap in the technology side, that component of the environment also has the driver role.

In addition to business needs, application knowledge has an essential role in this framework as well. Hevner et al. [5] state that the knowledge base provides raw materials that let the IS research be accomplished. Literature in BPM and PPM cover the central portion of the knowledge base for this research. CP studies also have an important contribution to the knowledge base of this research. In that sense, detailed descriptions of the knowledge base are given in this thesis report's literature review section.

3.4. Research Methodology Process

The DSR methodology suggested by Peffers et al. [6] provides both a mental and a process model for presenting DSR. The main aim of this methodology is to be consistent with prior literature. Although Peffers et al. [6] do not state that the suggested methodology is the only way to conduct a DSR, they argue that such a process model supports researchers in DSR in the right way. Figure 6 shows the Design Science Research Methodology (DSRM) Process Model suggested by Peffers et al. [6].

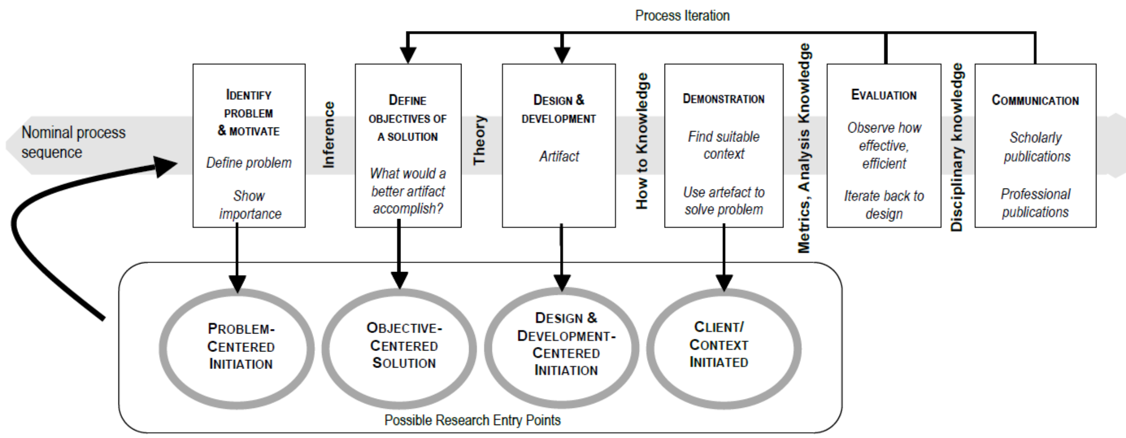

Figure 6 Design Science Research Methodology (DSRM) process model [6]

3.4.1. The Research Entry Point

From motivation to communication, the DSR process model is composed of six activities that form the entire research. There are also four possible research entry points: problem-centered initiation, objective-centered solution, design- and development-centered initiation, and client and context initiation. This research's entry point is problem-centered, so it starts with the first step, identifies the problem, and motivates. Figure 7 shows the specific model followed in this research.

3.4.2. Identify Problem and Motivate

The first activity in the DSRM process covers the problem definition and the justification of the solution value [6]. There are distinct views about where this motive should come from, which is "important and relevant problems" according to Hevner et al. [5].

This research focuses on how individuals would manage personal processes in their life in more effective ways. It aims to provide a taxonomy to understand personal processes' classifications, suggesting a reference model for future PPM systems, then finally creating a prototype application with a recommendation backbone supported by a CP model.

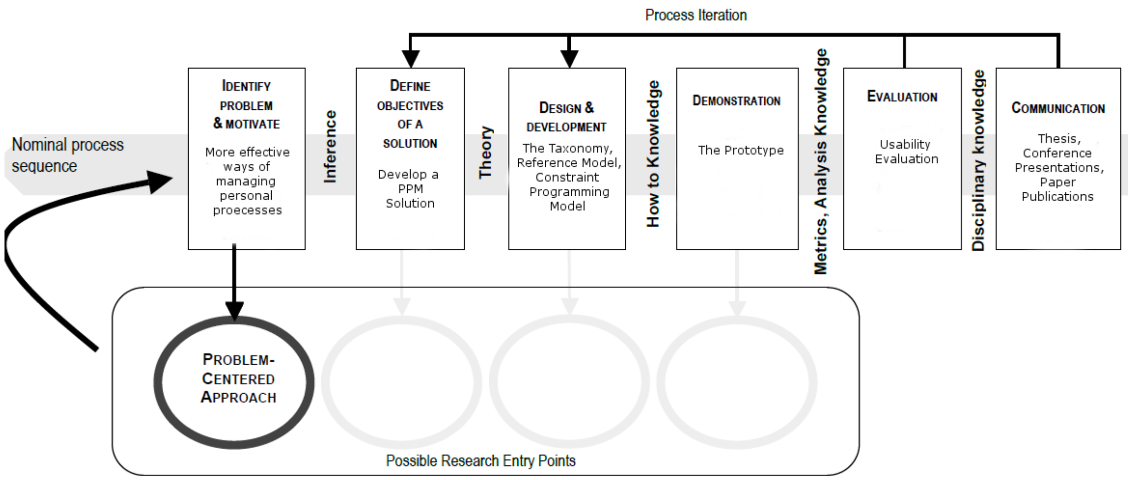

Figure 7 DSRM process model with the problem-centered approach entry point

3.4.3. Define Objectives of a Solution

In the DSRM process model, the second activity is defining the objectives of the proposed, which would be detailing the general identification given in activity one. These defined objectives could be qualitative as well as quantitative [6].

This research's qualitative objectives and the advantages of having a taxonomy, reference model, and PPM system as a personal recommendation system are described in corresponding chapters. Also, justification is supported with the design evaluation chapter.

3.4.4. Design and Development

This activity is related to creating the artifacts. The desired functionality, the artifacts' architecture, and the actual artifact are determined in this activity. Constructs, methods, models, and instantiations could be some potential artifacts [6].

In this research, a personal process taxonomy, a reference model for PPM systems, and a CP-supported mobile PPM system are the artifacts developed according to the identified objectives.

3.4.5. Demonstration

In the fourth activity, demonstrations of the artifacts are done, which could be done via a case study, experimentation, proof, a prototype, a simulation, or any other relevant way of showing the use of the proposed artifact.

In this study, taxonomy, reference model, and CP model are used for creating the prototype application, which is also tested with experimentations.

3.4.6. Evaluation

This activity has a very important place in the DSR process [5]. Evaluation activity covers observing and measuring the effectiveness of the artifacts in providing the expected solution. Hevner et al. [5] list five categories of evaluation methods. These are observational, analytical, experimental, testing, and descriptive, shown in Table 1.

Table 1 Design Evaluation Methods [5]

Category	Evaluation Method
1. Observational	*Case Study*: Study artifact in depth in business environment *Field Study*: Monitor use of artifact in multiple projects
2 Analytical	*Static Analysis*: Examine structure of artifact for static qualities (e.g., complexity) *Architecture Analysis*: Study fit of artifact into technical IS architecture *Optimization*: Demonstrate inherent optimal properties of artifact or provide optimality bounds on artifact behavior *Dynamic Analysis*: Study artifact in use for dynamic qualities (e.g., performance)
3. Experimental	*Controlled Experiment*: Study artifact in controlled environment for qualities (e.g., usability) *Simulation*: Execute artifact with artificial data
4. Testing	*Functional (Black Box) Testing*: Execute artifact interfaces to discover failures and identify defects *Structural (White Box) Testing*: Perform coverage testing of some metric (e.g., execution paths) in the artifact implementation
5. Descriptive	*Informed Argument*: Use information from the knowledge base (e.g., relevant research) to build a convincing argument for the artifact's utility *Scenarios*: Construct detailed scenarios around the artifact to demonstrate its utility

In this research, mainly experimental type of design evaluations and descriptive evaluations are done.

Table 2 Publication Schema for a Design Science Research Study [4]

Section	Content	Chapter
1. Introduction	*"Problem definition, problem significance/motivation, introduction to key concepts, research questions/objectives, scope of study, overview of methods and findings, theoretical and practical significance, structure of remainder of paper.* For DSR, the contents are similar, but the problem definition and research objectives should specify the goals that are required of the artifact to be developed."	Chapter 1
2. Literature Review	*"Prior work that is relevant to the study, including theories, empirical research studies and findings/reports from practice.* For DSR work, the prior literature surveyed should include any prior design theory/knowledge relating to the class of problems to be addressed, including artifacts that have already been developed to solve similar problems."	Chapter 2
3. Method	*"The research approach that was employed.* For DSR work, the specific DSR approach adopted should be explained with reference to existing authorities."	Chapter 3
4. Artifact Description	*"A concise description of the artifact at the appropriate level of abstraction to make a new contribution to the knowledge base.* This section (or sections) should occupy the major part of the paper. The format is likely to be variable but should include at least the description of the designed artifact and, perhaps, the design search process."	Chapter 4,5,6
5. Evaluation	*"Evidence that the artifact is useful.* The artifact is evaluated to demonstrate its worth with evidence addressing criteria such as validity, utility, quality, and efficacy."	Chapter 7
6. Discussion	*"Interpretation of the results: what the results mean and how they relate back to the objectives stated in the Introduction section. Can include: summary of what was learned, comparison with prior work, limitations, theoretical significance, practical significance, and areas requiring further work.* Research contributions are highlighted and the broad implications of the paper's results to research and practice are discussed."	Chapter 8
7. Conclusions	*"Concluding paragraphs that restate the important findings of the work.* Restates the main ideas in the contribution and why they are important."	Chapter 9

3.4.7. Communication of Research

Ph.D. thesis, journal and conference publications, conference presentations are some types of communication channels for sharing the knowledge collected or created in the research. Table 2 shows the publication schema for the DSR study suggested by Gregor and Hevner [4] and an added column giving the corresponding chapters in this thesis report.

3.5. Research Methodology Validation

Hevner et al. [5] suggest seven guidelines to validate the research methodology. These guidelines are provided to assist the researchers, reviewers, editors, and readers in recognizing the needs for an effective DSR [5]. We give a summary of these guidelines in Table 3. In this section, we explain each guideline and how it is implemented.

Table 3 Design-Science Research Guidelines [5]

Guideline	Description
Guideline 1: Design as an Artifact	*"Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation."*
Guideline 2: Problem Relevance	*"The objective of design-science research is to develop technology-based solutions to important and relevant business problems."*
Guideline 3: Design Evaluation	*"The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods."*
Guideline 4: Research Contributions	*"Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies."*
Guideline 5: Research Rigor	*"Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact."*
Guideline 6: Design as a Search Process	*"The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment."*
Guideline 7: Communication of Research	*"Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences."*

3.5.1. Design as an Artifact

In DSR studies, it is compulsory to create a purposeful artifact to address an essential organizational problem and effectively describe it [5]. In this study, we introduce three purposeful IT artifacts:

- Personal Process Taxonomy
- Reference Model for PPM Systems
- Prototype PPM System with a CP model

Personal Process Taxonomy is described in Chapter 4. It is developed by applying the method presented by [7]. There are four main classes and 22 sub-classes in this taxonomy, although it is flexible for additions in case new classes or subclasses are wanted to be added. The taxonomy's function is to direct practitioners and researchers by structuring personal process classes, clarifying the relationship among process types, and organizing the knowledge within the PPM domain. This knowledge ultimately would help practitioners and researchers in suggesting new methods that can be used in PPM.

Reference Model for PPM Systems is described in Chapter 5. The model has eight frontend, five backend, and three cross-cutting components. These components and the issues and challenges, which these components tackle are explained rigorously.

Prototype PPM System with a CP model is described in Chapter 6. The application is developed keeping in mind the structure of the reference model for PPM systems, with the focus on the optimization center component of the reference model. For this purpose, a CP model is constructed and used in the prototype personal recommendation system.

3.5.2. Problem Relevance

The problem domain of this research is in the management of personal processes that emerge in daily life of every individual. And in the end, the research tries to reach a highly accepted useful IS for these individuals.

3.5.3. Design Evaluation

This guideline focuses on the relevance of the DSR effort to the researchers "who plan, manage, design, implement, operate, and evaluate information systems and those who plan, manage, design, implement, operate, and evaluate the technologies that enable their development and implementation" [5].

The DSR activities in this study are conducted to help the researchers create information systems and technologies to help the individual manage their personal processes. It becomes harder for individuals to manage these processes as the number of activities and constraints increases. As stated earlier, experimental design evaluations are rigorously demonstrated to evaluate the design in this research.

3.5.4. Research Contributions

In this guideline, it is stated that the research should have clear contributions [5]. Three types of contributions are listed: the design artifact, foundations, and methodologies. In these terms, personal process taxonomy, reference model for PPM systems, and the prototype PPM system with a CP model are the main contributions of this study. The personal process taxonomy and reference model extend the knowledge base, whereas, with the prototype application, existing knowledge is applied in a new and innovative way. The experiments conducted using the prototype application also extended the knowledge base.

3.5.5. Research Rigor

This guideline points out the importance of the effective use of the knowledge base, whether the theoretical foundations or the research methodologies [5]. This research follows the DSR methodology proposed by Peffers et al. [6]. The research methodology process followed, and the corresponding activities are explained detailly in Section 3.4

3.5.6. Design as a Search Process

The iterative nature of designing solutions is emphasized in this guideline. Also, it is added that "design is a search process to discover an effective solution to problem" [5].

In this study, the artifacts are also developed and improved iteratively. For the taxonomy development, semi-structured interviews are conducted so that the limits would not be bound to the knowledge of the researchers. Then, the taxonomy development is done by following the method proposed by Nickerson, Varshney, and Muntermann [7], which has iterations in it. For the reference model, literature is analyzed rigorously, and the model is improved iteratively also with the feedback gathered from the domain experts. With each iteration, new components are added, some components are merged or improved. Finally, the prototype application is also iteratively developed. The CP model and the prototype implementation are tested by many participants in the experimentations. These experimentations also created valuable information to be used in reaching the desired end. The technological components are changed, and the structure is improved many times.

Even the underlying CP model implementation is once changed entirely for performance improvements.

3.5.7. Communication of Research

This guideline tells that it is important to present the research both to technology-oriented and management-oriented audiences.

For this purpose, in addition to the presentations made in a company environment to process management experts, the artifacts are presented in the following conferences:

- EURO2018 (http://euro2018valencia.com/) – 29th European Conference on Operational Research, Valencia. "Making schedule recommendations for managing personal processes by using a constraint programming model" by Sercan Oruç, P. Erhan Eren, Altan Koçyiğit, Sencer Yeralan

- CISTI2019 (http://cisti.eu) – 14th Iberian Conference on Information Systems and Technologies. "A Reference Model for Personal Process Management (PPM) Systems" by Sercan Oruç, P. Erhan Eren, Altan Koçyiğit

- I3E2019 (https://www.i3e2019.com) – The 18th IFIP Conference on e-Business, e-Services and e-Society. "A Taxonomy for Personal Processes: Results from A Semi-Structured Interview" by Sercan Oruç, P. Erhan Eren, Altan Koçyiğit, Sencer Yeralan

As a result of the last two conferences, the reference model for PPM systems paper [81] and personal process taxonomy paper [82] are published.

In addition to these conference publications, two journal papers are written to be published.

- "A Constraint Programming Model for Making Recommendations in Personal Process Management: A Design Science Research Approach" by Sercan Oruç, P. Erhan Eren, Altan Koçyiğit is submitted to Decision Support Systems, a journal of Elsevier, in December 2020. Reviews are collected in March 2021. Then, the revised manuscript is submitted in June 2021. Currently, the final results are expected from the editor.

- "A Systematic Literature Review on Personal Process Management" will be submitted to another journal. Which journal to be submitted is not decided yet.

3.6. Chapter Summary

This chapter describes the research methodology used in the research and justifies it. The chapter starts with the high-level research pyramid to give an overview of the research. Then a more detail on the paradigm and methodology used are given. Hevner et al.'s DSR as the research paradigm [5] and Peffers et al.'s DSR methodology research process model [6] are used to conduct the research. DSR paradigm gives an outline of research activities, leads the researcher to go through a rigorous research process, and declares a complete research methodology.

CHAPTER 4

PERSONAL PROCESS TAXONOMY

4.1. Introduction and Design Objectives

The objective of this chapter is to propose a personal process taxonomy. The taxonomy is developed by using the seven-step method proposed by Nickerson et al. [7]. This method is also used by many IS research, i.e. [67], [83]–[85]. The study [7] shows a better alternative than the ad hoc way of taxonomy development in the IS domain. The proposed method has requisite qualities that are developed based on well-established literature on developing a taxonomy.

Before developing a taxonomy, semi-structured interviews with 20 people from different age and occupation groups are conducted to collect personal process-related information. In these interviews, more than 60 process examples are listed. An inductive taxonomy development approach is applied with these processes following the method in the study [7]. Personal process taxonomy is defined step by step by listing classes, subclasses, and their properties. Also, each of these subclasses is illustrated by using examples.

4.2. Data Collection Using Semi-Structured Interview

Qualitative researchers use interviewing as an effective method to gather insights about things that cannot be observed, like attitudes, comments, experiences, intentions, perceptions, reactions, and thoughts [86]. For that same reason, in this study, semi-structured interviews are conducted to gather information from a diverse population. As it is stated in the study [87], semi-structured interviews may provide many possibilities. Although the interview has a structure to some level to lead to a specific topic, it also does have too tight boundaries for letting the participants create and share new ideas. Mostly open-ended questions are asked so that the discovery and gathering of unforeseen or unpredicted information become possible.

In this research, diversity sampling, a type of purposive or judgmental sampling, is used for maximum variation. Interviewed 20 people have 18 distinct occupations. Selecting the participants was done following the minimum conditions. These were that the participant should be using a mobile device and that the participant should be actively managing their personal processes. The diversity of the sample population is reflected by choosing from different age groups, occupations, genders, and education degrees as much as possible. Figure 8 shows the age distribution of participants. The youngest and the oldest participants are 22 and 60 years old correspondingly. Figure 9 shows the education levels of the participants.

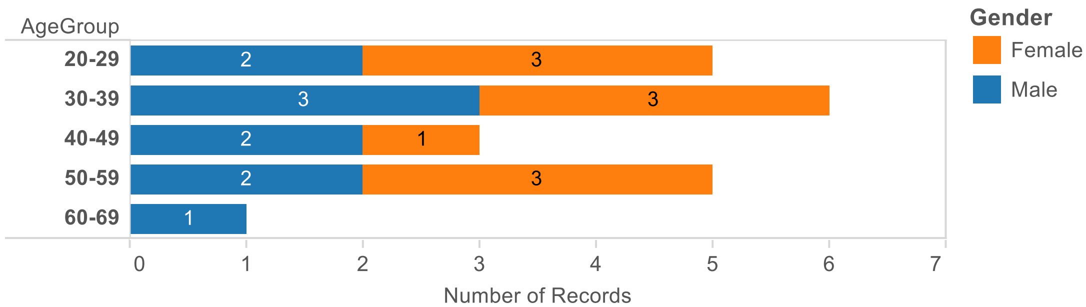

Figure 8 Age distribution

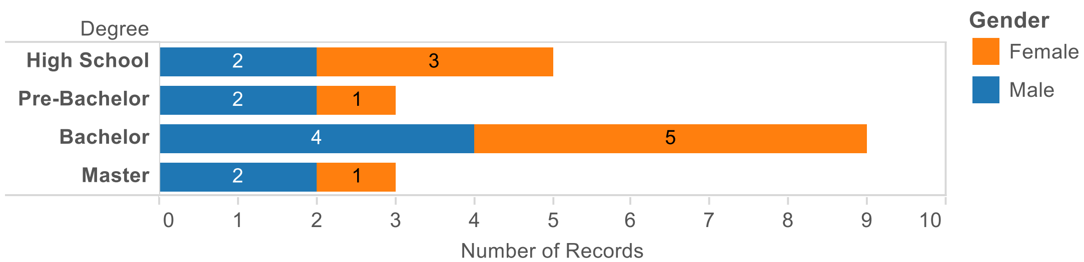

Figure 9 Educational degree distribution

4.3. Seven Steps of Taxonomy Development

The method proposed by Nickerson, Varshney, and Muntermann [7] is followed to develop the personal processes taxonomy using the data gathered from the semi-structured interviews. The taxonomy development method lists the seven steps given in Figure 10. Three iterations are performed to end the taxonomy development process.

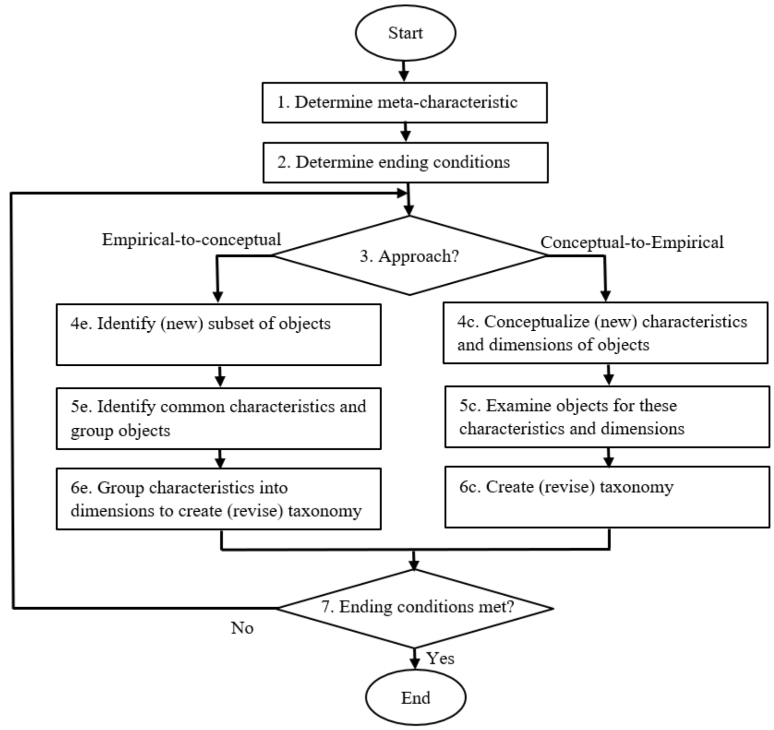

Figure 10 The taxonomy development method [7]

4.3.1. Step 1 – Determine meta-characteristics.

Study [7] defines meta-characteristic as "the most comprehensive characteristic that will serve as the basis for the choice of characteristics in the taxonomy". The goal in creating a personal process taxonomy is to structure personal process knowledge. Researchers and practitioners interested in personal processes are the target users. In the light of the personal process taxonomy, these target users can develop new applications, methods, or approaches for PPM. The taxonomy scope is bounded by the processes of people who use a mobile device and actively manage their personal processes. In this sense, the personal processes of a child using a mobile phone yet living a parent-dependent life or processes of a person living independently in a community yet not using a mobile device are not within the scope of this taxonomy. In accordance with these conditions, the meta-characteristic of the taxonomy is defined as a "connection between the management approach of the process owner and the personal process".

4.3.2. Step 2 – Determine ending conditions.

Study [7] proposes eight objective and five subjective ending conditions. These are used in this taxonomy development to decide when to end the taxonomy development process.

The objective ending conditions are defined as follows [7]:

- *"All objects or a representative sample of objects have been examined*
- *No object was merged with a similar object or split into multiple objects in the last iteration*
- *At least one object is classified under every characteristics of every dimension*
- *No new dimensions or characteristics were added in the last Iteration*
- *No dimensions or characteristics were merged or split in the last iteration*
- *Every dimension is unique and not repeated (i.e., there is no dimension duplication)*
- *Every characteristic is unique within its dimension (i.e., there is no characteristic duplication within a dimension)*
- *Each cell (combination of characteristics) is unique and is not repeated (i.e., there is no cell duplication)"*

The subjective ending conditions are defined as follows [7]:

- *"Concise*
- *Robust*
- *Comprehensive*
- *Extendible Explanatory"*

4.3.3. Step 3 – Approach.

For all three iterations, an empirical-to-conceptual or, in other words, an inductive approach is used.

4.3.4. Steps 4, 5, and 6 – Identify a Subset of Objects, Identify Common Characteristics and Group Objects, Group Characteristics into Dimensions to Create Taxonomy.

In each iteration, we evaluated a new subset of personal processes gathered from the semi-structured interview. At the end of the three iterations, all the personal processes collected via the semi-structured interviews are evaluated. As a result of this, the following common characteristics are formed:

- Essential: Some processes are essential to have an independent daily life.
- Optional: Again, to have an independent daily life, some processes are optional.
- Routine: Some processes are routinely performed.
- Ad Hoc: Yet some processes are performed irregularly.
- Obliged: Some processes are completed to fulfill some obligations. These processes emerge from something the person owns or is responsible for.
- Not Obliged: Some processes emerge from something other than the things that the person owns or is responsible for.

These characteristics are grouped into three dimensions:

- D1: Necessity (Essential, Optional)
- D2: Occurrence (Routine, Ad Hoc)
- D3: Obligation (Obliged, Not Obliged)

4.3.5. Step 7 – Ending Conditions Met?

As the ending conditions are met at the end of the third iteration, the taxonomy development is concluded at that stage.

4.4. Personal Process Taxonomy

A personal process taxonomy is defined by using the characteristics given in the previous section. The taxonomy can be found in Table 4. The process examples that have been written down in the semi-structured interviews are grouped into four classes: Diversions, Emergencies, Instrumental Activities of Daily Living (IADL), and Responsibilities. These four classes totally have 22 subclasses. The quality attributes, which are given in [7] as concise, robust, comprehensive, extendible, and explanatory, are considered during the taxonomy development process.

Table 4 Personal Process Taxonomy

		D1: Necessity		D2: Occurrence		D3: Obligation	
		Essential	Optional	Routine	Ad Hoc	Obliged	Not Obliged
Diversions	Exercising		*	*	*		*
	Hobbies		*	*	*		*
	Social Activities		*	*	*		*
	Traveling		*	*	*		*
Emergencies	Accidents	*			*		*
	Injuries and Sickness	*			*		*
	Missing Flight/Train/Bus Case	*			*		*
	Lost Wallet Case	*			*		*
IADL	Handling Finances	*		*			*
	Housework	*		*			*
	Mode of Transportation	*		*			*
	Preparing Meals	*		*			*
	Shopping	*		*			*
	Taking Medication as Prescribed	*		*			*
	Use Forms of Communication	*		*			*
Responsibilities	Business Processes		*	*	*	*	
	Care of Pets		*	*	*	*	
	Child Rearing		*	*	*	*	
	Citizenship Responsibilities		*	*	*	*	
	Garden Care		*	*	*	*	
	Real Estate Care		*	*	*	*	
	Vehicle Care		*	*	*	*	

For clarity and ease of description, the classes will be explained in the following order: IADL, Responsibilities, Diversions, and Emergencies.

4.4.1. Instrumental Activities of Daily Living

In healthcare, Activities of Daily Living (ADL), Basic Activities of Daily Living (BADL), and IADL are widely known terms.

BADL are essential for fundamental functioning, whereas IADL are needed to have an independent life in a community. For building the personal process taxonomy, IADL is considered instead of BADL, as via using IS, it would be more effective to manage IADL more than BADL. BADL covers “bathing”, “dressing”, “grooming”, “self-feeding”, “physical ambulation”, and “toilet hygiene” [68].

There are seven subclasses in the following adjustment of IADL listed in [68]:

- Handling finances (declared as “ability to handle finances” in [68]),
- Housework (declared as “housekeeping” and “laundry” in [68]),
- Mode of transportation,
- Preparing meals (declared as “food preparation” in [68]),
- Shopping,
- Taking medication as prescribed (declared as “responsibility for own medications” in [68]),
- and Use a form of communication (declared as “ability to phone” in [68])

Handling Finances: Although money management is mostly about making decisions, processes can also be very important, as in the case of payment timings for invoices.

Housework: An example process that arises after dinner would have the following activities: clearing the table, charging the dishwasher, starting the dishwasher, wiping the table, sweeping the ground, emptying the dishwasher, placing the dishes in the cupboards.

Mode of Transportation: Using various means of transport can lead to distinct processes. For example, going from one point to another in a town by mass transportation may have activities such as getting on a bus number X, then going 2 tram stations, lastly walking 400 meters.

Preparing Meals: Any dish recipe that lists activities to be finished in a particular order is an excellent illustration of a process form “Preparing Meals.”

Shopping: An individual may have a long list of shopping items. There could be many options for shops and products. The timing, following the discounts, or proximity to the stores may also be that individual’s some possible issues. If that individual wants to optimize the time and money he or she spends or the quality he or she buys, the process of shopping becomes computationally more complex.

Taking Medication as Prescribed: It is a principal component of any medical practice to make use of medication. The timing and dosage of medication are usually significant. So, it becomes essential to track the process.

Use A Form of Communication: This subclass consists of numerous atomic activities such as making a phone call or writing an e-mail. Some simple processes can be created by combining these activities with other adjacent activities. For example, someone starting his or her computer and sending an e-mail (signing in, writing the e-mail, writing lists to-cc-bcc, sending the e-mail).

4.4.2. Responsibilities

This class consists of processes that emerge from the things that the person owns or is responsible for. For instance, if the person owns a dog, she should handle the processes regarding dog care like tracking the vaccination guidelines or meeting the daily needs of walking or feeding. Although there are fewer than ten subclasses listed under the class "responsibilities", the number can easily increase depending on the variety of belongings the person has.

Business Processes: Business processes are for organizational objectives. If a person has a job, then this person would have activities of this type. From this person's perspective, business processes correspond to a set of responsibilities in this person's personal life. Depending on many factors like the organizational culture and policies or this person's preferences, these processes sometimes twist with the other, more personal processes. In the first situation, this set of processes could be managed more effectively by managing them comprehensively.

Care of Pets: Some instances would be following the vaccination schedules of the pet or feeding the cat.

Child Rearing: Some example activities would be playing, feeding, or taking the child to a doctor.

Citizenship Responsibilities: Some processes are a result of having citizenship from a country. Some instances are voting, compulsory military service, or serving jury duty.

Garden Care: Watering the grass, checking the weeds, disinfecting the tools, and fertilizing are some activities that may take place in garden care processes.

Real Estate Care: For instance, a person having a house should complete house maintenance tasks in the lifespan of that house, like inspecting the fire extinguisher, getting the air conditioner ready for the summer, getting the chimney cleaned or paying the taxes of the house.

Vehicle Care: Cleaning the car, changing the tires, or making the insurance payments are some examples.

4.4.3. Diversions

"Diversions" is the class of processes that divert from IADL processes and responsibilities. The motivations or causes behind these processes are intangible concepts like curiosity, happiness, health, etc.

Exercising: This subclass contains processes that are mostly structured. Domain experts may create these processes, and individuals may follow them.

Hobbies: Some example activities that would take place in the process of learning mandolin would include activities like following a course, doing rhythm training, practicing scales, and improving the technique.

Social Activities: This subclass consists of social organizations like gathering activities with some friends or organizing a barbeque day. Typical processes within this subclass are mostly people-centric as the main aim of these processes is consorting with other people.

Traveling: Buying a flight ticket, arranging a hotel, finding the attraction points, and scheduling the activities to do can be given as examples of activities and relations that would form processes of traveling type.

4.4.4. Emergencies

The last class covers processes that are performed in unplanned situations like "what should an individual do when that individual has lost his or her laptop?" or "what should a person do just after missing a flight?". The following four examples are collected from the conducted semi-structured interviews. New example cases can be added to these subclasses with the latest stories people have.

Accidents: This type of processes consists of activities performed in the case of having an accident.

Injuries: This type of processes consists of activities performed in the case of having an injury.

Lost Wallet Case: If a person lost a wallet, what would be the best set of activities to do? This set of activities and the order would create a process. One answer could be: the person should remember the last time he or she saw the wallet, and ask the people who may have seen it and check the locations he or she walked through since then. If that person cannot get a positive reply from those people, he or she should call the banks depending on the debit or credit cards in the wallet so that the cards could be canceled. That person should also inform the police about the lost ID case. Depending on the objects that person has lost together with the wallet, the process may have additional activities. Depending on the urgency and the importance of the activities, the order of those activities would be decided.

Missing Flight/Train/Bus Case: The set of activities that a person would perform when that person misses a flight, train, or bus, etc.

4.5. Chapter Summary

In this chapter, a personal processes taxonomy is proposed by applying the method presented by [7]. The method stands on acknowledged taxonomy development literature [7]. Empirical results of the semi-structured interviews that are conducted with a varied population are used as the input data in developing the taxonomy. As a result of this endeavor, four main classes with 22 sub-classes formed the personal process taxonomy. The taxonomy is flexible for extensions if new classes and subclasses are wanted to be added in the future. The following questions would help in defining the properties or attributes of corresponding subclasses and the related processes.

How frequently is the process executed? Although the frequency of the process execution of some type of processes is not used in creating this taxonomy, how frequently a person performs a process would also be used as a dimension.

Some personal processes are performed just once or twice in a lifetime, which could be defined as low-frequency processes, as in the example of marriage. On the other hand, some personal processes are performed much more frequently, which could be defined as high-frequency processes like preparing dinner. There could also be some other personal processes that could have a frequency less than high but more than low-frequency personal processes. These processes could be called medium frequency processes, such as registering a course in a university. Although it is hard to specify the frequency thresholds to define which processes are in low, medium, or high-frequency classes, and the thresholds may even change from individual to individual, having fuzzy thresholds for frequency classes does not change the importance of having those classes.

How important/critical/serious is the process? Some processes can be considered more important comparing to others. The activities within those processes must be completed without any errors. The process of following medical treatment routines is more critical than a travel-related process. Some activities in traveling a country may be skipped without any serious consequences. Yet, in the example of a medical treatment-related process, skipping an activity would have serious consequences.

Does the process have a legislative, a regulation, or some other strict process definition? If the process is executed in accordance with legislation, then it is expected that the actions should be completed exactly. The case if the process is in alignment with a legislative or not would have an impact on the flexibility of that process. This type of processes also has an important place in personal lives. Some examples could be child adoption or driver's license registration processes.

Is the process data-driven or judgment-driven? Some processes can be managed more effectively by solely using the available data and some predefined objectives like minimizing time, money, or energy consumption. On the other hand, other processes are affected more by the judgments of the person. The process of profession selection is more like a judgment-driven process than a data-driven process, whereas visa application process is a data-driven process.

The sample size and magnitude of the semi-structured interview are rather restricted, as this work is considered as an initial assessment of the validity of the approach and to investigate its expected success.

CHAPTER 5

REFERENCE MODEL FOR PPM SYSTEMS

5.1. Introduction and Design Objectives

The study [36] states that because of the erratic and varied nature of personal processes, the need for new solutions arises in PPM. As the context changes intermittently in personal lives, personal processes should be managed more flexibly [39]. By arranging flexible management and enhancing programming efficiency and quality, a tool would increase the productivity of PPM [36]. [40] says that individuals would accept to use a system with social workflow competencies, and this system would fill a significant gap in PPM.

In the Introduction section of this thesis, some scenarios are given to understand the characteristics of personal processes and what type of questions are asked in PPM. In this section, to extend that understating even further, issues and challenges in PPM are formalized first. After this, a reference model to be used in developing PPM systems is given.

5.2. A Sample Process Model of PPM

For each step of PPM, the system should support the user in various ways. These steps include a series of decision-making, performing, and monitoring tasks. Figure 11 shows a sample process model of PPM.

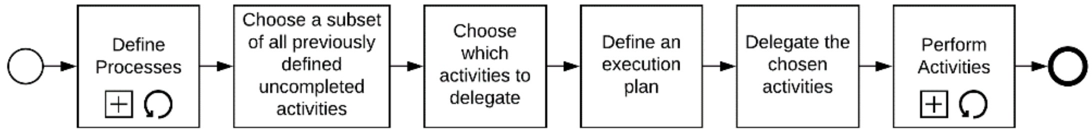

Figure 11 Sample process model for managing personal processes

The subprocess details of activity “Define Processes” and “Perform Activities” are given in Figure 12 and Figure 13, respectively. These definitions may change from one person to another person in essential ways. Yet still, having a sample process model is convenient to understand the issues and challenges in PPM.

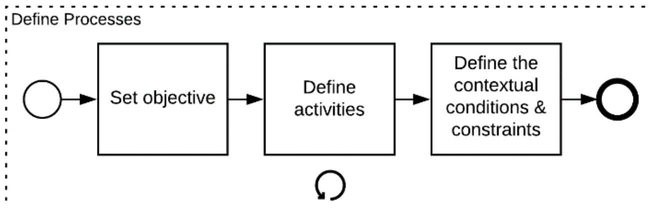

Figure 12 Subprocess model for managing personal processes: “Define Processes”

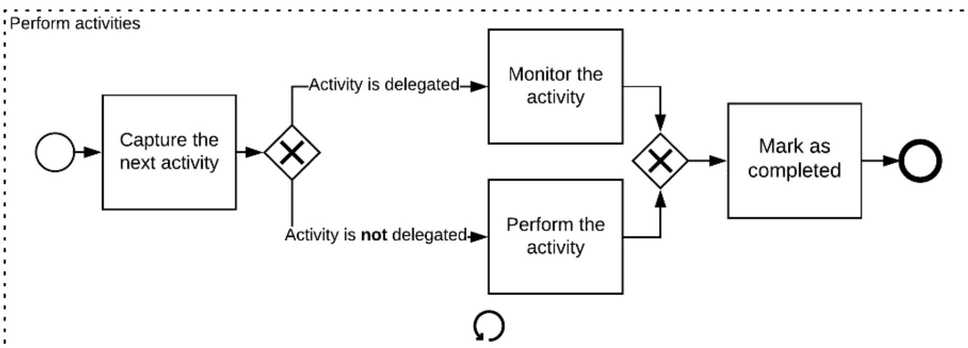

Figure 13 Subprocess model for managing personal processes: “Perform Activities”

To describe the steps in Figure 11, Figure 12, and Figure 13, the motivational scenario “*Planning a Day*” given in the Introduction section is used.

Set objective. The objective is to get a transcript from the university, meet with the mother, and do utility registrations in minimum time and effort.

Define activities. Mete may list the activities to be completed using his knowledge. Or, if he does not know, he may learn the activities to be completed in some way, e.g., checking some web pages or asking some friends to discover the needed tasks or activities to do utility registrations.

Define the contextual conditions and constraints. Time windows and traffic status would be two examples of contextual conditions and constraints. For example, for water registration, a potential user cannot do the registration after 18:00. The traffic on the roads and the queue length before registration desks also may change depending on the time of the day.

Choose a subset of all previously defined uncompleted activities. Mete may have some other uncompleted activities on his to-do list, like fixing his TV, reading a book, and cleaning the house. Yet, he wants to prioritize getting the transcript, meeting with the mother, and completing the registrations. So, he decides to plan only these processes and related activities.

Choose which activities to delegate. He chooses one of the activities on his list for her friend Dora, i.e., getting the transcript from the university.

Delegate the chosen activities. Mete talks with his friend Dora and asks her if she could get the transcript.

Define an execution plan. Mete orders the activities the five processes that he wants to complete within the day, i.e., calling her mother, then to a restaurant to arrange the lunch, going to location B, C, and D given in Figure 1, and gathering earthquake insurance document and photocopying ID card for gas registration.

Monitor the delegated activities. Mete calls his friend Dora to ask if she got the transcript from the university. If the answer is no, then he asks her when she can take it.

Perform not delegated activities. Mete performs not delegated activities during the day.

Mark as completed. When Dora takes and brings the transcript to Mete, and also when Mete completes the listed activities, he marks the activities as completed either in his mind or on his checklist.

5.3. Issues and Challenges

If the number of processes to manage as well as the number of activities in these processes increases, and if the mentioned processes become more complex with new transitions or constraints, the management of these personal processes would create more cognitive load as well. For instance, what if Mete's car runs out of fuel? What if when Mete arrived at the electricity registration desk, the queue is exceptionally long? PPM system should bring some core functionalities in a way that the management of personal processes would form a minimum cognitive load. PPM system would work like a personal assistant who helps to complete the processes both effectively and efficiently. The following list gives the issues and challenges in PPM:

Flexibility. Flexibility is a critical issue in PPM because personal processes are highly dependent on the person and the context information. It is not surprising that flexibility is considered an essential feature by many PPM related studies, including [36], [38]–[45], [48], [50]–[52].

Reachability. The system has the potential to integrate every step in personal life. So, it is critical to have reachability anytime, anywhere. For that reason, mobile personal computers can effectively be used in PPM [48]. Technological momentum in wearable devices, sensors, and communication also supports this [46].

Context Awareness. Sometimes the day of the month, time of the day, the weather, or the location, etc., may have an effect on the decision of when or at which order to perform an activity. So, the system should take the context information into account as well. [48] also points out the importance of temporal and spatial operations design.

Usability and Acceptance. The system should be embraced by the user so that the cooperation of PPM could be done effectively. Functionalities should be easily used. Graphical interface design is also essential [48]. Process modeling languages can be simplified for the end-users [88].

Decision Support. The system would help the user in deciding which activity to perform next, which activity to delegate, which process model to follow. This could be done by leveraging optimization models or using historical data by using process mining techniques [46]. Data collected from devices can be used in process discovery, personal behavior monitoring, checking deviations from the reference model, and operational support [46]. As an example, [43] is a study of capturing users' experiences and making recommendations for new process executions.

Monitoring. The state of the processes, activities, and contextual information, as well as the historical information, would be valuable to create insights for the user.

Reminding. Depending on the context information and the activity, the system would advise or remind the user to take some actions. This would increase the efficiency and effectiveness gathered in PPM. For instance, in the "Planning a Day" scenario, the system may advise Mete to buy the magazine that is on his to-buy list when he passes by the bookstore.

Using predefined processes. In some cases, the user may not know all the necessary activities to perform to complete a process. Even in the case that the user knows the activities to complete, having some predefined processes would decrease the effort needed to manage these processes. Process definitions could be searched and used for reaching the objectives of the user. The goal of [44] is to provide a model with related algebraic operations that are used to specify and query personal processes. A searching mechanism is proposed by [51], considering both the keywords and the structure of the activities and semantic similarity of words. [52] also deals with the case when a personal process description is not satisfying all the constraints of a query.

Defining new processes. In some instances, a predefined fitting process would not be possible to be used. So, the user would choose to define a new process. As [45] points out, personal process modeling language should be simple to have user acceptance. To show personal process control and data flows and to describe, query, analyze, share, and reuse personal processes, [50] proposes a graph-based description language. A new modeling language is also provided by [41] for these purposes.

Modifying predefined processes. In some instances, modifying a predefined process is preferable as it would increase the fit of that process to the user's objective. [45] also emphasizes the discrepancy between the process design and execution and adds that it should be possible for the users to modify the processes by the individual person.

Storing historical data. Historical data is essential in supporting various functionalities, some of which are discussed before in this chapter. The importance of keeping and managing personal process data is also pointed out by [44], [48].

Sharing and subscribing to processes. The user may have gathered some processes from public libraries or may have created some other processes and keep them in the private library. These processes could be shared among different users as in the framework proposed by [37]. Social network integrations, as in the examples of [38], [89], would also increase the effectiveness of PPM can be increased. During task enactment, people may participate as proposed by [41], which could be considered as another dimension from a social perspective.

Marking the activities. Using the completion criteria of the activities and the information that the system has, it may figure out if an activity is performed or not. If the system is not filled with enough information for completion criteria check, the user would also have the option to mark an activity as completed, canceled, or some other alternative state.

The above-mentioned issues and challenges would stimulate a large number of research topics. Successful implementations that satisfy the corresponding needs would decrease the cognitive complexity of PPM.

5.4. Reference Model Overview

A reference model for PPM systems to deal with the issues and challenges listed in the previous subsection is proposed in this chapter. This subsection will give an overview of a reference model for PPM systems as it is sketched in Figure 14. The user manages the personal processes with the support of a PPM system that has frontend and backend components. The backend is composed of a group of services and servers that have the computational power and the collective knowledge base. The frontend is composed of mobile and ubiquitous technologies and applications that mediate the communication between the backend and the users and also collect information from the environment.

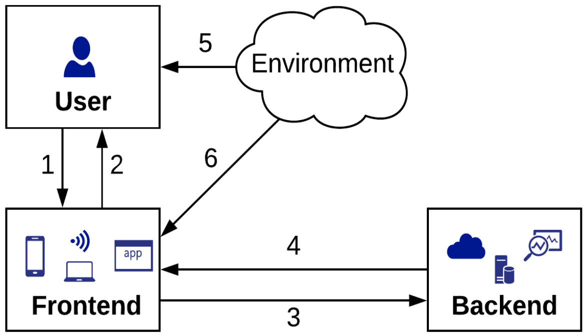

Figure 14 The proposed reference model for PPM systems overview

The user and the frontend could be in the same location, whereas the backend would be in a different location in many scenarios. The definitions of each arrow in Figure 14 are explained in Table 5.

Table 5 Reference Model Information Flow Descriptions

Arrow#	Description
1	The user chooses the processes to be completed. The objectives are set by the user. Sometimes an activity is marked as completed, additional constraints and priorities are set.
2	The statuses of activities/processes are reported to the user by the frontend. When the conditions are met, it also reminds the user to take some actions.
3	Collected information transfer from the frontend is to the backend
4	The optimal execution plan and answers to the user's following example questions are given by the backend: Which activity to perform? When to perform the remaining activities? How is process completion performance?
5	The environment has an effect on the user's decisions and actions.
6	Context information from the environment is collected by the frontend.

Figure 15 shows the proposed reference model components.

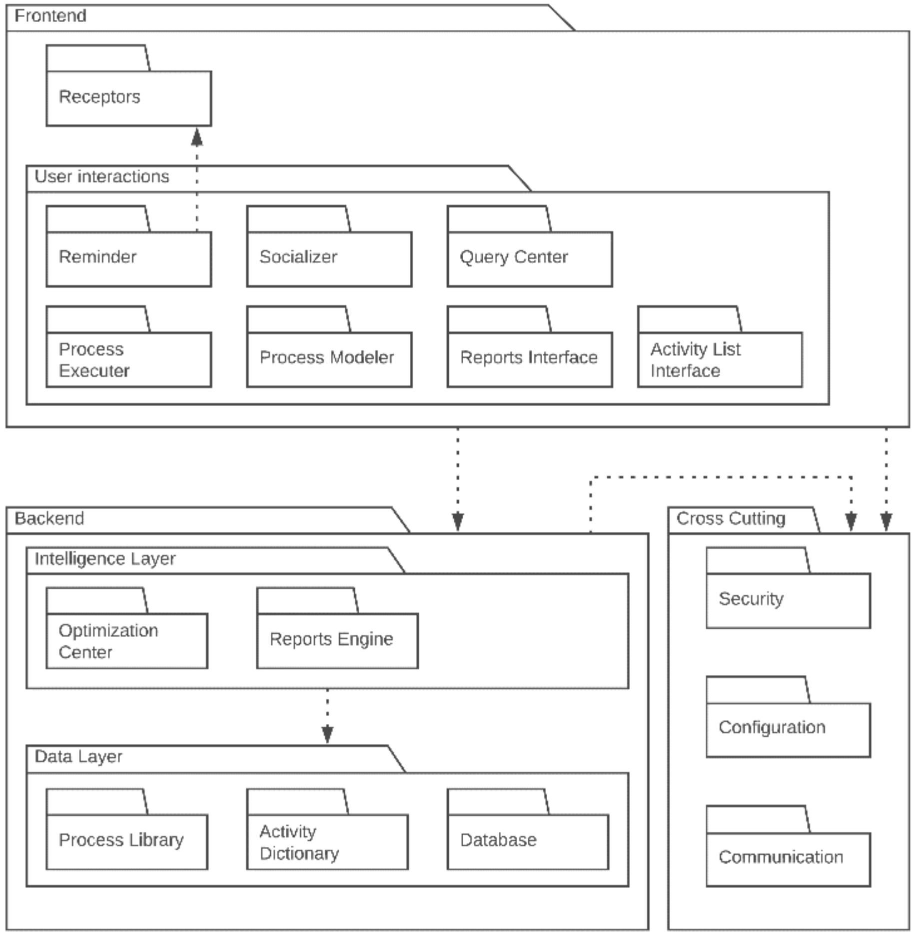

Figure 15 Reference model components (UML Package Diagram)

5.5. Frontend Components

Receptors. Context information and user preferences are collected by the Receptors in visual, aural, or kinesthetic ways. Context information could be light, location, weather, time, the health of the user, inclination, noise, etc. On top of these, user preferences could be collected with speech recognition techniques or in a written way. Other components of the system consume the collected information.

Reminder. Reminder checks the conditions for the activities defined in the user processes. It informs the user that the activity can be performed if the conditions are met. For example, considering the “Planning a Day” scenario, if Mete has an activity of “buying paper” with no urgency, this activity would not be in the first activities of the execution plan. But, if Mete passes by a stationary, the Reminder component may suggest buying that book.

Socializer. This component lets the users share their processes and activities with their friends, request activity delegation to and from their friends, rate or comment processes, and make recommendations.

Query Center. The users can query their own private libraries, public process libraries, or shared private libraries via the Query Center to find processes.

Process Executer. Core process engine functionalities are met with the Process Executor component.

Process Modeler. New process models can be created, or predefined models can be modified using the Process Modeler. After a process model is created or modified, the process takes its place in the user's private process library.

Reports Interface. Statistical information about the user processes is reported via Reports Interface. Reports Engine in the backend calculates the statistics by using instance-related data kept in the Database.

Activity List Interface. This interface shows a list of actions by collecting information from the Process Library and the Optimization Center.

5.6. Backend Components

Optimization Center. Optimization Center finds the best execution plan for a given set of personal processes and related activities. In any complex system or everyday life, better decisions are made as the set of alternatives and the set of selection criteria gets large [90]. But, this also leads to additional cognitive load. The Optimization Center builds an order of activities considering the user's preferences, process constraints, and context information. In the case of having enough historical process and activity data, Optimization Center may use the data to generate better solutions. Yet, in the case of not having enough historical data, then it becomes necessary to use heuristics or optimization techniques.

Reports Engine. The Reports Engine calculates statistics for monitoring the user processes by using process-related instance data.

*Process Library***.** Process Library is the logical name of the component where the system keeps the process models. Predefined process models could be searched from public libraries or shared private libraries. Process Library would be the critical component that would establish the knowledge base for the PPM community. Because processes are context-dependent, process libraries are context-dependent too. For instance, a process named “marriage” or “natural gas registration” could be composed of different activities in different cultures or countries. So, the user may also choose to use local libraries instead of global libraries for keeping local processes.

*Activity Dictionary***.** The user may search and find simple activities in Activity Dictionary. The items in the dictionary would be used as the building blocks for activities. For instance, “*Bake the potato*” would mean “*Put the potato on the grill,*” then “*Wait*” then “*Take the potato off the grill*”. On the other hand, “*Bake the potato for 20 minutes*” would mean “*Put the potato on the grill*” then “*Wait 20 mins*” then “*Take the pan off the grill*”. Processes can be managed in more detail by using this approach of resolution. In the example above, if “*bake the potato*” is considered as an atomic activity, then the waiting time would also be considered as an active task. Yet, active tasks take only 2 minutes by putting and taking out the cake, instead of 20 minutes.

Database. The most important data that the system keeps is historical activity data. Which execution plans were created in the past? Did the user follow these execution plans? What percentage did the user follow of suggestions that the Reminder made? What insights are generated from the behavior of the user and the system? The success of the system would rise by the degree of integration of the user and the system as well as the learning through historical data mechanisms of both the user and the system.

5.7. Cross-Cutting Components

The study [88] suggests Security, Configuration, and Communication components. Authentication, authorization, configuration management, message protection, communication between the frontend and the backend components, and the external sources are some of the components that should be delved into.

5.8. Chapter Summary

The study [90] states that in complex decision-making systems as in everyday life, an increase of the set of alternatives and selection criteria would also increase the decision quality, although it would also increase the cognitive load on the person as well. Many significant studies focus on relevant business process models to have practical implementations in BPM. Yet, a focus on personal processes, their management, and complementary models would generate new solutions to existing process management problems in everyday life. This would also create higher values in PPM as some characteristics of personal processes are more prominent in the PPM domain comparing to the BPM domain. Flexibility can be given as an example. As van der Aalst points out in the foreword of [9], process flexibility is crucial in less structured domains.

In this chapter, a reference model for PPM systems is given. For this purpose, first, a sample process model of PPM is given, and then issues and challenges are explained for defining the problem and reasoning better. Then, the reference model is explained in the overview, frontend, backend, and cross-cutting components' sections.

CHAPTER 6

PROTOTYPE PPM SYSTEM WITH A CP MODEL

6.1. Introduction and Design Objectives

This chapter gives the details of the implemented prototype application. The implemented prototype PPM system mainly focuses on the Optimization Center subsystem that was explained in the Reference Model for PPM Systems section. In this particular example, the approach covers the case that the system has no historical data to train using machine learning techniques. Instead, the system uses a CP model to create some execution plans for the user. Because of that, the following descriptions are given in this chapter:

1. How the problem is modeled as a CP model, which stands at the core of the PPM system.

2. How the CP model is implemented.

3. How the prototype mobile application is used as the interface between the user and the CP model.

6.2. Constraint Programming Model

In this subsection, we first verbally define the problem in the next paragraph, then formulate the problem as a CP model.

Given a set of processes having both optional and non-optional activities and some constraints, the goal is to decide which optional activities to perform and find a start date-time for each activity to be performed such that they form an acceptable schedule for the person. The schedule's acceptability depends on multiple criteria like the makespan, total distance traveled, the total value created, how early the important or urgent activities are performed, or how much money is spent. As the same person performs all the undelegated activities, these undelegated activities should be performed at different date-times. Delegated activities can be performed simultaneously as the other delegated or undelegated activities unless it is stated otherwise. Some activities should be performed at a specific location. For this type of activities, the time it takes to change the location should be considered in determining the schedule.

For this problem definition, the model below is developed. First, Table 6 is given to describe some notations used in the model.

Table 6 CP Model Notation Descriptions

Notation Example	**Description**
$X = \{ x_1, \ldots, x_{\#x}\}$	A set X with $\#x$ number of elements.
$x_i =< a, b, c >$	The i[th] of X with attributes: a, b, and c.
$(x_i \cdot c) * y$	Attribute c of x_i multiplied by a value y

Given a set of Processes $P = \{p_1, \ldots, p_{\#p}\}$ *where* $p_i = <n>$ with Boolean value *n* showing if the process will be used in planning or not.

Given a set of Locations $L = \{l_1, \ldots, l_{\#l}\}$ *where* $l_i = <lt, ln>$ with *lt* the latitude and *ln* the longitude of the location.

Given a set of Activities $A = \{a_1, \ldots, a_{\#a}\}$ where $a_i = < l, t_s, t_d, t_e, d, p, o, m, u, c, v >$ with ***l*** ∈ L the location of the activity, integer $\boldsymbol{t_s}$ the minimum start time slot, integer $\boldsymbol{t_d}$ the number of timeslots needed to perform the activity (duration), integer $\boldsymbol{t_e}$ the maximum end time slot, Boolean ***d*** the delegation status of the activity, ***p*** ∈ P the process the activity belongs to, Boolean ***o*** if the activity is optional or not, integer ***m*** the importance of the activity, integer ***u*** the urgency of the activity, integer ***c*** the cost of performing the activity, and integer ***v*** the value created by performing the activity. a_o is the dummy node that stands for the current status of the person. For a_o, *l* is the current location of the person, t_s, m, u, c, and v are 0; t_d and t_e are 1; d and o are false.

Given a set of Precedences Pre = $\{pre_1, \ldots, pre_{\#pre}\}$ where $pre_i = < a_j, a_k, t_{dif}, x>$ with $a_j \in$ A the preceded activity, $a_k \in$ A is the antecedent activity, t_{dif} is the minimum or maximum amount of time slots between a_j and a_k, x the term if the difference of timeslots in maximum or minimum relationship, i.e., $< a_j, a_k, 3, min>$ means that a_k may start minimum 3 slots later than a_j ends.

Given a set of SimpleChoices SC = $\{sc_1, \ldots, sc_{\#sc}\}$ where $sc_i = <a_j, a_k>$ with a_i and $a_k \in A$. At most one of these two activities can be performed.

Given a set of ExclusiveChoices EC = $\{ec_1, \ldots, ec_{\#ec}\}$ where $ec_i = <a_j, a_k>$ with a_j and $a_k \in A$. One and only one of these two activities can be performed.

Given a set of forbidden TimeWindows W for each activity A. $W_A = \{w_1, \ldots, w_{\#w\_for\_A}\}$ where $W_i = <w_s, w_e>$ with w_s start timeslot of W_i and w_e end timeslot of W_i.

Given a value for budget B.

Given a set of coefficients for value gained (M_v), importance penalty (M_m), Urgency penalty (M_u), cost of performing an activity and transportation (M_c), total distance (M_d), the end time of the last completed activity (M_e).

Given the following variables:

- **bool** b_y; $y \in [1 \ldots \#a]$. If a_y is performed, then b_y is 0.
- **int** s_y in [$a_y \cdot t_s \ldots a_y \cdot t_e - a_y \cdot t_d$]; $y \in [1 \ldots \#a]$ which shows the start time of a_y
    - **interval** r_y; $y \in [1 \ldots \#a]$ time interval that a_y covers within the planning horizon where $r_i = < t_s, t_d, t_e, b_y >$ with again $\mathbf{t_s}$ the minimum start time slot, $\mathbf{t_d}$ the number of timeslots needed to perform the activity (duration), $\mathbf{t_e}$ the maximum end time slot, and $\mathbf{b_y}$ boolean variable showing if a_y is performed or not.
- **bool** $arc_{j,k}$; $j \in [1 \ldots \#a]$, $k \in [1 \ldots \#a]$. Arc between a_j and a_k where $a_j \cdot d = 0$, $a_k \cdot d = 0$.

The problem can be stated as follows (the descriptions and reasonings for these constraints and objective function are also given after the definitions):

Maximize $M_v * \sum_{y \in 1 \ldots \#a}((a_y \cdot v) * b_y)$	Value gained
$-M_m * \sum_{y \in 1 \ldots \#a}((s_y + a_y \cdot t_d) * (a_y \cdot m) * b_y)$	Importance penalty
$-M_u * \sum_{y \in 1 \ldots \#a}((s_y + a_y \cdot t_d) * (a_y \cdot u) * b_y)$	Urgency penalty
$-M_c * \sum_{y \in 1 \ldots \#a}((a_y \cdot c) * b_y) + \text{travelCost}$	Cost of performing an activity and transportation (Monetary Cost)
$-M_d * \text{totalDistance}$	Total distance
$-M_e * max_{y \in 1 \ldots \#a}((s_y + a_y \cdot t_d) * b_y)$	The end time of the last completed activity (Process completion time)

The model tries to maximize the value gained while trying to minimize the penalties that may occur depending on the end time of important or urgent activities, cost of performing an activity and traveling for that activity, travel distance, or the end time of the complete processes. If an activity is optional yet creates no value, then the model recommends not to perform that activity (sets b_y to 0). For the optional activities that the model recommends to perform, together with the required activities, the model tries to complete them as soon as possible depending on the urgency and importance values of these activities and the coefficients of the penalties. The model minimizes monetary cost which is a summation of the cost of performing an activity and incurred travel cost. Total distance is the distance that the user travels in order to fulfill the need to be at some specific location to perform some activities. The model tries to minimize the end (expected completion) time of the last completed activity as a part of the objective function.

Subject to

- TimeSlot Conversion Function:

  Time_to_Slot(given_datetime) = roundup ((given_datetime – slot0_end_datetime)/slot_duration)

  As CP algorithms work on discrete solution sets, we transform the time into 15-minute timeslots. So, the moment the model is run is in timeslot 0. The next quarterly hour (one of x:00, x:15, x:30, or x:45) is the start of time slot 1. For example, if the model is run at 15:57, then 15:45 to 16:00 is timeslot 0, then 16:00 to 16:15 is timeslot 1, and so on.

- Distance Function: $Distance(a_j \cdot l, a_k \cdot l)$ takes $a_j \cdot l$ and $a_k \cdot l$ as inputs and gives the distance between $a_j \cdot l$ and $a_k \cdot l$ in meters. If at least one of the activities has no assigned location, then the result is 0, as it is assumed that an activity with no assigned location can be performed anywhere. Although the function may return various types of distances, e.g., Euclidian or Manhattan distances, we have experimented with both Euclidian distance and Google Distance Matrix API [91].

- Travel Time Function: $TravelTime(a_j \cdot l, a_k \cdot l)$ takes $a_j \cdot l$ and $a_k \cdot l$ as inputs and gives the travel time needed to go between the activity locations of j and k. Travel time is calculated first in minutes and then converted into time slots using the timeslot conversion function. Similar to the distance function, if at least one of the activities has no assigned location, then the result is 0.

  We use four different transformation functions depending on the distance between two points and a series of assumptions:

  - The person may choose different modes of travel (walk, drive, intercity drive, flight) depending on the distance between two locations, i.e., if the distance in kilometers between two locations is in the interval [0-2) choose walking, [2-35) choose driving, [35-600) choose intercity driving, [600- or more) choose flight.

- Depending on the mode of travel, the speed of the person would change. Walking, driving, intercity driving, and flight speeds are 5 km/hr (83 m/min), 60 km/hr (1000 m/min), 100 km/hr (1667 m/min), 900 km/hr (15000 m/min) respectively.

- Overhead minutes for preparation are 0, 10, 30, 300 minutes for walking, driving, intercity driving, and flight, respectively.

$$\forall j,k \in [1,\dots,\#a]: TravelTime(a_j \cdot l, a_k \cdot l) = roundup\left(\left(Overhead + Distance(a_j \cdot l, a_k \cdot l)/Speed\right)/15\right)$$

- Travel Cost Function: Again, depending on the distance between two points, we assume different cost functions depending on the travel mode. For instance, as it is assumed that the user would walk when the distance between two points is smaller than 2 km, the travel cost is zero. This time an additional assumption is made for unit cost:

  - Unit costs for traveling are 0, 50, 31, and 25 cents/km for walking, driving, intercity driving, and flight, respectively.

$$\forall j,k \in [1,\dots,\#a]: TravelCost(a_j \cdot l, a_k \cdot l) = \left(Distance(a_j \cdot l, a_k \cdot l) * unitCost\right)$$

- Travel Time Constraint: Travel time is considered in deciding the starting time slot of an activity depending on the ending time slot of the predecessor activity.

$$\forall_{j,k\in[1,\dots,\#a]} b_j \wedge b_k \Longrightarrow \left(s_k \geq s_j + a_j \cdot t_d + TravelTime(j,k)\right) \vee \left(s_j \geq s_k + a_k \cdot t_d + TravelTime(k,j)\right)$$

- Budget Constraints: There is a budget of the user, which would define the upper limit for the costs of performing activities and tr avel.

$$B \geq \sum_{y\in 1\dots\#a}((a_y \cdot c) * b_y) + travelCost$$

- Arc Constraints: If an activity is not performed, then there is no arc from or to that activity other than themselves.

$$\forall_{j,k\in[1,\dots,\#a] \mid a_j \cdot l \neq NULL,\, a_k \cdot l \neq NULL} \left(b_j = 0 \vee b_k = 0 \Longrightarrow arc(a_j, a_k) = 0\right)$$

For these activities, an arc is assigned from/to themselves.

$$\forall_{j\in[1,\dots,\#a]\ |\ a_j\cdot l\neq NULL}\left(b_j = 0 \implies arc(a_j, a_j) = 1\right)$$

For each performed activity having a location attribute, the number of arcs both from and to these activity nodes is 1.

$$\forall_{j\in[1,\dots,\#a]\ |\ a_j\cdot l\neq NULL}\left(\sum_{k\in[1,\dots,\#a]|\ a_k\cdot l\neq NULL} arc(a_j, a_k) = 1\right)$$

$$\forall_{k\in[1,\dots,\#a]\ |\ a_k\cdot l\neq NULL}\left(\sum_{j\in[1,\dots,\#a]|\ a_j\cdot l\neq NULL} arc(a_j, a_k) = 1\right)$$

a_0 is the dummy activity node, so there is one arc from that dummy activity node to the initial activity, and there is no arc from any activity node to the dummy activity node. The location of the person for dummy activity node a_0 ($a_0 \cdot l$) is that person's initial location.

$$\sum_{j\in[1,\dots,\#a]} arc(a_o, a_j) = 1$$

$$\sum_{j\in[1,\dots,\#a]} arc(a_j, a_0) = 0$$

Arc constraints show the change in person's location. They define the order of that person's location change. An arc from a_i to a_j tells that the person was at $a_i \cdot l$ then at $a_j \cdot l$ which is significant information for measuring the total distance the person would travel to perform these activities in the list.

- Total Distance Function: The total travel distance is calculated to use in the objective function.

$$\sum_{j\in[0\dots\#a],k\in[1\dots\#a]} Distance\ (a_j \cdot l, a_k \cdot l) * arc(a_j, a_k)$$

- Process – Activity Relationship Constraint: If a process is not considered in planning, then the pertinent activities are not planned as well.

$$\forall_{j\in[1,\dots,\#p]}\ (p_j \cdot \mathrm{n}) = \mathrm{false} \implies \forall_{i\in[1,\dots,\#a]\ where\ a_i\cdot p=j}\ b_i = 0$$

- Precedence Constraint: If a precedence relationship is defined, then it is considered as well.

$$\forall_{<a_j,a_k,t_{dif},x>\in Pre}\ \mathrm{b_j} \land \mathrm{b_k} \land (x = min) \implies \mathrm{s_k} \geq \mathrm{s_j} + (\mathrm{a_j} \cdot \mathrm{t_d}) + \mathrm{t_{dif}}$$

$$\forall_{<a_j,a_k,t_{dif},x>\in Pre}\ b_j \land b_k \land (x = max) \implies (s_k \leq \mathrm{s_j} + (\mathrm{a_j} \cdot \mathrm{t_d}) + \mathrm{t_{dif}}) \land (s_k \geq s_j + (a_j \cdot t_d))$$

- Simple Choice Constraint: If there is a simple choice relationship between two activities, then at most one of these activities can be performed.

  $\forall_{<a_j,a_k> \in SC}\; b_j + b_k \leq 1$

- Exclusive Choice Constraint: If there is an exclusive choice between two activities, then one and only one of these activities is performed.

  $\forall_{<a_j,a_k> \in EC}\; b_j + b_k = 1$

- Disjunction Constraint: If two activities are not delegated, then these activities cannot be performed at the same time.

  $\forall_{j,k \in [1,\ldots,\#a]}\; b_j \wedge b_j \wedge \neg\, a_j \cdot d \wedge \neg\, a_k \cdot d \implies nooverlap(r_j, r_k)$

- Time Windows Constraint: If an activity cannot be performed in some time intervals, then these are defined and considered in the model.

  $\forall_{j \in [1,\ldots,\#a],\; w \in W_j}\; (s_j \in [(s_j \cdot t_s), (s_j \cdot t_e) - (s_j \cdot t_d)] \setminus [(w \cdot w_s) - (s_j \cdot t_d), (w \cdot w_e)])$

6.3. Implementation of the Constraint Programming Model

In order to transform the model in the previous subsection into a running prototype application, we use Python programming language [92], Google OR-Tools [93], and Django framework [94]. The application code reads from and writes to a PostgreSQL [95] database using psycopg adapter [96]. On the other hand, the application code has the configuration to communicate with other systems, such as a mobile application, via RESTful APIs.

In the first set of iterations of code development, we used Google's CP Solver. Yet, then we updated the code to have better performance, and we started using Google's CP-SAT solver. Google states that the CP-SAT solver is “technologically superior” to the original CP Solver [97]. With this new solver, parallelism is also used.

The reason for using Python is that its simplicity speeds up the development cycle. Django is one of the frameworks that can be used for rapid and clean development in Python. Both are open source and have strong community support. As the third open-source component of the implementation, we have chosen Google OR-Tools because it has Python implementation and is a successful solver with gold medals from international CP competitions.

In the CP-SAT solver's implementation detail, we use four parallel workers, set some time limits in seconds, which is defined by the user, and use the CP-SAT solver, which does local search and meta-heuristics on top of CP, which is explained in [98].

6.4. Mobile Application for the User Interactions

To show the effect of using CP in PPM via some experiments, we develop a mobile application using the Ionic framework [99]. Users interact with the recommendation system running at the backend via this application. The mobile application is the complementary component of the "optimization center" component within the PPM reference model shared before in Figure 15 on page 51. This development's main purpose is to meet the need for an interface that will work as an intermediary between the user and the CP model, which would recommend execution plans to the user. The CP model gets inputs from the user via this mobile application together with the context information like the date, time, and location.

With the prototype application, users can perform the following actions:

- Define processes by setting the fields in Table 7
- List all defined processes
- Define activities by setting the fields in Table 8
- List all defined activities
- Define and list the following constraints: precedence, simple choice, exclusive choice, time windows
- Set budget, run time limit, planning start-end times (horizon)
- Get an execution plan from the system

The options in setting processes could be found in Table 7. If a field is mandatory, then that field name is marked with an asterisk (*) in the table.

Table 7 Define Process" Fields

Field	Description
Name *	The user chooses an activity name.
Description	The user writes a description.
Use in Planning	If this button is checked, the application uses this process in making recommendations. In other words, the background activity planning code uses the activities of processes with the "use in planning" button clicked as input. The activities of the processes without the "use in planning" button clicked can only be seen on the All Activities page.

The options in setting activities can be found in Table 8. Mandatory fields are marked with an asterisk (*) in the table.

Table 8 "Define Activity" Fields

Field	Description
Name *	Name of the activity
Description	A description of the activity
Duration	The estimated duration of the activity.
Earliest Start *	Allowed the earliest start time of the activity.
Latest End *	Allowed the latest end time of the activity.
Monetary cost	The estimated monetary cost of the activity.
Value	Value of the activity to the user.
Importance	Importance of the activity to the user.
Urgency	The urgency of the activity to the user.
Location	If the activity should be performed at a specific location, this field is filled. If location information for an activity is not given, then it is assumed that the activity can be performed independently from the location.
Process *	The process to which the activity belongs.
Delegated *	If the user decides that another person will perform an activity, then "Delegated" checkbox is checked. So, the planned time interval may cross with other activities' time intervals. However, the user may still monitor the activity.
Optional *	If an activity is optional, then the "Optional" checkbox is checked.

A screenshot from the “All Processes” page is given in Figure 16.

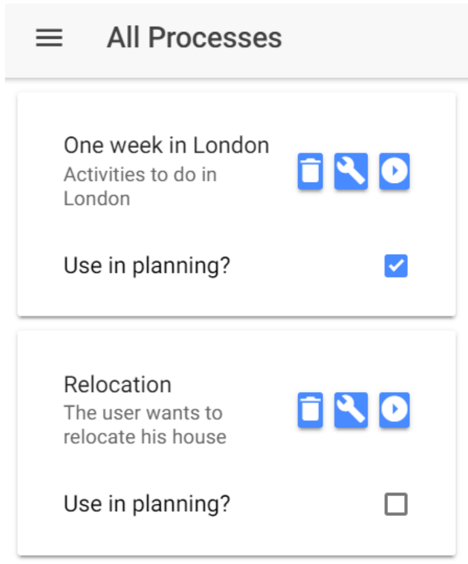

Figure 16 “All Processes” page

A screenshot from the “All Activities” page is given in Figure 17.

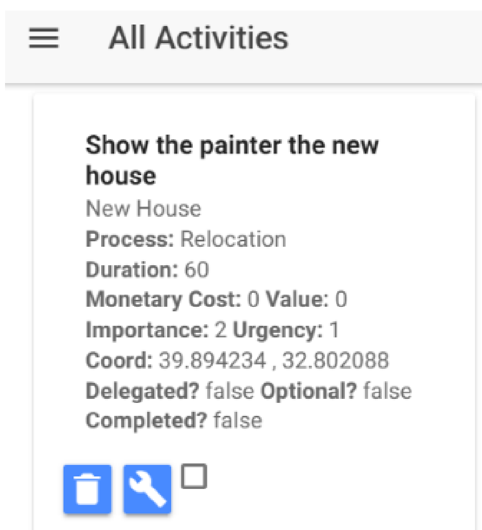

Figure 17 “All Activities” page

A screenshot from the “Precedences” page is given in Figure 18.

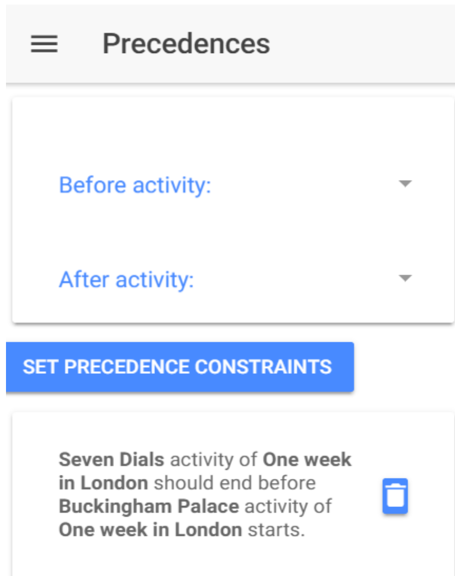

Figure 18 “Precedences” page

Although in the live usage of the application, it would get the latest context information and transfer it to the back end to the CP model, in our experiments, we simulate context according to the parameters specified by the user in the configuration page, which can be seen in Figure 19.

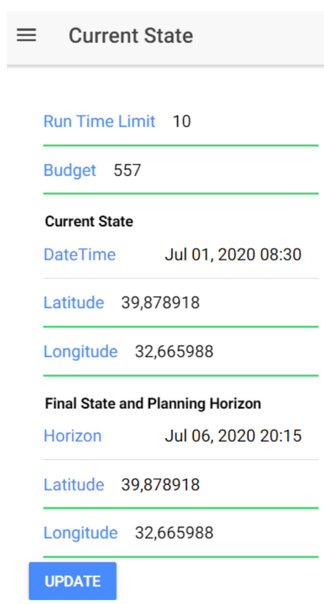

Figure 19 "Current State" form

6.5. Chapter Summary

In this chapter, a prototype implementation of a PPM system is described. For this purpose, first, the CP model is defined, then how it is implemented is explained. Lastly, a description of the mobile application as a part of the prototype PPM system is given.

CHAPTER 7

DESIGN EVALUATION

As DSR states, the artifact should be evaluated after it is built. We used two types of evaluations to assess the CP model through the prototype mobile application. The first one consists of experiments with two different scenarios. With these scenarios, the aim is to see the participants' performance difference with and without the prototype PPM system, which consists of the core functionality of recommending execution plans. The second one is from the usability perspective. For this part, we used the System Usability Scale (SUS) questionnaire and some additional open-ended questions to collect the participants' opinions and experiences with the prototype in order to see the usability.

This chapter gives detailed information on the design evaluation process and the results. The study [6] states that design evaluation covers the activity of "comparing the objectives of a solution to actual observed results from use of the artifact in the demonstration".

7.1. Design Process and Evaluation Method

In this research, to reach the research objectives, the following design process is followed:

1. Besides doing the literature review, semi-structured interviews are conducted to understand personal processes. METU Ethics Committee approved the semi-structured interview questions as well as PPM test scenarios and questions on November 8, 2018. APPENDIX B shows the approval.

2. Semi-structured interview results are used to create Personal Process Taxonomy.

3. A reference model for PPM systems is designed to understand what details of a PPM system are in the vision of the researchers and what specific types of problems are wanted to be solved.

4. Considering some scenarios that take part in the Diversions class of the Personal Process Taxonomy and focusing on the Optimization Center component in the

PPM reference model, a prototype application with the core functionality is developed and evaluated with some experimentations with potential users.

Although expert opinions on the designed personal process taxonomy and the reference model are collected first, a more detailed evaluation is implicitly done design of prototype PPM system as it uses the outcomes of both personal process taxonomy and the reference model. It is considered that the evaluation results of the prototype PPM system also would reflect the evaluation results of the personal process model and the reference model for PPM systems.

Two scenarios are used to evaluate the prototype PPM system.

1. “Journey to Tyrol” is the scenario used in the Alaska Project [100]. Alaska simulator is a tool used for testing, analyzing, and improving users' planning behavior, which was built in Alaska Project [100]. We used the tool in its “Agile Approach” mode, together with the scenario “Journey to Tyrol”. In this scenario, participants try to plan two days of a journey (planning phase), trying to maximize gained utility at the end of these two days (execution phase). “Agile Approach” lets the participant make changes in the planning in the execution phase. The utility is gained by performing activities, i.e., seeing the old town or shopping. There are various things to consider in the simulation. Some of these are expected activity duration, the locations(cities) where an activity can be performed, the expected utility gained by performing an activity, the cost of performing an activity, the time needed to go from one city to another.

2. “Relocation” is the second scenario that has developed in this research. In this scenario, the participants try to plan their week for moving house. We designed this scenario with 33 activities, 18 precedence constraints, 14 time window constraints, and five days to plan. Increased number of activities and broader planning horizon make the problem computationally more complex, which affects the performance of the model negatively.

By using these scenarios, the performance of the users both with and without the help of the prototype application is compared. Also, after the tests with the first scenario, a usability questionnaire is conducted to understand how useful the participants find the prototype application.

7.2. Experimental Design

Before the experiments took place, we conducted pilot studies with three participants for each scenario to enhance the scenarios and the evaluation methodology. Then, we used this improved experimental design in the experiments.

We conducted the experiments and questionnaires in an isolated room for the participants not to be disturbed by external factors. The participants were free to use a smartphone, laptop, pen, or paper to take notes or make calculations if needed. We also gave additional information like the distance between two locations at the beginning of the experiments to minimize the need for using external tools. For each scenario, we gave the instructions in written format and then explained them. After the explanation, the participant completely understands how to use the experimentation tools, the scenarios' constraints, and the possible actions. The participants consist of people with high education degrees, mobile device users, actively managing their processes in their personal lives, and ages between 24 and 38.

For the mentioned scenarios and the corresponding evaluation processes, after giving the initial information about the experiment, the following steps are followed.

7.2.1. Scenario 1: Journey to Tyrol

In our experiments, we compared participants' planning and execution performances when done on their own and with the support of PPM application for two different PPM implementations (PPM v1 and PPM v2). We used the expected and gained utility values to make the comparisons.

We used two already available solvers, CP and CP-SAT solvers, for PPM v1 and PPM v2 implementations, respectively. CP-SAT solver is "technologically superior to the CP solver" although in some cases, CP solver may give better results than CP-SAT solver [97].

We conducted the tests with 30 participants by following the steps below:

1. Initial Planning Stage 1 without PPM (noPPM_Stage1): 10 minutes is given to the participants to plan their two days in Alaska Simulator without the help of the PPM system.

2. Initial Planning Stage 2 without PPM (noPPM_Stage2): The participants continue planning within an additional 20 minutes.

3. Execution without PPM (noPPM_Exec): The participants execute the actions one by one, dealing with the unforeseen, random events (i.e., traffic, cancellation of an event) to gain the maximum utility.

4. Initial Planning with PPM (PPM_v1_Plan & PPM_v2_Plan): After the previous three steps, a new simulation is started for the participants to plan their two days

in Alaska Simulator now with the help of the PPM system. A runtime limit of 10 seconds is set for the model. PPM system initially recommends an execution plan.

5. Execution with PPM (PPM_v1_Exec & PPM_v2_Exec): The participants execute the actions one by one, dealing with the unforeseen, random events to gain the maximum utility. They run the model via the PPM system whenever the conditions change significantly.

6. Results are compared.

Steps 4 and 5 are repeated for two separate CP model implementations.

“Journey to Tyrol” scenario explanation text is given in APPENDIX C.

7.2.2. Scenario 2: Relocation.

With this scenario, we checked the performances of both the participants and the PPM system and observed the participants’ preferences over their plan versus the system’s plan.

We conducted the tests with 20 participants by following the steps below:

1. Ninety minutes are given to the user for planning.

2. Meanwhile, 3 seconds is given to prototype the PPM system for planning in parallel with the user.

3. Results are compared. The user is asked if he would use the plan suggested by the PPM system as well as the reasons behind his decision.

“Relocation” scenario explanation text is given in APPENDIX D.

7.2.3. Usability Evaluation

SUS is a widely accepted tool among the usability community. After the experiments of the “Journey to Tyrol”, for the qualitative usability evaluation, System Usability Scale (SUS) [101] is employed. The SUS consists of 10 five-point Likert scale type questions. These ten questions consist of alternating five positive, five negative statements. With an intense analysis of 206 usability tests, [102] concludes that SUS is a reliable, robust, and versatile tool for usability testing. SUS questions can be found in APPENDIX A.

7.3. Participants and Backgrounds

For both scenario tests, background questions to determine age, gender, and mobile application usage frequency are asked. The study [103] says that only five participants would be enough to identify 50% to 85% of the problems. The study [104] demonstrates that with the SUS questionnaire, 12 users are sufficient to get a presumed usability metric of a system. Also, [105] states that with 20 participants, at least 95% of the usability problems can be gathered.

For the first scenario, namely “Journey to Tyrol”, 30 people (17 males, 13 females) participated in the experiments with ages between 24 and 37. The age distribution of these 30 participants can be seen in Figure 20. The details can also be seen in APPENDIX E. All the participants state that they use computers and mobile applications daily, and they are actively managing processes within their daily life.

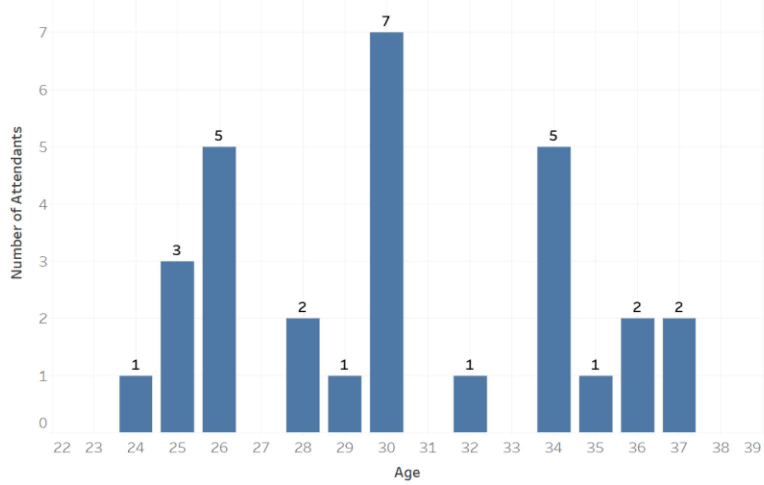

Figure 20 Age distribution of the participants of "Journey to Tyrol" scenario tests

For the second scenario, namely “Relocation”, 20 people (11 males, 9 females) participated in the experiments with ages between 24 and 38. The age distribution of these 20 participants can be seen in Figure 21. The details can also be seen in APPENDIX F. All the participants state that they use computers and mobile applications daily, and they are actively managing processes within their daily life.

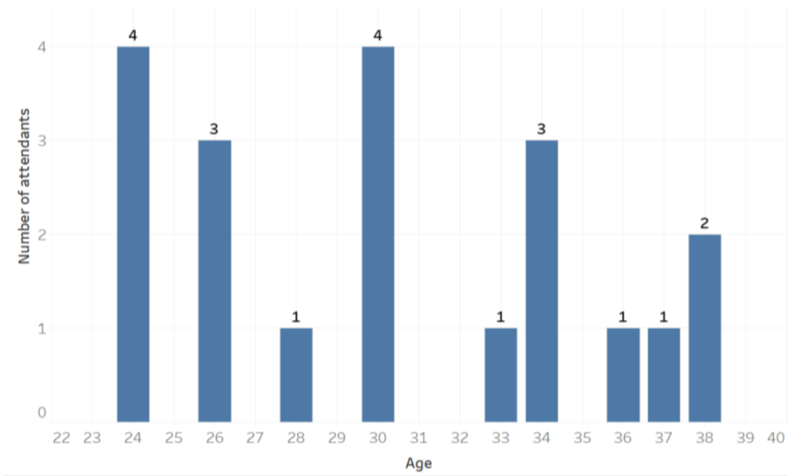

Figure 21 Age distribution of the participants of "Relocation" scenario tests

7.4. Results

This section gives the results of tests conducted with the scenarios “Journey to Tyrol” and “Relocation” together with the SUS questionnaire results. The quantitative results are evaluated in addition to collecting the participants’ experiences of using the prototype. The efficacy of the system and its contributions are evaluated.

7.4.1. Scenario 1 – “Journey to Tyrol”

The raw data of the results for this scenario can be found in APPENDIX E. This test is conducted with 30 participants. So, for all data sets for the corresponding stages of the test, there are at most 30 data points.
In the case of not using the PPM system, among those 30 participants:

- 6 (20%) of them could not even come up with a feasible plan within 10+1 minutes.
- Only 2 (6.6%) participants were satisfied with the plan within the first 10 minutes and decided not to use the additional 20 minutes. The remaining 28 participants continued planning and used some portion of additional 20 minutes.
- 23 (76.6%) participants created plans with higher expected business values with the additional 20 minutes.
- 2 (6.6%) participants created plans with lower expected business values with the additional 20 minutes.

- 5 (16.6%) participants created plans with the same expected business values as in the first 10 minutes, although they used the additional time to get better results.

On the other hand, in the case of using the PPM system, an execution plan with the highest expected business value is created within seconds.

The execution phase results will be described in the following paragraphs.

Table 9 shows "Journey to Tyrol" Test Scenario Descriptive Statistics on the “Business Value” expected or gained in initial planning or execution phases, respectively. The following list explains the names in the “Variable” column of the table.

- noPPM_Stage1: Initial Planning without PPM, Stage 1.
- noPPM_Stage2: Initial Planning without PPM, Stage 2.
- noPPM_Exec: Execution without PPM
- PPM_v1_Plan: Initial Planning with PPM version 1
- PPM_v1_Exec: Execution with PPM version 1
- PPM_v2_Plan: Initial Planning with PPM version 2
- PPM_v2_Exec: Execution with PPM version 2

Table 9 "Journey to Tyrol" Test Scenario Descriptive Statistics

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
noPPM_Stage1	24	6	696.3	19.9	97.3	413.8	634.3	728.4	780.6	798.8
noPPM_Stage2	30	0	738.7	13.9	76.2	566.1	670.5	779.6	797.6	802.8
noPPM_Exec	30	0	765.2	18.2	99.7	568.9	704.5	769.8	828.8	965.4
PPM_v1_Plan	30	0	797.6	0.0	0.0	797.6	797.6	797.6	797.6	797.6
PPM_v1_Exec	30	0	850.8	12.7	69.4	713.9	816.9	849.0	891.6	996.0
PPM_v2_Plan	30	0	802.8	0.0	0.0	802.8	802.8	802.8	802.8	802.8
PPM_v2_Exec	30	0	856.7	13.7	74.9	716.6	810.6	868.3	902.4	1025.7

N and N* columns in Table 9 show that for the noPPM_Stage1 phase, six data points could not be collected. The reason is that six participants could not create a feasible plan within 10+1 minutes. That means 20% of the participants could not manage to create a feasible execution plan within 11 minutes.

For the planning phases for both versions of the PPM prototype, the standard deviation is 0 as there is no randomness in the planning phase. So, the prototype always gives the same result. Yet as in the execution phase, there is some randomness in the simulation, the results have some distributions.

Another view of the results can be seen in Figure 22. There are also two reference lines for the planning phases of two PPM algorithms. The first CP algorithm always finds an expected business value of 797.6, whereas the second one finds 802.8. The boxplot clearly shows that the prototype PPM system gives better results for both versions in the planning phase, although the second version gives a slightly better result. In addition to that, again prototype PPM system gives better results for both versions in the execution phase.

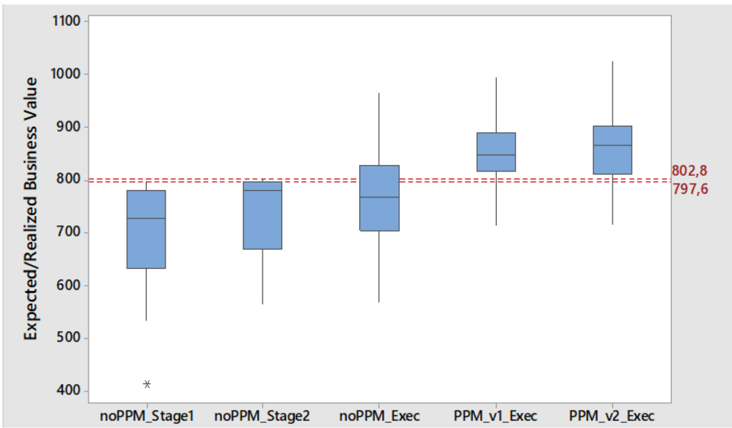

Figure 22 Boxplot of planning and execution phase results

In order to show the contribution of the prototype PPM application, additional statistical analyses are conducted with two-sample t-test. Before conducting these analyses, the distribution of the results should be checked to see if they are normally distributed or not.

Figure 23 and Figure 24 show that “Initial Planning without PPM, Stage 1” and “Initial Planning without PPM, Stage 2” are not normally distributed. Anderson-Darling Normality Test results show that P-Value is smaller than the 0,05 significance level.

On the other hand, Figure 25, Figure 26, and Figure 27 show that “Execution without PPM”, “Execution with PPM version 1”, and “Execution with PPM version 2” data are normally distributed.

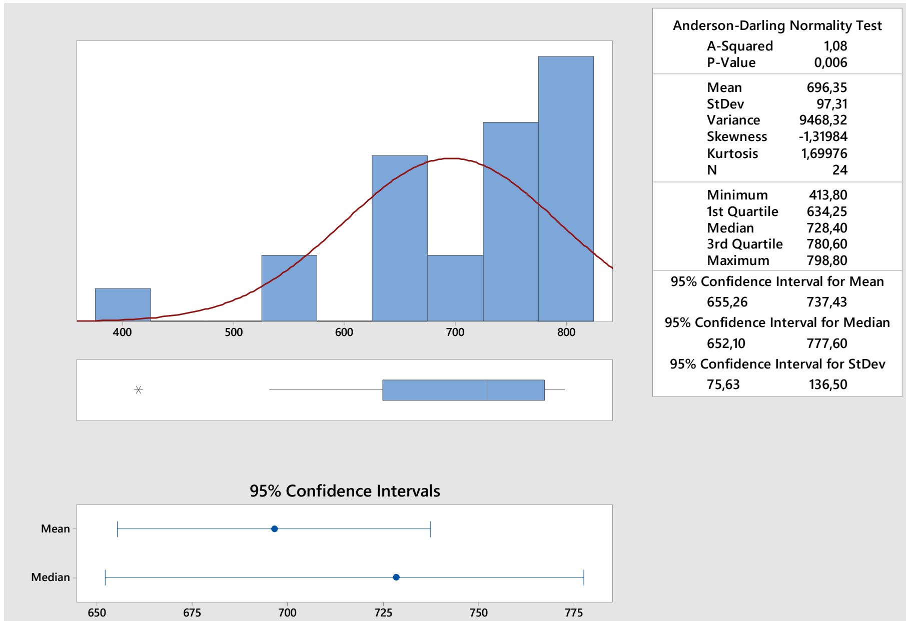

Figure 23 Summary report for initial planning without PPM, stage 1

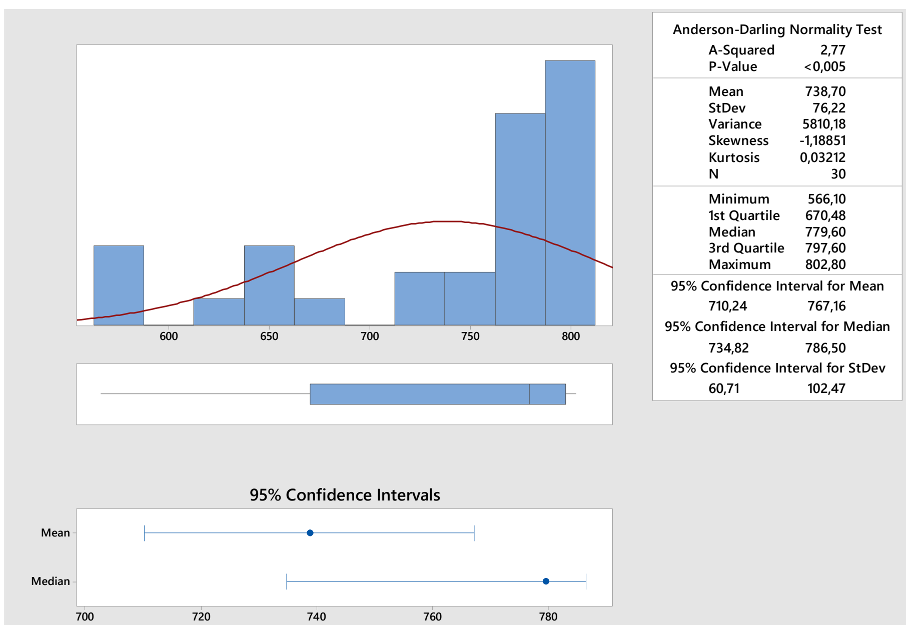

Figure 24 Summary report for initial planning without PPM, stage 2

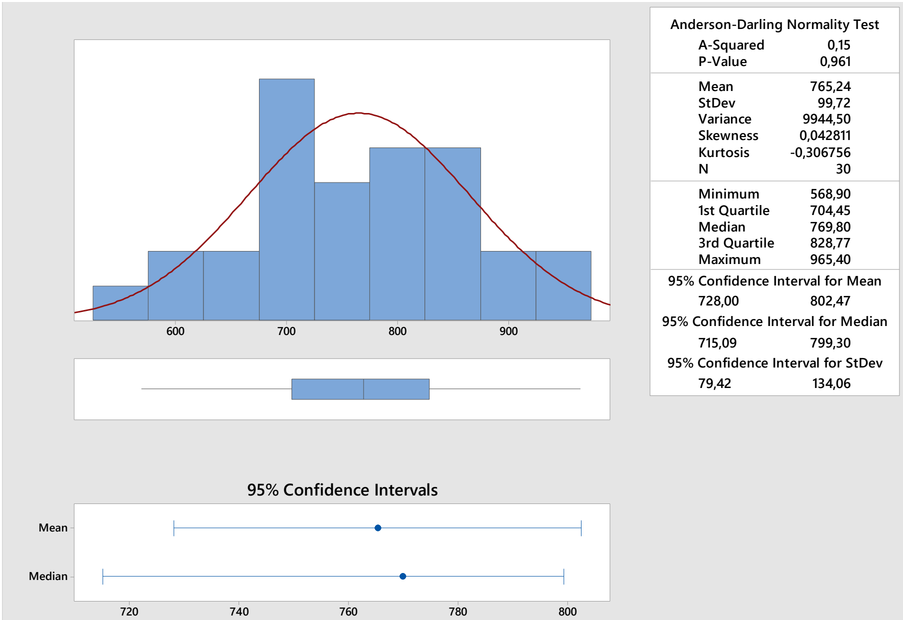

Figure 25 Summary report for execution without PPM

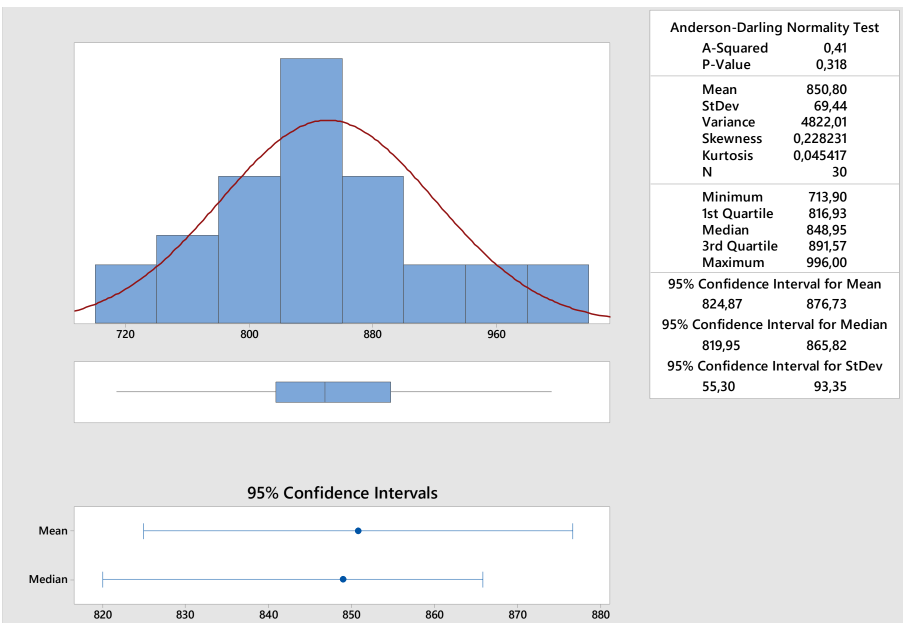

Figure 26 Summary report for execution with PPM version 1

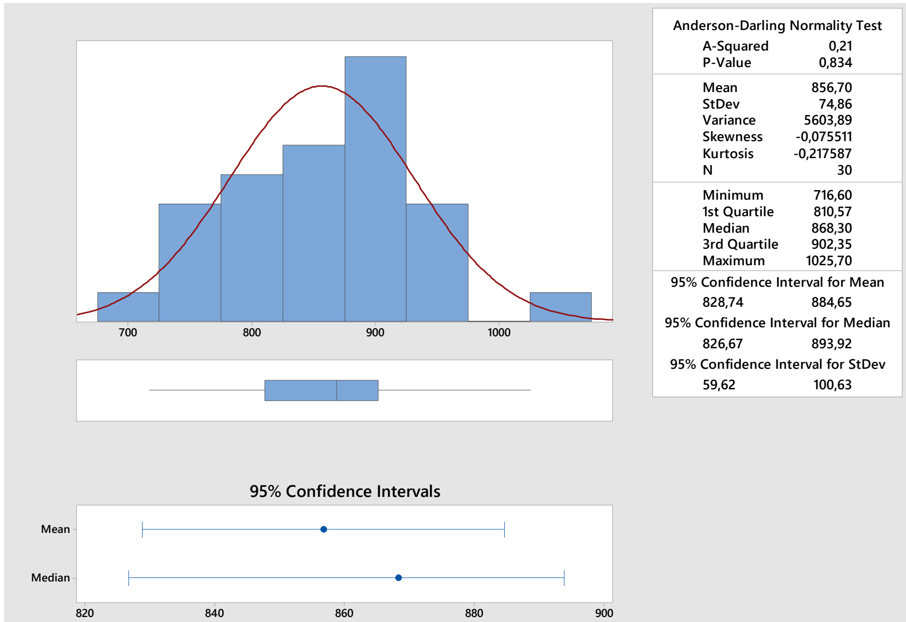

Figure 27 Summary report for execution with PPM version 2

As the execution phase results are normally distributed, it is possible to compare the results by conducting two-sample t-tests.

Table 10 shows that with a 95% confidence interval, the mean value for "Execution with PPM version 1" is greater than the mean value for "Execution without PPM".

Table 10 Comparing PPM_v1_Exec and noPPM_Exec with Two-Sample T-Test

Definitions:	μ_1: mean of PPM_v1_Exec μ_2: mean of noPPM_Exec Difference: $\mu_1 - \mu_2$ Equal variances are not assumed for the analysis.
Estimation for Difference:	Difference: 85.6 95% CI for Difference: (41.0, 130.1)
Null hypothesis:	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis:	H_1: $\mu_1 - \mu_2 \neq 0$
α level:	0.05
Results:	DF = 51 T-Value = 3.86 P-Value = 0.000 As P-Value ≤ 0.05, Can claim Mean(PPM_v1_Exec) ≠ Mean(noPPM_Exec).

Table 11 shows that with a 95% confidence interval, the mean value for "Execution with PPM version 2" is greater than the mean value for "Execution without PPM".

Table 11 Comparing PPM_v2_Exec and noPPM_Exec with Two-Sample T-Test

Definitions:	μ_1: mean of PPM_v2_Exec μ_2: mean of noPPM_Exec Difference: $\mu_1 - \mu_2$ Equal variances are not assumed for the analysis.
Estimation for Difference:	Difference: 91.5 95% CI for Difference: (45.8 , 137.1)
Null hypothesis:	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis:	H_1: $\mu_1 - \mu_2 \neq 0$
α level:	0.05
Results:	DF = 53 T-Value = 4.02 P-Value = 0.000 As P-Value ≤ 0.05, Can claim Mean(PPM_v2_Exec) ≠ Mean(noPPM_Exec).

One last Two-Sample T-Test is conducted to check if "Execution with PPM version 2" is better than "Execution with PPM version 1". Yet, as Table 12 shows, it is failed to reject the hypothesis that the means of these two data sets are different. For the execution phase of the simulation, it is not possible to say that the second CP algorithm is better than the previous one, just considering the realized business value. That is most probably because the previous model was good enough to make recommendations on a small scenario like "Journey to Tyrol". There was not enough room for improvement. Although for the execution phase, that is the case, for the planning phase, the new model gives better results. The previous model was giving 797.6, as seen in Figure 22, although the new model gives 802.8.

Table 12 Comparing PPM_v2_Exec and PPM_v1_Exec with Two-Sample T-Test

Definitions:	μ_1: mean of PPM_v2_Exec μ_2: mean of PPM_v1_Exec Difference: $\mu_1 - \mu_2$ Equal variances are not assumed for the analysis.
Estimation for Difference:	Difference: 5.9 95% CI for Difference: (-31.4 , 43.2)
Null hypothesis:	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis:	H_1: $\mu_1 - \mu_2 \neq 0$
α level:	0.05
Results:	DF = 57 T-Value = 0.32 P-Value = 0.753 P-Value > 0.05, Cannot claim Mean(PPM_v2_Exec) ≠ Mean(PPM_v1_Exec).

In addition to the statistical analyses, some figures can be drawn to visualize the results. This would help to understand the relationship among time, money, and business value.

Figure 28 shows the expected business value results for the plans of each participant.

- Red circles stand for expected business values for different participants created at the end of Initial Planning – Stage 1 without using the PPM system.
- Blue circles stand for expected business values for different participants created at the end of Initial Planning – Stage 2 without using the PPM system.
- Two reference lines are drawn for the planning results of PPM CP algorithms version 1 (797.6) and version 2 (802.8).
- The radiuses of the circles are proportional to the planning durations in seconds.
- For most of the participants, in the second stage of the planning phase, business values are better comparing the first phase. This is an expected result. As the participants take more time to create an execution plan, the execution plans become better. There are two exceptions, participants 5 and 14. These participants obtained high values in stage one, tried to get better results in stage two. They got almost the same yet a little worse result in stage two.

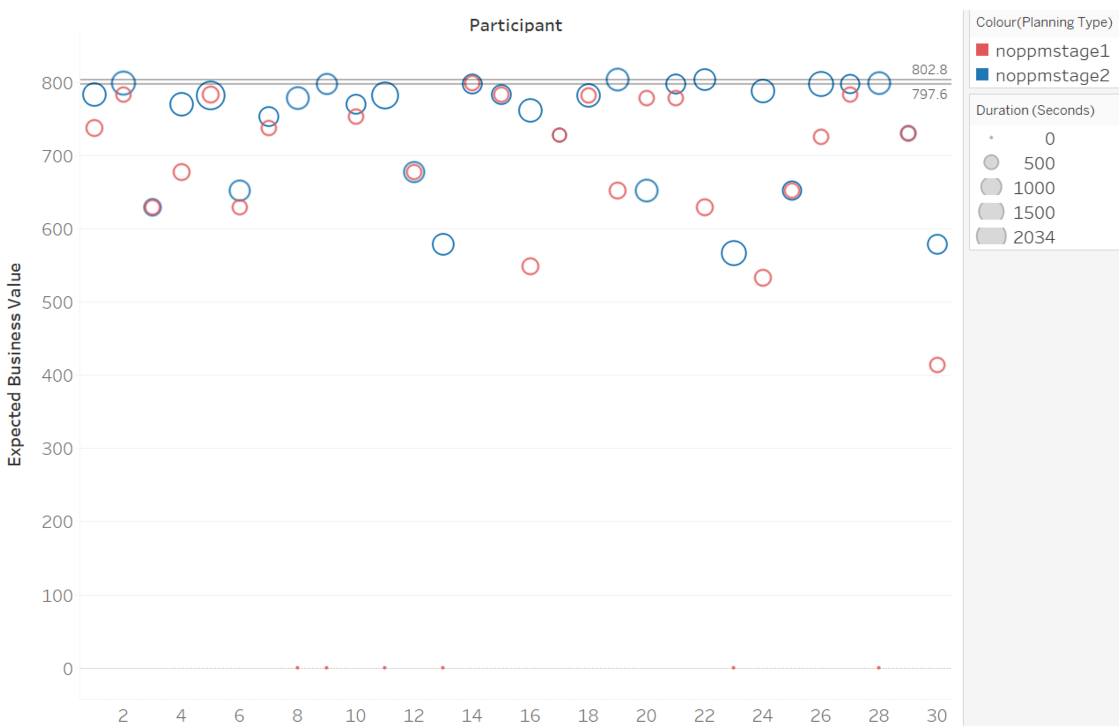

Figure 28 Expected business values in planning phases for each participant

Figure 29 shows the expected business values versus money spent in the planning phases.

- Red squares stand for expected business values for different participants created at the end of Initial Planning – Stage 1 without using the PPM system.
- Blue crosses stand for expected business values for different participants created at the end of Initial Planning – Stage 2 without using the PPM system.
- There is a reference line where money spent is 200, which is the budget in this scenario.
- For all the tests, planning with PPM_v1 results are at the same point, with the expected value at 797.6 and the expected money spent at 195.
- For all the tests, planning with PPM_v2 results are at the same point, with an expected value at 802.8 and expected money spent at 183.

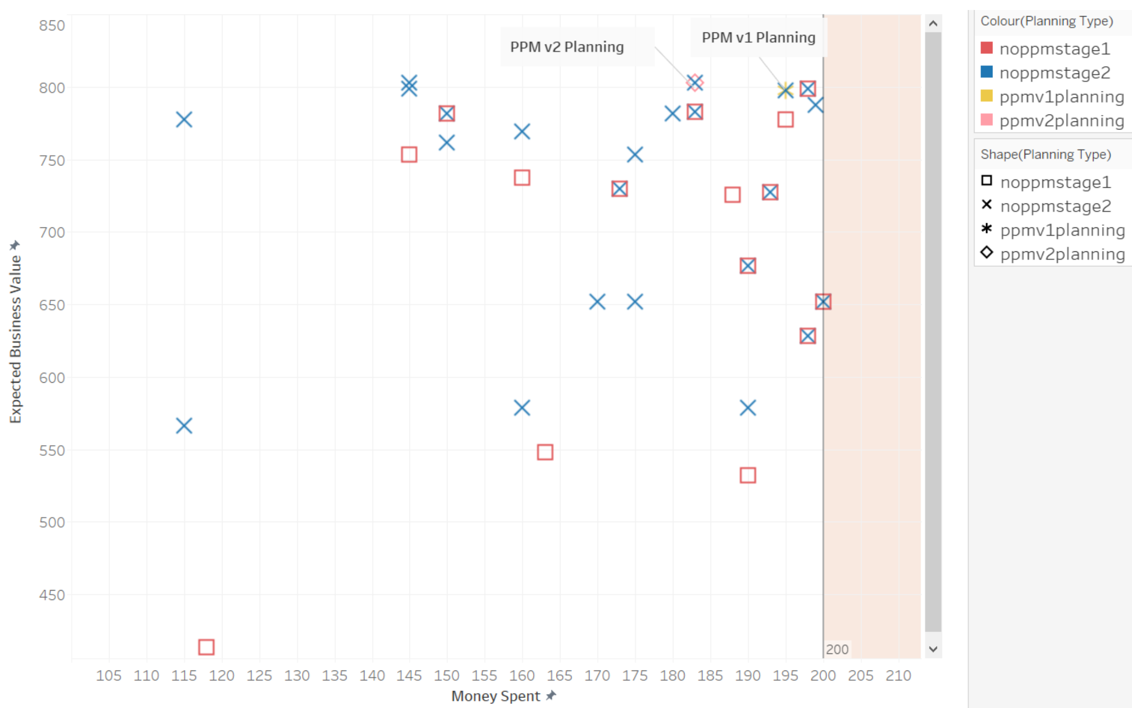

Figure 29 Expected business value vs. money spent in planning phases

Figure 30 shows created business values and money spent in execution phases.

- Red circles are the results when the PPM system is not used.

- Cyan asterisks are the results when the PPM_v1 algorithm is used.
- Blue pluses are the results when the PPM_v2 algorithm is used.
- For most cases, PPM algorithms lead to more business value.

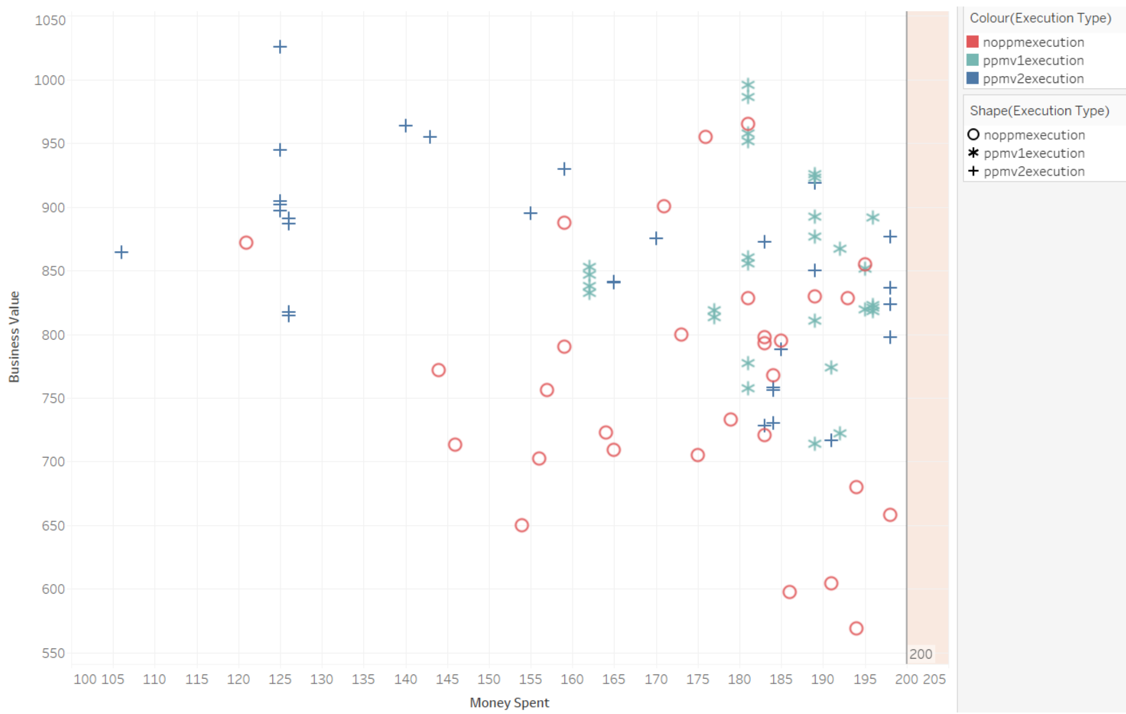

Figure 30 Business Value vs. Money Spent in execution phases

7.4.2. Scenario 2 – "Relocation"

In this scenario, there are considerably more activities to plan. Also, the planning horizon is wider than the "Journey to Tyrol" scenario. The details of the scenario are explained in APPENDIX D, and the details of the results are given in APPENDIX F. The aim of this part of the tests is to understand if the CP algorithm would perform well to create acceptable execution plans for the users in the case of having many activities, constraints, and wider planning horizon.

The distribution of the time it took for the 20 participants to plan the relocation process is given in Figure 31.

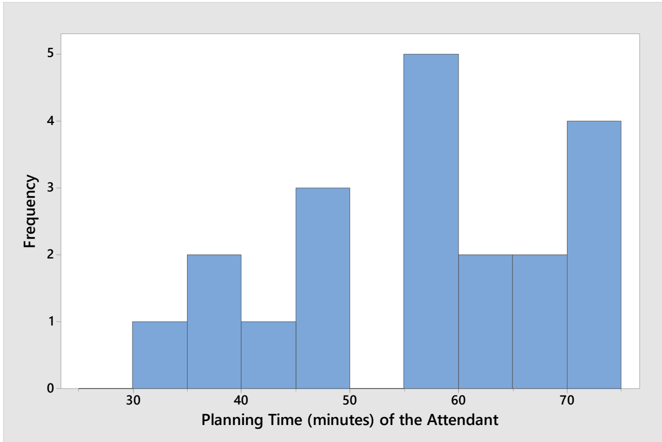

Figure 31 Distribution of time used by the participants (#of participants vs. minutes)

The fastest participant used 30 minutes to create an execution plan for the activities of the "Relocation" process. On the other hand, it took 75 minutes to plan the days of this scenario for another participant.

Although the participants had 90 minutes, the minimum, median, and maximum time it took for them to complete the planning were 30, 55, and 75 minutes respectively. Considering this and the fact that they used an Excel sheet that was informing them whether time window and precedence constraints were satisfied, it is surprising that 75% (15) of the participants violated the constraints and created infeasible execution plans. Violations are done in various ways: at least one precedence constraint is not satisfied (Precedence), at least two undelegated activities are planned for the same time interval (Collided Acts), at least one activity does not satisfy a time window constraint (Time Window). The violations are also given in APPENDIX F, in the "error type" column. Some examples for these three types of errors are as follows:

- Precedence: "Unloading the truck" cannot be done before loading the truck.
- Time Window: "Natural gas subscription" cannot be done after 17:30.
- Collided Acts: "Electricity subscription" and "arrange a cleaner" activities cannot be planned for the same time.

In creating the execution plan, the primary goal of the participants was to create it in a way that the completion time of the last activity is minimized. So, the primary aim was to complete the process as soon as possible. After this objective, the second objective was to reach the first objective in a way that the total traveling distance would be as less as possible. Among these feasible execution plans given by five participants, only one of them (Participant 4) created a plan that has the same end date-time as the plan recommended by the application. Yet, for this one plan traveling distance (204km) is 37% longer than the execution plans created by the prototype (149km).

If we do not think of the feasibility of the solutions for a while, considering the two objectives, 8 of the 20 participants created competitive execution plans. Six of these execution plans (Participants 3, 4, 6, 10, 15, and 16) have the same end date time as the execution plan that the prototype application made (Day 4 at 13:00). Another one of these eight execution plans (Participant 12) has an earlier end date-time (Day 3 at 21:15), and the final one of these eight execution plans (Participant 17) has almost the same end date-time (Day 4 at 13:30) with the execution plan that the prototype application made. Yet, seven of these eight plans are infeasible because of constraint violations. Only one of these 8 challenging execution plans (Participant 4) is feasible, which has a longer traveling distance than the execution plans created by the prototype PPM application.

Besides minimizing the completion time of the last activity (total process time) and the total distance traveled, the time and effort it takes for the participant to create the execution plan is a consideration. For that reason, after the participants created their own execution plans for the Relocation scenario, the execution plan that the prototype PPM application created in 3 seconds was shared with the participants. At the end of the experiments, we asked the participants if they would choose to use an application for this purpose or not. All the 20 participants commented that they would use a PPM application with this functionality and the execution plan that is suggested.

7.4.3. SUS Questionnaire

After the "Journey to Tyrol" tests are conducted, 30 participants are asked to complete the SUS questionnaire, which is also given in APPENDIX A. The average SUS score is 80.8, whereas the median SUS score is 83.8. According to [102], these scores define the prototype as better than good, almost excellent, both of which are in the acceptable range. These ranges can also be seen in Figure 32.

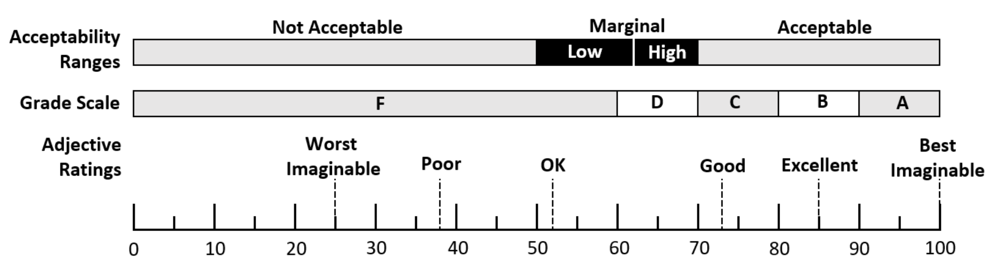

Figure 32 A comparison of the adjective ratings, acceptability scores, and school grading scales in relation to the average SUS score [106]

The distribution of the 30 scores can be seen in Figure 33. The minimum score is 42.5, the maximum score is 95, whereas the standard deviation of the distribution is 12.6.

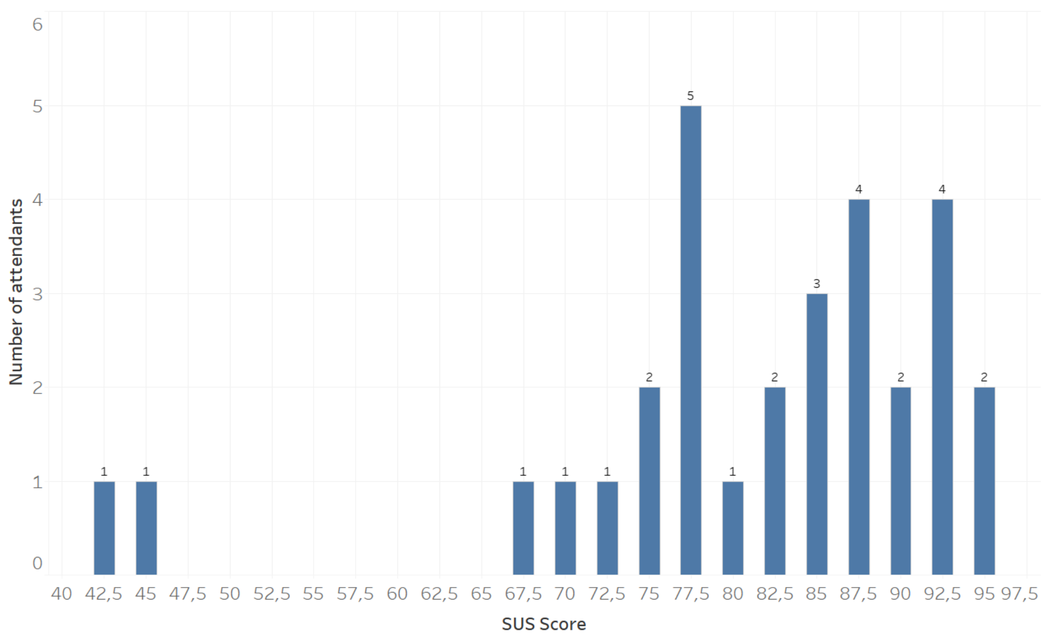

Figure 33 SUS Score Distribution

The distribution of the answers to the individual questions can be found in Figure 34. The higher the scores, the more positive the response is. For instance, for question 6, 25 out of 30 respondents strongly disagree that there is too much inconsistency in the application. For questions 1,3,5,7, and 9 having a high value means that the participant agrees, whereas for questions 2, 4, 6, 8, and 10, having a high value means that the participant disagrees.

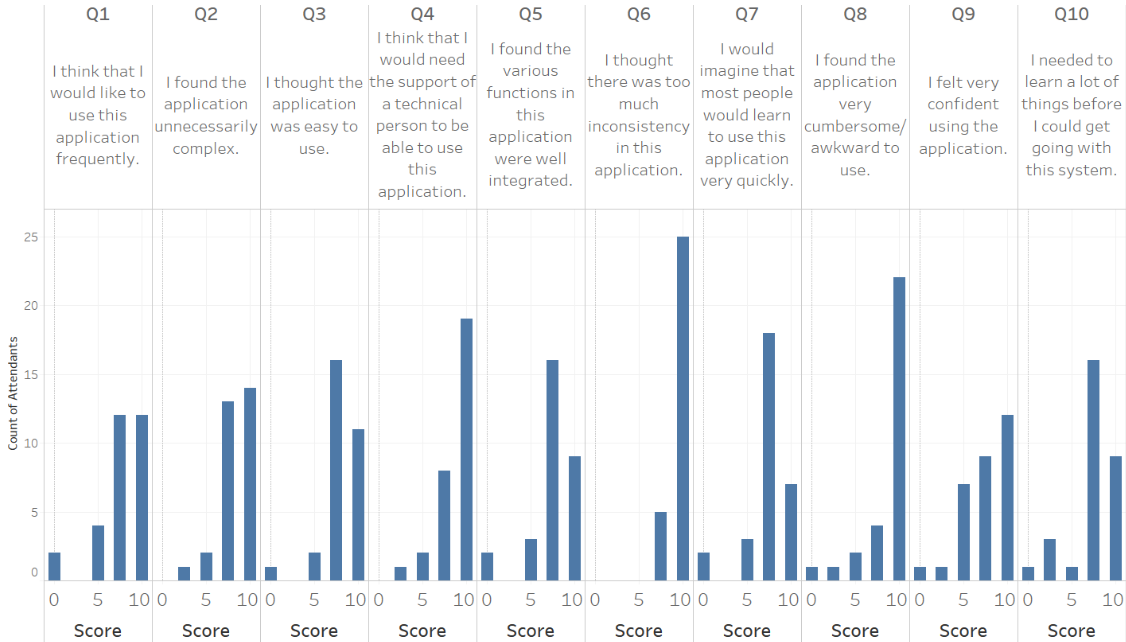

Figure 34 Score distributions for each SUS question (High score for more positive response)

7.5. Chapter Summary

This chapter gives the design evaluation of the study, first by explaining the design process and evaluation method. Then, the experimental design is given. The milestones of experimental design are “Journey to Tyrol” scenario experiments conducted with 30 participants, the SUS questionnaire with these 30 participants, and “Relocation” scenario experiments conducted with 20 participants. The results of these experiments are also given in this chapter.

CHAPTER 8

DISCUSSION

In this chapter, the interpretation of the results will be discussed. Finally, the descriptions of these results and how they relate to the objectives listed in the introduction section are described.

8.1. Summary of what was learned

After the literature review, the study continued with the semi-structured interview. The interviews were significantly helpful in collecting a list of personal processes. In these semi-structured interviews, the participants not only helped to create a list of personal processes but also shared their ideas on what the impact of a PPM system would be. Without the interviews, formulating the problem definition would have been more challenging and deficient. So, it is worth stating that it is more than helpful to talk with the potential users of the artifacts before starting to structure these artifacts. As it is noted in [86], interviewing is used by qualitative researchers to gather insights about intangible things like attitudes, comments, experiences, intentions, perceptions, reactions, and thoughts. As DSR studies create outputs as purposeful IT artifacts, it would be constructive to keep the qualitative side of these studies and communicate with the potential users of these purposeful IT artifacts.

When the outputs of the semi-structured interviews were used in creating a personal process taxonomy, first, it wasn't easy to choose the characters and dimensions. Yet, after the activities in the method proposed by Nickerson, Varshney, and Muntermann [7] were iterated a couple of times, a helpful taxonomy has emerged. The taxonomy is especially invaluable in understanding the type of personal processes that exist and deciding which class of these various processes to focus on.

Similarly, to communicate the ideal case of finding a solution to the defined problem, the reference model for PPM systems is introduced. This model was also essential to focus on prototype development while not losing sight of the big picture.

Although a lot was learned in conducting semi-structured interviews, building a personal process taxonomy, and defining a reference model for PPM systems, the most are discovered in the prototype development and the experimentations stages.

The following insights are gathered in the "Journey to Tyrol" scenario, which has ten activities, two hotel alternatives, and two types of travel.

- *Planning time*: In the planning phase, when the PPM system is not used, the more time the participants use, the better results they get in terms of expected business value. However, for most participants, ten minutes was not enough to create an acceptable plan for them. So, after using the first ten minutes, most participants decided to use some portion of the additional twenty minutes to make better plans. The PPM system created the execution plans within seconds for both versions of the PPM CP algorithms. So, it always takes less time to plan with the PPM system. the participants use 19 minutes (mean and median) for creating the plan whereas it is 10 seconds for the PPM application.

- *Expected business value with and without the PPM system*: In the planning phase, the PPM system constantly gives the same business value result as there is no randomness in this stage. The first version of the PPM system almost always (28 out of 30 participants), and the second version of the PPM system always generated some expected business values better than the values generated in participants' plans.

- *Expected money spent in the planning phase:* Money is considered as a constraint in this scenario. The model underneath the PPM system first tries to maximize the business value gathered in the journey. Then if there are multiple solutions with the same business value, it chooses the one with the minimum money spent among these solutions. The participants are also asked to behave similarly. Yet, if the money spent was also used in the objective function with the same weight of business value gained, then the solution approach would be much different. For instance, some solutions with a little less business value and less cost could have been selected as the best solution.

- *Total time usage with and without the PPM system*: The participants tend to use more time to plan and execute these two days without the help of the PPM system.

- *The business value gained in the execution phase with and without the PPM system*: It is shown that plan execution with the PPM system gives statistically better results than execution without the PPM system.

- *Simulation environment*: In the time measurement, there was also an overhead of reflecting the changes in the simulation environment to the PPM system. It increased the time usages in the execution phase with the PPM systems. That could have been neglected because, in real-life use, the users would only check their phones to see what to do next.

- *Participant comments*: Some participants commented that they would prefer to use the system in scenarios with more activities to plan. Some participants commented that they would use the system even if the system would not give the best execution plan as it is easier to improve a prebuilt plan instead of creating a plan from scratch.

- *Flexibility*: Fast replanning capability provides flexibility during the process execution. If the conditions or priorities change in a day, users do not prefer to use another 30-40 minutes to make a good plan for the rest of the day. The Journey to Tyrol scenario is built considering the unforeseen events [107] during the execution time. For instance, people may plan to visit a museum but may encounter a long queue at the entrance. So, they may choose to skip the museum visit. It is also possible that before even reaching the museum entrance, an accident may increase the 30-minutes-planned travel to an hour. Or sometimes, a four-hour-planned museum visit event may take two hours if it does not satisfy the expectations. Unpredictability can also be that an unplanned, new activity option (e.g., an invitation to a party) may arise. Such examples may be expanded. Yet, with each unplanned change in activities, people should find ways to alter their plans. The more this type of event occurs, the more valuable a solution like this will be. And these changes happen more frequently in personal processes. That is why process flexibility is a more useful feature in PPM than in BPM. Since fast and automated (re)planning provides flexibility to the users, it is advantageous to have this functionality.

In the "Relocation" scenario, which has 38 activities, the following insights are gathered.

- *Number of Activities*: As the number of activities increases, it becomes more challenging to create a plan. In this case, some people stop attempting to develop a comprehensive plan in daily life. They would prefer to use a PPM system, especially in scenarios with many activities. Even if the system may not guarantee to provide the best possible plan when there are many activities and a short amount of time for planning, it is still worth using the system if it gives some acceptable results to start with, which can then be refined iteratively. Participants state that it is challenging to evaluate too many activities and make a plan from scratch rather than modifying an initial imperfect plan.

- *Mistakes*: When the scenario is computationally complex, the participants are more prone to make mistakes in planning. The participants would need more time, more caution, so more effort to create plans with no errors.

- *The success of the execution plans*: Even if some participants created feasible plans without violating any constraints, these execution plans could be improved in terms of the day and hour when the relocation would be completed or the total distance to travel.

- *Planning Time*: Even if in some cases the plan suggested by the participants has the same end day and hour as the plan proposed by the PPM system has, it takes significantly more time for the participants to create these plans. The participants use about 55 minutes (mean and median) to create a plan, whereas the PPM application uses 3 seconds.

- *Multi-objective*: When both "minimize makespan" and "total distance taken" are considered in creating the plan, it takes more time for the PPM system to find the optimal solution.

- *Usability*: According to the interviews we made, some participants think that excessive data input may cause difficulties for them to use the tool. Therefore, it is helpful to provide means of entering less amount of data, e.g., using predefined plan templates and modifying them if needed. A defined process can be used multiple times if the process is shared with other people or if the same person executes it at another time. Studies like [37], [42], [38], [40], and [41] focus on such social aspects of PPM. Even when a defined process is executed only once, using a PPM system could still compensate for entering all input and constraints in some cases. For instance, our experiments show that users tend to create infeasible execution plans when the number of activities increases. Also, it would be helpful if the system can sense the change in the conditions, adapt the plan accordingly, and notify the participant. This would increase the usability of the application. Then, the users would not need to track the conditions and decide if a new schedule should be created or not. Although not within the scope of this study, we also think that recent improvements in voice assistants may further reduce the data input effort. All the participants said they would use a PPM system for this type of scenario, considering the plans that the prototype PPM system made and the plan they created.

- *Additional participant comments:* Some participants commented that the prototype PPM system has the strength of giving better execution plans quickly. Some added that when the number of activities so the computational complexity increases, they stop planning and start completing the activities which could be done in the vicinity. Some participants pointed out the importance of creating a plan quickly during the execution of a process. They continued to argue that when the conditions change, they would not stop make another plan using 30-40 minutes during the execution of a process, which increases the importance of having a PPM system. Some participants said that the PPM system should sense these context changes and adapt the plan accordingly, then notify the user, which would increase the system's usability. This context change could be the change in the traffic during the day, which would affect the time it takes to go from one location to another, a change in the weather, an unforeseen closing of a shop, etc.

8.2. Theoretical significance

Developing a PPM system is a complex issue that is likely to take time to mature before it evolves into a universally accepted technology. The approach in this study is to commence this process by employing the most scientifically rigorous methodologies available.

With the mentioned approach in mind, a personal process taxonomy is developed, which would start the research and development scientifically and support the emergence of novel approaches not directly applicable through customary software development endeavors. The goal of the personal process taxonomy is to accompany practitioners and researchers by forming personal process classes, clarifying the connections among process types, and organizing the knowledge in the PPM domain with the hope that it would help practitioners and researchers in suggesting methods or methodologies to be used in the effective management of personal processes.

In addition to personal process taxonomy, the reference model for PPM systems would help the researchers and practitioners to have a head start in creating a PPM system by formulating the core challenges and corresponding potential solution components. Furthermore, it supports them in creating structured solutions to PPM-related issues and challenges.

Also for the CP model part, this study makes an exaptation [4] type of contribution to the PPM domain. The DSS domain is mature in utilizing CP for making recommendations. Yet, there is no example in the PPM domain of applying CP models to make recommendations for creating execution plans.

The primary theoretical innovation of this study is formulating and solving two major problems in the PPM domain, process flexibility and context awareness, by utilizing a CP model in a multiple attribute DSS. The presented formulation of the problem is important because the mathematical definition creates the chance to approach the problem analytically and improve iteratively. For instance, in this study, we opted to use the lexicographic method for ordering the objective functions to reduce the users' cognitive load. Yet, in a future study, experiments with the weighted-sum method or the desirability function approach can be conducted as well.

As a follow-up theoretical contribution within the PPM domain, our study shows that CP fits well when the process is defined declaratively. The research illustrates that declarative process definitions can be easily translated into CP constraints. We used a subset of declarative relations given in [108] as reusable constraints in our CP model per the experimentation scenarios.

8.3. Practical significance

The prototype PPM system development and the experimental test results construct the practical significance of this study. The study clearly shows that a mobile application that acts as a recommendation system for process execution in PPM is helpful and desirable. One significant assumption is that creating process definitions takes time comparable to the time required to create to-do lists. This can be realized with the social components in reference model (Figure 15 in page 51) or user-friendly input methods such as speech-to-text. The participants commented that they would accept guidance from a DSS for PPM, and the empirical results show that a CP model implementation can provide better plans for personal processes in less time. Creating an execution plan within seconds instead of minutes or hours also has significant implications for PPM. It provides greater flexibility and agility in adapting to changing conditions. A user can run the model multiple times during process execution to check if the changing needs or context information leads to better execution plans.

In accordance with this idea, the prototype PPM system and the implementation of the CP model make up an essential portion of the practical significance of this study. On top of that, the comments and ideas of the test participants add value in practical significance.

8.4. Chapter Summary

In this chapter, a collected understanding of the results is shared. The perception is described with the sections of "summary of what was learned", "theoretical significance", and "practical significance".

CHAPTER 9

CONCLUSIONS AND FUTURE WORK

9.1. Conclusions

As in any academic study, we grab a promising idea and evaluate its usefulness by pushing it to its practical and logical limits. This study is an effort to best address the robust advancement of the PPM domain and subsequent applications within this domain. PPM is a promising emerging field interested in the management of processes within every individuals' life. These processes are more diverse and unstructured by nature than the processes within the boundaries of businesses. That increases the challenge of providing some generic, robust solutions to these types of processes. In this study, after the literature review, semi-structured interviews are conducted to understand the domain better. Then, a personal process taxonomy is developed to have a more structured view of the personal processes. After this initiative, which helped make a better problem definition, the solution proposal part of the study is constructed, starting with developing a reference model for PPM systems. All these components of the reference model can be studied in detail, and many theoretical and practical contributions can be made to the field. This study directed into the optimization center part of that reference model. So, to suggest a solution in that component, a CP model is developed. That CP model is implemented in a prototype PPM system as a minimum viable product to show the effects and contributions of having the optimization center of such a system. Experiments are conducted with participants to understand the consequences. Both quantified and qualified results are collected via these experimentations and questionnaires. The results showed that it would be beneficial for individuals and accepted by them to have a PPM system as a personal assistant that could be used to manage these individuals' processes. As in any academic study, the future unqualified success of the approach taken cannot be promised. Yet, reporting on the results of the persevering and truthful scientific efforts is a cultivating contribution to the academic literature. The experience acquired during this study demonstrates that this work has supported the confidence in its usefulness and consequential benefits.

9.2. Future Work

There is a great potential for research in the PPM domain, some of which are mentioned in this report. Personal process taxonomy can be improved by conducting new semi-structured interviews and collecting new sets of processes. Depending on these collected personal processes, new iterations can be done using the taxonomy development method proposed by Nickerson, Varshney, and Muntermann [7]. A new dimension can also be added to the taxonomy by asking questions on the frequency of the process execution, importance, criticality, or seriousness of the activities in the process, on the dependency of legislative or regulatory constraints, on the driving force of the process whether it is data- or judgment-driven.

Although the CP model and the prototype application are complete within the scope of this research, as a future study, the scope can be extended, e.g., by implemented additional constraint types like “existence at most n” or “responded existence” stated in [109]. Also, an integration between the PPM system and an imperative modeling tool would let the potential users easily model their processes in some cases. If the potential users would prefer to model via that imperative modeling tool in these cases, then a transformation from the imperative model to the declarative model would be needed. Wedemeijer L. [108] explains constructs for transforming an imperative workflow to declarative business rules. Another improvement could be to have multiple execution plans from the model and providing two or three options to the user, in case these options overperforms for at least one criterion with respect to the other options.

There is also significant research potential in all the components of the reference model, although, in this study, only the optimization center is being focused on. Finding effective ways of collecting, keeping, searching, sharing, modeling, and executing processes are some concerns that are listed in Reference Model for PPM Systems chapter. The first crucial future work would be to make experiments within daily life instead of using test scenarios and collecting data accordingly. The scope of the application can also be narrowed down using the personal process taxonomy to collect data within the same class of processes. For instance, a mobile application for supporting traveling can be developed and distributed to support decision-making in travels by creating execution plans. Then, usage, acceptance, conformance, the satisfaction of process recommendation, and execution-related data can be collected. So, optimization center functionalities can be extended using machine learning or deep learning techniques after collecting historical data. The CP model is used for recommending execution plans, which has proved its success in the conducted experimentations. Yet, with collected data, new insights may emerge. Augmented data discovery or gamification techniques and speech-to-text methods can be used on the user acceptance and interface side.

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APPENDICES

APPENDIX A

SYSTEM USABILITY SCALE QUESTIONNAIRE

Please check the box that reflects your immediate response to each statement. Don't think too long about each statement. Make sure you respond to every statement. If you don't know how to respond, simply check the box "neutral".

	System Usability Scale	strongly disagree	disagree	neutral	agree	strongly agree
1	I think that I would like to use this application frequently.					
2	I found the application unnecessarily complex.					
3	I thought the application was easy to use.					
4	I think that I would need the support of a technical person to be able to use this application.					
5	I found the various functions in this application were well integrated.					
6	I thought there was too much inconsistency in this application.					
7	I would imagine that most people would learn to use this application very quickly.					
8	I found the application very cumbersome/awkward to use.					
9	I felt very confident using the application.					
10	I needed to learn a lot of things before I could get going with this system.					

APPENDIX B

METU ETHICS COMMITTEE ACCEPTANCE

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
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Sayı: 28620816 / 526

08 KASIM 2018

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Doç.Dr. P. Erhan EREN

Danışmanlığını yaptığınız doktora öğrencisi Sercan ORUÇ'un **"Kişisel Süreçlerin Yönetimi"** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2018-FEN-056** protokol numarası ile **08.11.2018 - 31.08.2019** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Ş. Halil TURAN
Başkan V

Prof. Dr. Ayhan SOL
Üye

Prof. Dr. Ayhan Gürbüz DEMİR
Üye

Prof.Dr. Yaşar KONDAKÇI
Üye

Doç. Dr. Zana ÇITAK
Üye

Doç. Dr. Emre SELÇUK
Üye

Doç.Dr. Üyesi Pınar KAYGAN
Üye

APPENDIX C

"JOURNEY TO TYROL" SCENARIO EXPLANATION

Summary

In this test, you are going to plan and execute a two-day-long journey. First without (Phase 1), then with the help of a mobile recommendation system (Phase 2). In phase 1, you are expected to complete an initial plan in 10 minutes. Then if you need extra time, you will have 30 minutes to complete that initial plan. At the end of phase 2, you will be asked 10 questions with Likert scale answers. This test will take about 1 hour in total.

Story

Planning Phase: You are planning a two-day long journey to Tyrol, Austria, for next month. There are three locations in this journey to Tyrol: Innsbruck, Wattens, and Schwaz. You will begin your journey in Innsbruck at 8:00 on the first day. You should end your journey in Innsbruck at 18:30 on the second day. For the first and only night (from 18:30 on the first day to 8:00 on the next day), you plan to stay in one of two alternative hotels.

Execution Phase: After a month, you start executing what you have planned. During the execution, random events may occur, which can be an emergence of a new activity, traffic, a crowd in a museum, etc. And those random events may affect the business value you get from activities, the cost or duration of those activities.

Simulation Tool

Alaska Simulator is used for testing, analyzing, and improving the users' planning behavior. A screenshot of the simulator can be seen in Figure 35. All the components will be explained below in the **Additional Information** section. You will plan and execute your two days in Tyrol using this tool. You will see the results of your decisions and random events on the fly.

Assumptions

- Every activity within a city takes place at the same location, i.e., there is no transportation time or cost between two activities in Innsbruck.
- In your plan sheet, time is divided by 15 minutes of time slots, i.e., if an activity is 35 minutes long, then it takes 3 time slots (45 minutes) in your plan.
- You have a budget of €200.

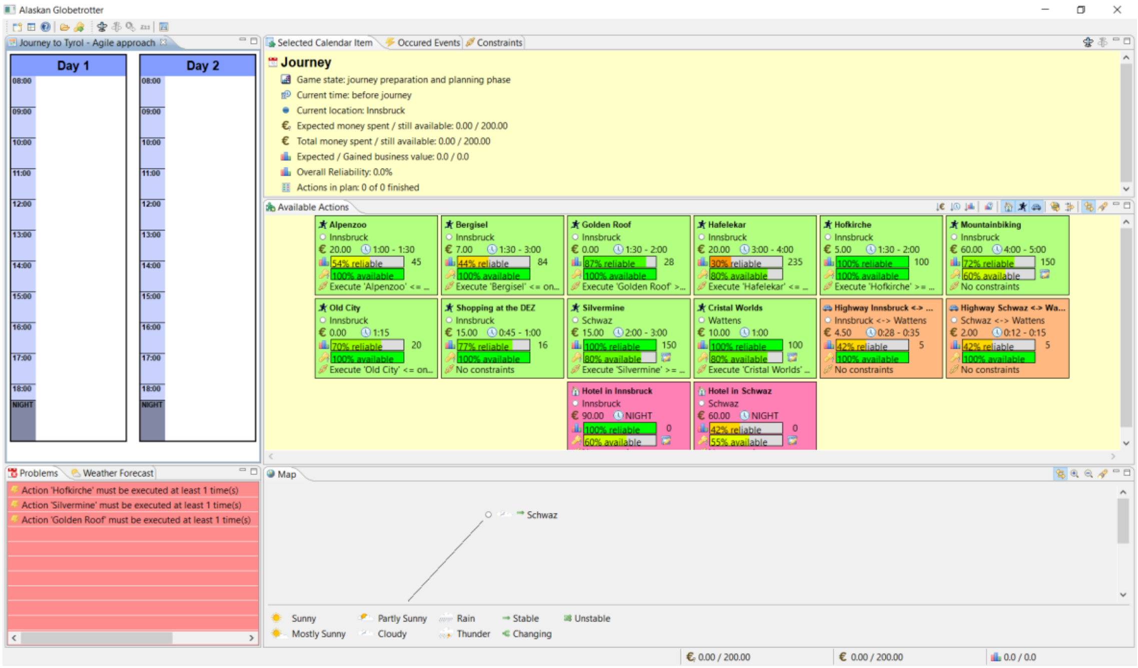

Figure 35 Alaska Simulator [100]

Additional Information

- **Activity**: Each activity has a set of attributes:
  - Location: One of Innsbruck, Wattens, or Schwaz.
  - Expected Cost
  - Expected Duration: Maximum and minimum limits are given.
  - Expected Business Value: This shows your expectation from the activities. Gained business value may differ from this value.
  - Reliability: This shows the reliability of having expected business value. The distribution graph of expected business value is also given.
  - Availability: Some activities may have high demand that they may not be available at all times.
  - Reservation: For some activities, it is possible to make a reservation. Canceling a reservation may create an extra cost. Booking deadline and cancellation fees can also be seen.
  - Constraints: Some activities have some additional constraints.
    - The action can only be executed once.
    - The action must be executed at least once.
    - The action can be executed on every day at 9:00, 10:00, 11:00, 12:00, 13:00, 14:00, 15:00, 16:00, and 17:00

- The action can be executed every day from 9:00-18:00

An example activity can be found in Figure 36.

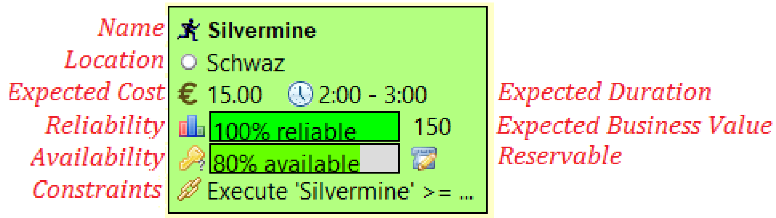

Figure 36 An example activity

- If any constraint is violated, it can be seen in the Problems section of the simulator as in Figure 37.

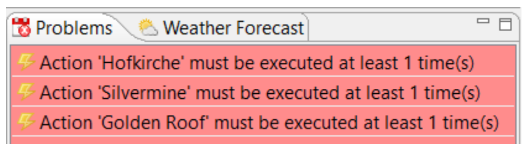

Figure 37 Problems

- **Accommodation**: First night, there are two accommodation alternatives: One in Innsbruck and one in Schwaz, as shown in Figure 38.

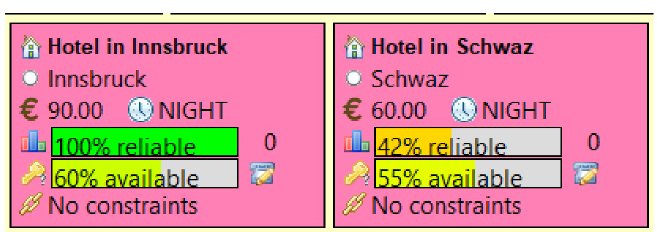

Figure 38 Hotel Alternatives

- Sleeping in a car is also another accommodation alternative, yet it is not suggested. This can be done by clicking the buttons shown in Figure 39 and Figure 40.

Figure 39 Sleep in Car button

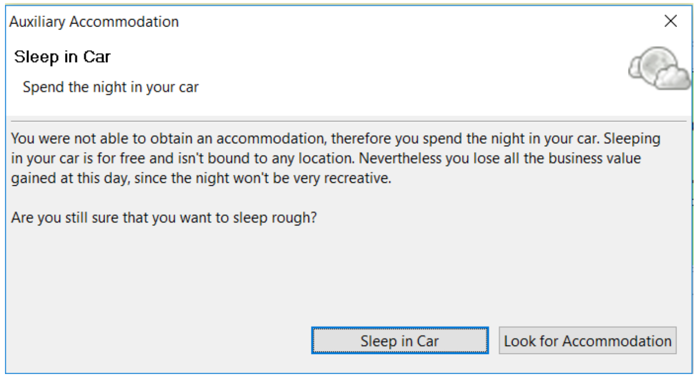

Figure 40 Sleep in Car Message

- **Route**: There are two transportation-related actions; one between Innsbruck and Wattens and one between Wattens and Schwaz, which are shown in Figure 41.

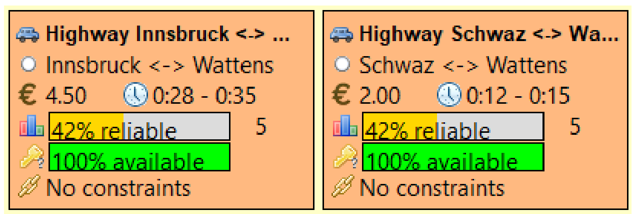

Figure 41 Transportation Alternatives

- To go to Schwaz from Innsbruck, or vice versa, you should first go to Wattens. It is depicted in the simulator, as is shown in Figure 42

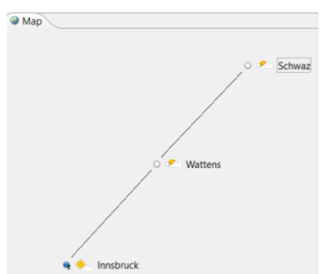

Figure 42 Map showing the three locations in Tyrol

- In the planning phase, you will see that there are 10 alternative activities, 2 alternative accommodations, and 2 alternative route types of actions.
- The journey section of the simulator gives you a summary of the current state of the journey, as in Figure 43.

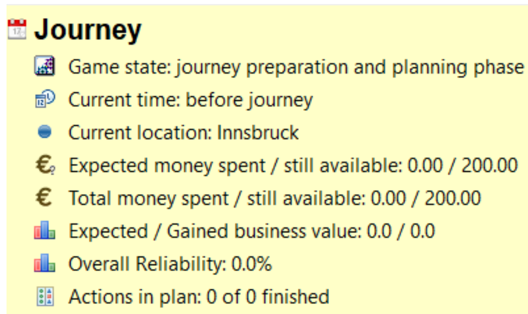

Figure 43 Summary of the Current State of the Journey

- The Weather Forecast section of the simulator gives you the information in the execution phase, as in Figure 44.

Figure 44 Weather Forecast

- Occurred Events and Constraints sections also give additional information. The buttons for these can be seen in Figure 45.

Figure 45 Occurred Events and Constraints

- The button for finishing the planning phase and starting the journey (execution phase) can be seen in Figure 46.

Figure 46 Button for finishing planning phase and starting the journey

- The button for finishing the journey can be seen in Figure 47.

Figure 47 Button for finishing the journey

APPENDIX D

"RELOCATION" SCENARIO EXPLANATION

Note: Below listed instructions and schemas are given to the test participants via an Excel sheet.

Scenario Explanation

Assume you are living in Konutkent, Ankara, and you will move your house to 100. Yıl, Ankara. You have listed some activities, and you want to plan your days using those activities such as electricity subscription or painting the new house. You set the estimated durations for those activities that you have listed. You took note of where to perform those activities although some activities can be performed anywhere, like arranging a cleaner. You decided to delegate some of those activities as well. Your objective is to perform all those activities (or to be performed the delegated activities) as soon as possible within 5 days (4 or 3 days if possible) because you will begin your preparations on Monday, and you want to complete the activities consecutively by taking the least possible amount of day off from work. The instructions box below explains how to conduct this test.

Instructions

You are kindly requested to fill **only** the **Day** and **Start Hour:Min** cells for the corresponding activities below (

- Table 13). **Day** column refers to the day that you will perform the activity.
- **Start Hour:Min** column refers to the time of the day (i.e., 17:25) that you will start performing the activity. Sleep days and start hour:mins are fixed. Please do not change them.
- First, read the **Activity** names and where they will be performed (**Locations** column). Delegated activities are stated by **delegated** column.
- Then read the Assumptions box to understand how delegation and - locations affect your planning, what your goal is, and more.

- Then, please check the information given in **Precedences**, **Time Windows, Distances(meters),** and **Time(minutes)** tables to understand the constraints that you have listed in Table 14 and Table 15.

- Finally, start planning the activities without any interruption and write how long it took to complete your planning. It is expected to take 30 to 90 minutes long.

- Note: You may change the order of activities as you wish. After clicking an activity name Sort&Filter -> Custom Sort -> Sort by E, Then F will give a chronological sort.

<u>Assumptions</u>

- Activities with no specific location, i.e., locations defined as -, can be performed anywhere, even when you are on the road to somewhere. For instance, you may arrange a cleaner while you are going from old house to new house.

- Planning ends when the last activity, other than sleeping, lunch, and dinner activities, is planned.

- You are requested to complete all the activities except the delegated ones on your own. Even if you don't do an undelegated activity on your own, you should spend the amount of time (minutes) given at the given location.

- The old house and the new house are cleaned by the same cleaner.

Distances between each pair of locations can be found in Table 16 and Table 17.

Table 13 "Relocation" Scenario Activities, Activity Durations, and Plan Form

Activity	Loca-tions	Dele-gated	Day	Start Hour: Min	Dura-tion (Mins)	End Hour: Min	Check Time Windows
Arrange a cleaner	-	0			30	00:30	0
Arrange a mover service	-	0			60	01:00	0
Arrange a painter	-	0			30	00:30	0
Change the residence address	Cankaya Municipality	0			40	00:40	0
Cleaning the new house	-	1			300	05:00	0

Activity	Loca-tions	Dele-gated	Day	Start Hour: Min	Dura-tion (Mins)	End Hour: Min	Check Time Windows
Cleaning the old house	-	1			270	04:30	0
Determine Curtain Rod Length and Order	New House	0			60	01:00	0
DinnerBreak1	-	0	1		45	00:45	0
DinnerBreak2	-	0	2		45	00:45	0
DinnerBreak3	-	0	3		45	00:45	0
DinnerBreak4	-	0	4		45	00:45	0
DinnerBreak5	-	0	5		45	00:45	0
Electricity unsubscription/subscription for the old/new house	Enerjisa	0			40	00:40	0
Give the household goods to be given	Cankaya Mun. Annex Building	0			60	01:00	0
Group the household goods: to be sold, to be given, to be thrown away, to be moved	Old House	0			180	03:00	0
Hang curtain rods	New House	0			120	02:00	0
Lighting and electricity-related works for the new house	New House	0			50	00:50	0
Load the truck to move the packages	Old House	0			180	03:00	0
LunchBreak1	-	0	1		45	00:45	0
LunchBreak2	-	0	2		45	00:45	0
LunchBreak3	-	0	3		45	00:45	0
LunchBreak4	-	0	4		45	00:45	0
LunchBreak5	-	0	5		45	00:45	0
Meet the cleaner at the new house	New House	0			10	00:10	0
Meet the cleaner at the old house	Old House	0			30	00:30	0
Meet the painter at the new house	New House	0			30	00:30	0
Natural gas unsubscription/ subscription for the old/new house	Baskent Gaz	0			60	01:00	0

Activity	Loca-tions	Dele-gated	Day	Start Hour: Min	Dura-tion (Mins)	End Hour: Min	Check Time Windows
Pack the small or fragile household goods	Old House	0			180	03:00	0
Painting the new house	-	1			330	05:30	0
Put on sale the household goods to be sold	Old House	0			120	02:00	0
SleepDay1	Old House	0	1	00:00	480	08:00	1
SleepDay2	Old House	0	2	00:00	480	08:00	1
SleepDay3	Old House	0	3	00:00	480	08:00	1
SleepDay4	Old House	0	4	00:00	480	08:00	1
SleepDay5	Old House	0	5	00:00	480	08:00	1
Throw away the household goods to be thrown	Local garbage containe r	0			60	01:00	0
Unload the truck to move the packages	New House	0			180	03:00	0
Water unsubscription/subscription for the old/new house	ASKI	0			40	00:40	0

Table 14 "Relocation" Scenario Precedences

Precedences			Check Precedences
Before	After	Difference	
Arrange a Cleaner	Meet the cleaner at the new house	Minimum 12 hours	0
Arrange a Cleaner	Meet the cleaner at the old house	Minimum 12 hours	0
Arrange a mover service	Load the truck to move the packages	Minimum 12 hours	0
Arrange a Painter	Meet the painter at the new house	Minimum 12 hours	0
Cleaning the new house	Unload the truck to move the packages		0
Determine Curtain Rod Length and Order	Hang curtain rods	Minimum 1 hour	0
Group the household goods: to be sold, to be given, to be thrown away, to be moved	Give the household goods to be given		0
Group the household goods: to be sold, to be given, to be thrown away, to be moved	Pack the small or fragile household goods		0
Group the household goods: to be sold, to be given, to be thrown away, to be moved	Put on sale the household goods to be sold		0
Group the household goods: to be sold, to be given, to be thrown away, to be moved	Throw away the household goods to be thrown		0
Hang curtain rods	Cleaning the new house		0
Lighting and electricity-related works for the new house	Painting the new house		0
Load the truck to move the packages	Unload the truck to move the packages	Maximum 2 hours	0
Load the truck to move the packages	Cleaning the old house		0
Meet the cleaner at the old house	Cleaning the old house		0
Meet the painter at the new house	Painting the new house		0
Pack the small or fragile household goods	Load the truck to move the packages		0
Painting the new house	Cleaning the new house	Minimum 12 hours	0

Table 15 "Relocation" Scenario Constraints

Time Windows		
Dinner Break		18:30-20:30
Lunch Break		11:30-13:30
Sleep		00:00-08:00
Working Hours		
ASKI		8:30-12:30, 13:30-17:30
BaskentGaz		8:30-12:30, 13:30-17:30
Cankaya Municipality		8:30-12:30, 13:30-17:30
Cankaya Municipality Annex Building		8:30-12:30, 13:30-17:30
Enerjisa		8:30-12:30, 13:30-17:30
Other Constraints		
Cleaning the new house		08:30-17:30
Cleaning the old house		08:30-17:30
Hang curtain rods		08:30-17:30
Load the truck to move the packages		08:30-17:30
Painting the new house		08:30-17:30
Unload the truck to move the packages		08:30-17:30
Location	**Coordinates**	**Address**
Enerjisa	39.92767,32.854455	Korkutreis Mahallesi, Atatürk Bulv./ilkiz Sok. No:1, 06430 Çankaya/Ankara
BaskentGaz	39.907459,32.809059	Kızılırmak Mahallesi, Ufuk Ünv. Cd No:13, 06510 Çankaya/Ankara
ASKI	39.944859,32.848906	Anafartalar Mahallesi, Aski Genel Müdürlüğü Kazım Karabekir Caddesi No:70, 06050 Altındağ/Ankara
New House	39.894234,32.802088	İşçi Blokları Mahallesi, 1427. Cd. No:28, 06530 Çankaya/Ankara
Old House	39.878918,32.665988	Konutkent Mahallesi, 06810 Çankaya/Ankara
Cankaya Municipality	39.921445,32.856241	Cumhuriyet Mahallesi, SSK İşhanı, 06430 Çankaya/Ankara
Cankaya Municipality Annex Building	39.875386,32.686765	Prof. Dr. Ahmet Taner Kışlalı Mahallesi, Prof. Dr. Ahmet Taner Kışlalı Mahallesi 2914. Cad. Özçelik İmaj İş Merkezi D:1, 06810 Çankaya
Local garbage container	39.879269,32.666654	Konutkent Mahallesi, 2955. Sk. 22-24, 06810 Yenimahalle/Ankara

Table 16 "Relocation" Scenario Distance Matrix in Minutes

From \ To	Enerjisa	Baskent Gaz	ASKI	New House	Cankaya Municipality	Can. Mun. Annex Buil.	Local garbage container	Old House
Enerjisa	0	11	9	11	12	21	20	23
BaskentGaz	9	0	12	5	11	17	15	16
ASKI	9	9	0	12	10	23	22	23
New House	15	6	14	0	14	18	16	17
Cankaya Municipality	11	11	8	13	0	23	22	23
Can. Mun. Annex Buil.	25	18	25	18	24	0	6	7
Local garbage container	22	15	23	16	22	6	0	3
Old House	21	16	23	18	22	6	3	0

Table 17 "Relocation" Scenario Distance Matrix in Kilometers

From \ To	Enerjisa	Baskent Gaz	ASKI	New House	Cankaya Municipality	Can. Mun. Annex Buil.	Local garbage container	Old House
Enerjisa	0	6.4	3.7	7.6	0.9	18.4	19.4	19.9
BaskentGaz	5.7	0	9.1	2.7	7.3	13.8	15	15.1
ASKI	3.8	7.9	0	9.7	4.1	21	21.7	21.8
New House	8.4	2.4	10.7	0	9.1	14.4	15.8	15.9
Cankaya Municipality	0.9	6.3	3.5	8.1	0	18.7	20	20.1
Can. Mun. Annex Buil.	20.9	15.9	23.3	16.9	21.6	0	2.4	2.5
Local garbage container	19.8	14.8	22.2	15.8	20.5	2.3	0	0.2
Old House	19.6	15	22.4	15.7	20.7	2.6	0.2	0

APPENDIX E

"JOURNEY TO TYROL" SCENARIO TEST RESULTS

Table 18 shows the age and gender information of the participants of the "Journey to Tyrol" test.

Table 18 Age and Gender Information for "Journey to Tyrol" Scenario Test Participants

participant#	Gender	Age	participant#	Gender	Age	participant#	Gender	Age
1	F	30	11	M	30	21	M	25
2	F	34	12	F	25	22	M	25
3	M	30	13	M	36	23	F	26
4	M	36	14	F	24	24	M	26
5	F	30	15	F	30	25	F	26
6	M	37	16	M	34	26	M	26
7	F	26	17	M	34	27	F	29
8	M	28	18	F	34	28	M	37
9	M	28	19	M	34	29	M	35
10	F	30	20	M	32	30	F	30

Table 19 shows the test results of the "Journey to Tyrol" scenario without the help of the PPM system for the first three phases. Here the participant first makes the initial planning in 10 minutes (Stage1), then continues initial planning for at most 20 additional minutes (Stage2).

Table 20 shows the test results of the "Journey to Tyrol" scenario with the help of the first version of the PPM system for the initial planning and execution phases. As the PPM system can plan quickly, the second phase of initial planning does not exist. This table also shows the improvement in time usages.

Table 21 shows the test results of the "Journey to Tyrol" scenario with the help of the second version of the PPM system. For these 30 tests, the expected business value in initial planning, the business value gathered, and the money spent at the end of the execution are given.

Table 19 "Journey to Tyrol" Scenario Test Results - Planning without the Support of PPM

	Without PPM								
	Initial Planning - Stage1			Initial Planning - Stage2			Execution		
Partici-pant#	Time (min: sec)	Expec-ted Money Spent	Expec-ted Busi-ness Value	Time (min: sec)[1]	Expec-ted Money Spent	Expec-ted Busi-ness Value	Time (min: sec)	Mo-ney Spent	Busi-ness Value
1	10:25	160	737.1	22:09	183	782.8	13:58	146	713.4
2	09:45	183	782.8	23:15	198	798.8	03:04	179	732.8
3	09:15	198	628.3	11:56	198	628.3	04:23	154	650.1
4	10:36	190	676.6	21:58	160	769.1	05:06	181	965.4
5	10:03	183	782.8	33:54	150	781.6	03:35	144	771.7
6	08:29	198	628.3	17:43	170	652.1	05:26	194	679.6
7	09:52	160	737.1	15:02	175	753.1	02:16	175	705.2
8	-	-	-	20:43	115	777.6	02:56	159	790.4
9	-	-	-	16:29	195	797.6	11:55	171	900.4
10	09:15	145	753.1	15:40	160	769.1	03:39	165	708.9
11	-	-	-	29:49	180	781.6	07:38	157	756.3
12	09:48	190	676.6	17:13	190	676.6	02:32	184	767.9
13	-	-	-	18:17	190	578.6	10:58	191	604.2
14	09:05	198	798.8	15:42	195	797.6	10:30	185	795.2
15	09:40	183	782.8	15:40	183	782.8	07:01	186	597.7
16	10:59	163	547.8	21:52	150	761.6	09:36	159	887.8
17	07:36	193	727.4	07:36	193	727.4	06:32	164	722.6
18	09:20	150	781.6	21:29	180	781.6	09:06	189	829.6
19	10:39	200	652.1	20:19	145	802.8	06:31	183	720.8
20	08:53	195	777.6	19:59	175	652.1	05:41	194	568.9
21	09:30	195	777.6	15:46	195	797.6	07:39	181	828.4
22	10:36	198	628.3	19:05	183	802.8	06:52	183	797.6
23	-	-	-	25:39	115	566.1	04:33	183	792.6
24	10:04	190	532.1	22:27	199	787.6	09:15	193	828.5
25	09:31	200	652.1	13:55	200	652.1	09:27	198	657.8
26	09:40	188	725.4	25:33	195	797.6	06:35	195	855
27	08:49	183	782.8	14:50	195	797.6	07:16	176	954.8
28	-	-	-	20:23	145	798.8	04:43	121	871.5
29	08:59	173	729.4	08:59	173	729.4	04:06	173	799.8
30	09:35	118	413.8	15:49	160	578.6	05:22	156	702.2

[1] Time value in Initial Planning Stage 2 is the sum of the time it takes to make the first planning (Stage 1) and the extra time to enhance that first plan. So, Stage 2 Planning time value is always greater than Stage 1 Planning time value.

Table 20 "Journey to Tyrol" Scenario Test Results - Planning with the Support of PPM version 1

	Initial Planning			Execution			Total Time			
user#	Time (min: sec)	Expec-ted Money Spent	Expec-ted Busi-ness Value	Time (min: sec)	Money Spent	Busi-ness Value	Without PPM	With PPM	Diffe-rence	%
1	04:04	195	797.6	08:06	181	957.9	36:07	12:10	23:57	66%
2	04:53	195	797.6	11:21	181	757.4	26:19	16:14	10:05	38%
3	02:39	195	797.6	10:53	162	852.6	16:19	13:32	02:47	17%
4	05:57	195	797.6	14:24	196	818.1	27:04	20:21	06:43	25%
5	02:41	195	797.6	10:37	181	996	37:29	13:18	24:11	65%
6	02:25	195	797.6	03:06	196	820.8	23:09	05:31	17:38	76%
7	01:58	195	797.6	05:01	181	951.4	17:18	06:59	10:19	60%
8	01:50	195	797.6	11:40	181	985.9	23:39	13:30	10:09	43%
9	02:26	195	797.6	16:03	181	860.5	28:24	18:29	09:55	35%
10	02:59	195	797.6	09:54	181	777	19:19	12:53	06:26	33%
11	04:15	195	797.6	08:47	196	891.4	37:27	13:02	24:25	65%
12	03:56	195	797.6	10:28	181	855.6	19:45	14:24	05:21	27%
13	04:39	195	797.6	12:41	196	823	29:15	17:20	11:55	41%
14	03:57	195	797.6	13:02	191	773.8	26:12	16:59	09:13	35%
15	01:28	195	797.6	09:41	189	922.8	22:41	11:09	11:32	51%
16	01:18	195	797.6	09:44	189	810.8	31:28	11:02	20:26	65%
17	02:03	195	797.6	10:47	195	851.1	14:08	12:50	01:18	9%
18	02:22	195	797.6	13:37	162	837.9	30:35	15:59	14:36	48%
19	03:17	195	797.6	19:02	189	713.9	26:50	22:19	04:31	17%
20	03:47	195	797.6	13:43	162	846.8	25:40	17:30	08:10	32%
21	01:47	195	797.6	07:07	177	818.9	23:25	08:54	14:31	62%
22	02:01	195	797.6	07:51	177	813.4	25:57	09:52	16:05	62%
23	01:29	195	797.6	06:30	162	832.3	30:12	07:59	22:13	74%
24	01:36	195	797.6	11:33	192	867.4	31:42	13:09	18:33	59%
25	01:23	195	797.6	06:59	189	925.6	23:22	08:22	15:00	64%
26	01:37	195	797.6	11:30	189	876.3	32:08	13:07	19:01	59%
27	01:39	195	797.6	08:36	189	892.1	22:06	10:15	11:51	54%
28	01:34	195	797.6	06:03	192	851.8	25:06	07:37	17:29	70%
29	01:57	195	797.6	08:05	192	721.8	13:05	10:02	03:03	23%
30	02:23	195	797.6	10:20	195	819.7	21:11	12:43	08:28	40%

Table 21 "Journey to Tyrol" Scenario Test Results - Planning with the Support of PPM ver. 2 - SAT Solver

sample#	Expected Business Value	Business Value	Money Spent	sample#	Expected Business Value	Business Value	Money Spent
1	802.8	894.9	155	16	802.8	872.4	183
2	802.8	823.7	198	17	802.8	836.7	198
3	802.8	897	125	18	802.8	904.6	125
4	802.8	814.9	126	19	802.8	890.6	126
5	802.8	756	184	20	802.8	876.3	198
6	802.8	788.4	185	21	802.8	840.2	165
7	802.8	1025.7	125	22	802.8	963.6	140
8	802.8	945	125	23	802.8	716.6	191
9	802.8	728.2	183	24	802.8	901.6	125
10	802.8	954.7	143	25	802.8	919.1	189
11	802.8	864.2	106	26	802.8	758	184
12	802.8	886.6	126	27	802.8	730.5	184
13	802.8	875.3	170	28	802.8	797.6	198
14	802.8	929.7	159	29	802.8	850.1	189
15	802.8	841.1	165	30	802.8	817.6	126

APPENDIX F

"RELOCATION" SCENARIO TEST RESULTS

Table 22 shows the age and gender information of the participants of the "Relocation" scenario experiment.

Table 22 Age and Gender Information for "Relocation" Scenario Test Participants

participant#	Gender	Age	participant#	Gender	Age
1	M	38	11	M	26
2	M	33	12	M	28
3	F	30	13	F	30
4	F	34	14	M	34
5	M	34	15	M	37
6	F	24	16	M	24
7	F	26	17	F	24
8	F	24	18	F	26
9	M	30	19	M	38
10	M	36	20	F	30

Table 23 shows the planning results of the 20 participants and the PPM system recommendations with three different preferences: minimize makespan (time), minimize distance, minimize both time and distance. Error type column shows the errors that the participants made, which could be at least one precedence constraints is not satisfied (Precedence), or at least two undelegated activities are planned for the same time interval (Collided acts), or at least one activity does not satisfy a time window constraint (Time Window).

Table 23 "Relocation" Scenario Test Results

Participant#	Plan Duration	End Day	End Time	Total Distance (meters)	Error exists?	Error Type
PPM – Minimize Time	3 secs	4	13:00	178100	No	-
PPM – Minimize Distance	5 secs	4	16:00	117100	No	-
PPM – Minimize Time & Distance	71 secs	4	13:00	140600	No	-
1	45 mins	5	13:00	154500	Yes	Precedence
2	48 mins	5	16:00	164500	Yes	Precedence
3	60 mins	4	13:00	92800	Yes	Time Window
4	74 mins	4	13:00	204100	No	
5	35 mins	4	17:15	195900	Yes	Collided Acts
6	40 mins	4	13:00	169000	Yes	Precedence
7	58 mins	4	17:15	195900	Yes	Collided Acts
8	75 mins	5	13:00	158800	Yes	Collided Acts
9	55 mins	4	17:30	153200	No	
10	35 mins	4	13:00	131800	No	Precedence
11	30 mins	5	14:30	173200	Yes	Collided Acts
12	55 mins	3	21:15	148400	Yes	Collided Acts
13	74 mins	4	16:15	163900	No	
14	75 mins	4	16:15	163900	Yes	Collided Acts
15	60 mins	4	13:00	154800	Yes	Collided Acts
16	65 mins	4	13:00	187800	Yes	Collided Acts
17	55 mins	4	13:30	195800	Yes	Collided Acts
18	55 mins	5	13:00	125300	Yes	Time Window
19	45 mins	4	16:45	160000	No	
20	65 mins	5	13:00	159000	No	

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PUBLICATIONS

B. Atamer, A. S. Çetin, D. Eke, S. Oruç, F. Şen, C. Çilingir, S. Kayalıgil, "Total Oraganizational Improvement in PTT Ankara Post Processing Center," Endüstri Mühendisliği Dergisi, 2008.

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