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EMPLOYEE-TASK ASSIGNMENTS FOR ORGANIZATION MODELING: A REVIEW OF MODELS AND APPLICATIONS

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Abstract
In this study, we present a review of task assignment problems in organizations, an area that has become more important as tasks become more complex and personnel skills become more specialized. The challenge is to design task assignments that meet all requirements and result in the best organizational performance. The consequences of poor design include failed tasks, reduced efficiency, and inability to meet deadlines. Moreover, inequity of workload between employees can cause lack of job satisfaction, loss of motivation and also boredom.

In general, work processes in organizations consist of different tasks, which require different expertise. Personnel usually have various degrees of qualifications and their performance may vary for different tasks. The outcome of the work process depends heavily on which tasks are assigned to which personnel. Performance of an organization can be increased by assigning the tasks to the most qualified available personnel. However, it could result in overloading some personnel while the others remain under-loaded. So, the even distribution of the workload between them also needs to be taken into consideration. In addition, it helps to increase organization's productivity by distributing personnel's knowledge, time, and attention more extensively.

We review task-employee assignment problems in organization modeling with the computational models that have been reported in the literature with their applications. Human factors engineering, in terms of workload in organizational modeling is included as the work process performance is heavily dependent on the human (personnel). Based on the initial findings, we propose to investigate an improved workload model that allows the use of optimization of select constraints, such as balancing workload among team members. While current workload models allow the evaluation of workload among team members interacting in a work process, it is up to the analyst to suggest improvements. By providing an optimized solution, we present the Engineering Manager, that can then be adjusted to meet practical criteria.

Keywords
Mental workload analysis, assignment problem, computational organization modeling

Introduction
In general, creating new technologies, rules or procedures to collect data and make analysis in real-world or laboratories are time consuming and expensive. As the problems in organizations get more challenging, scientists are starting to rely on computational modeling to address and resolve the consequent complexity (Carley, 2002). These computational models provide a virtual world that new policies, technologies, and conditions can be tested without making any changes in real-world operations. Decision makers can examine hypothetical conditions that do not exist. What-if scenarios can be used to predict the impact of the changes. Another reason to use computational models is to predict the performance outputs for the personnel.

Computational modeling and analysis is a cost effective, intellectually appropriate technique for understanding organizations. Consequently, there is an explosion of computational models, computationally generated findings, interest in doing simulation, and a much support from decision makers for using these types of models in organizational design (Levitt et al., 1999). For the purpose of this paper the literature related to computational modeling and analysis on task-personnel assignments in organizations is reviewed. As Krackhardt and Carley (1997) claim, organizations are comprised of intelligent, adaptive agents who are controlled and enabled by their positions in networks linking agents, knowledge, resources and tasks. Organizations can be modeled as "dynamic networks"; this network is composed of personnel, knowledge and tasks, and the relationships between these elements is captured as "assignment (personnel to tasks); knowledge requirements (knowledge to tasks); and precedence (tasks to tasks) (Carley, 2002).

It needs to be noted that excess or insufficient workload can result in a number of problems or compensating behaviors including errors, slowing of the tasks, task shedding, or quick task swapping. Moreover, inequity of workload between team members can cause lack of job satisfaction, loss of motivation and also boredom. For this reason, literature review on human factors engineering in organizational modeling associated with personnel workload is also mentioned.

In this paper, we define work process as a collection of related structured tasks that produce a specific service or product or serve a particular goal. A team is composed of the personnel serving for that particular goal, service, product or goal in an organization.

The rest of this paper is composed of three sections. First, we review the literature related with task-personnel assignment problems in the field of computational organization modeling. In the second section, we focus on personnel workload analysis. Then, we propose suggestions that take into consideration both optimization of personnel-task assignment and balance of workload in a work process.

Assignment Problem in Organization Modeling

In the field of operations research, correct assignment of tasks to workers based on evaluation of their suitability and resource constraints is known as the "assignment problem". This section focuses on the solution methods of this type of problem in literature

The measure of skill level generally changes according to the type of the organization. For instance in a military organization the skill level can be related with the rank of the personnel. Some studies use ranking scales for skill levels and ask subject matter experts to rate them. Also, there are studies that use experience (such as time spends for a specific skill) as the skill level.

Minxin, Gwo-Hshiung, and Liu (2003) proposed a multi-criteria assessment model capable of evaluating the suitability of individual workers for a specified task according to their capabilities, social relationships, and existing tasks. Candidates are ranked based on their suitability scores to support workflow administrators in selecting appropriate workers to perform the tasks assigned to a given role. The proposed assessment model overcomes the lack of role-based task assignment in current workflow management systems.

Similarly, Eiselt and Marianov (2008) developed a mathematical model for the assignment of tasks to individual employees with different capabilities. They defined a skill space where an employee's position represents the level acquired in each skill. Tasks can also be mapped into the skill space. Once feasible task assignments are determined, tasks are assigned to employees. The objectives are to minimize inequity between the individual employees' workload and minimize employee-task distances to avoid boredom and costs. Both Eiselt and Marianov (2008) and Minxin et al. (2003) measure workload as the total number of hours that the employee works.

Otero, Otero, Weissberger, and Qureshi (2010) claims that completing reliable software products within the expected time frame is a major problem for companies that develop software applications. The reason for that situation can be attributed to inadequate resource allocation. Consequently, they state that it is beneficial to generate systematic personnel assignment processes that consider the complete candidate skill set and provide the best fit in order to increase quality, reduce cost, and reduce training time. Moreover, Tsai, Moskowitz, and Lee (2003) argue that software development projects are often unsuccessful because of inadequate human resource project planning. A major contributor to this problem is the inefficient allocation of resources that may result in schedule overruns, decreased customer satisfaction, decreased employee morale, reduced product quality, and negative market reputation. The inevitable consequence is a decrease in potential profit for companies. Accordingly, Otero et al. (2010) proposed a multi-criteria decision making approach for allocating resources to software engineering task assignment. They used a Desirability Function (developed by Derringer and Suich (1980)) to provide a unified metric representative of the suitability between the complete set of skills available from employees and skills required for tasks to quantitatively assign resources to tasks even when the most desirable skills are not available from the existing workforce. They took into consideration project specific capabilities, such as years of experience, level of perceived expertise on a particular language, operating system, domain knowledge, etc.

In the case where optimum skill sets are not available, Otero, Centeno, Ruiz-Torres, and Otero (2009) developed a linear programming assignment model to match resources to tasks that considers existing capabilities of employees, required levels of expertise, and priorities of required skills the task. Also, Acuna and Juristo (2004) and Acuna, Juristo, and Moreno (2006) developed procedures for assigning personnel to software tasks according to the assessment of behavioral competencies. Tsai et al. (2003) proposed critical resource diagram (CRD) method and the Taguchi's parameter design approach for the selection of employees. The CRD was used for resource scheduling to represent human-resource workflow and tasks' precedence. The Taguchi's parameter design was used to obtain a scheme that would optimize the selection of engineers for tasks under dynamic and stochastic conditions.

Kamrani, Ayani, and Moradi (2012) considered the tasks to be part of a business process model, being interconnected according to defined rules and constraints (a more complex form of assignment problem). Business process modeling refers to "describing business processes at a high abstraction level, by means of a formal notation to represent activities and their causal and temporal relationships, as well as specific business rules that process executions have to comply with" (Kamrani, Rassul, & Karimson, 2010) (p.1). Business process modeling focuses on the representation of the execution order of activities. They used two main categories of business processes, assignment-independent and assignment-dependent. In the first category, different assignments of tasks to employees do not affect the flow of the business process. In the second category, processes contain critical tasks that may change the workflow, depending on who performs them. The Hungarian Algorithm is combined with either the analytical method or simulation to provide an optimal solution. They conducted a series of tests which showed that the proposed algorithms efficiently found optimal solutions for assignment-independent and near-optimal solutions for assignment-dependent processes.

In the last two decades several papers have appeared in the literature where the multi-resource generalized assignment problem (MRGAP) was used to solve employee allocation problems (Alidaee, Gao, & Wang, 2010). In these problems the number of variables grew exponentially. In their research, they consider a generalization of MRGAP and show the improvement upon several published models based on MRGAP where the number of variables were exponentially larger. They used computational experiments to demonstrate the advantages of the new model over existing ones.

A summary of the methods and their applications can be found in Exhibit 1. All of the approaches mentioned in this section aim to assign tasks/jobs to limited resources (personnel) in an efficient way. Also, it has generally been found that task assignment problems for business environments are solved with deterministic optimization. In deterministic optimization, we ignore the uncertainty in order to come up with a unique and objective solution. However, the nature of a business environment that embraces work processes is stochastic. Moreover, not every approach mentioned here take into consideration the workload of the employee.

Exhibit 1. Summary of task-employee assignment methods

Approach-Method	Description	Application	Reference
Multi-Criteria Optimization	Evaluates the suitability of individual workers for a specified task according to their capabilities, social relationships, and existing tasks. Candidates are ranked based on their suitability scores.	Uses a simulated example to illustrate the application of the proposed assessment model with 5 employee, 7 skills, and 5 tasks.	Minxin, Gwo-Hshiung, and Liu (2003)
Mixed Integer, Non-Linear Mathematical Model	Aims to assign tasks to individual employees with different capabilities. The objectives are to minimize inequity between the individual employees' workload, minimize employee-task distances to avoid boredom and costs.	The approach has applied in DICTUC S.A., a company owned by the Pontificia Universidad Católica de Chile, to a subset of 15 employees, 14 skills, and 22 (recurring) tasks.	Eiselt and Marianov (2008)
Multi-Criteria Decision Making	Allocates resources to software engineering task assignment. They used a Desirability Functions They took into consideration project specific capabilities, such as years of experience, level of perceived expertise on a particular language, etc.	The case study assumes a scenario where 10 candidates are available. The identified required skill set involves 5 skills.	Otero, Otero, Weissberger, and Qureshi (2010)

Linear Programming Assignment Model	Matches resources to tasks that consider existing capabilities of employees, required levels of expertise, and priorities of required skills the task.	A sample scenario is used. Survey analysis was conducted to test its validity.	Otero, Centeno, Ruiz-Torres, and Otero (2009)
Critical Resource Diagram (CRD) and Taguchi's Parameter Design	The model used for the selection of employees. The CRD was used for resource scheduling to represent human-resource workflow and tasks' precedence. The Taguchi's parameter design was used to obtain a scheme that would optimize the selection of engineers for tasks under dynamic and stochastic conditions.	They used a scenario that contains 3 jobs; each job has 2 possible candidates.	Tsai et al. (2003)
A conceptual model/ procedure	Assigning personnel to software tasks according to the assessment of behavioral competencies	They used statistical tests for validation	Acuna and Juristo (2004) and Acuna, Juristo, and Moreno (2006)
Hungarian algorithm combined with either the analytical method or simulation	They used two main categories of business processes, assignment-independent and assignment-dependent. In the first category, different assignments of tasks to employees do not affect the flow of the business process. In the second category, processes contain critical tasks that may change the workflow, depending on who performs them.	They used a model inspired by a work process of military staff. They conducted a series of tests which shows that the proposed algorithms efficiently find optimal solutions for assignment-independent and near-optimal solutions for assignment-dependent processes.	Kamrani, Ayani, and Moradi (2012), Kamrani, Rassul, & Karimson, 2010
Multi-resource generalized assignment problem (MRGAP)	Propose a compact generalized assignment problem model that can be used to solve employee allocation problems.	They used computational experiments to demonstrate the advantages of the new model over existing ones.	Alidaee, Gao, & Wang, 2010

Since the assignment problem is heavily depending on humans, the next section focuses on workload analysis in work teams which are a part of human system integration analysis.

Employee Workload Analysis

Acuna et al. (2006) state that in general, employees with the required skills to work tasks are not available, and decision makers are forced to assign employees to tasks based on subjective measures. In order to address these types of concerns, new studies on methods to ensure better employee-task assignments are required to assist Engineering Managers. One venue for further research is leveraging past work in using employee workload as the assignment criteria. Moreover, both excess and lack of workload has negative effects on the performance of the employee. While allocating the employees to the tasks, their workload level should be taken into consideration as well. While some studies calculate workload simply as the total number of hours that the employee works, other studies consider the workload measurement techniques that rely on various theories.

Basically, there are three different measurement of workload. These are psychophysiological, subjective and performance measurement (Miller, 2001). Psychophysiological measurement of workload is a concept based on evidence that increased mental demands lead to increased physical response from the body. Psychophysiological workload measures rely on continuous measurement of the physical responses of the body. Subjective measurement of levels of workload is based on the use of rankings or scales to measure the amount of workload a person is feeling. Subjective workload measures rely on the question-answer type response to varying levels of workload.

Performance measurement of workload relies on examining the capacity of an individual by means of a primary or secondary task. An estimate of mental workload can be determined by measuring how well a person performs on the task, or how their performance gets worse as workload increases. The literature review shows that the subjective workload measures are the most popular since they are reliable and transferable to new systems or new task conditions.

In spite of the disagreement between researchers, there are a number of different methods such as rating scales, questionnaires, or interviews, that system designer can use to collect subjective data of workload. Xie and Salvendy (2000) state that the most progress has been made in subjective measures. They also added that the analytical models are the most attractive since they can be applied early in system. In general input on workload for these models gathered from subject matter experts (SMEs).

The scales typically used to obtain subjective ratings of workload are the subjective workload assessment technique (SWAT) (Reid, Potter, & Bressler, 1989); the National Aeronautics and Space Administration (NASA) task load index (TLX) (Hart & Staveland, 1988); and the visual, auditory, cognitive and psychomotor (VACP) model (McCracken & Aldrich, 1984). Description of each rating is shown in Exhibit 2. According to Wickens (2002), they are the most sensitive, most transferable, and the least intrusive techniques for workload estimation. For instance, SWAT and NASA TLX, would provide appropriate workload indications in case of a mock-up of the proposed system exists. On the other hand, the analytical techniques can be used to predict mental workload when no mock-up exists and the system is just a concept.

Exhibit 2. Brief explanation of subjective workload measurement scales

Subjective workload measurement scales	**Reference**	**Brief explanation**
Subjective workload assessment technique (SWAT)	(Reid et al., 1989)	Uses three levels (low, medium, and high) for each of the three dimensions of time load, mental load, and physiological stress load to assess workload. The three steps that used to analyze workload: 1. scale development, 2. rating the workload. 3. convert the scores into a 0 to 100 scale using the scale developed in step one.
National Aeronautics and Space Administration (NASA) task load index (TLX)	(Hart & Staveland, 1988)	Uses six dimensions to assess workload: mental demand, physical demand, temporal demand, performance, effort, and frustration. The workload scale is obtained for each task by multiplying the weight by the individual dimension scale score, summing across scales, and dividing by the total weights.
Visual, auditory, cognitive and psychomotor (VACP) model	(McCracken & Aldrich, 1984); (Mitchell, 2000)	Any task performed by a person can be broken down into these components. Rating scales provide a relative rating of the degree to which each resource component is used. The steps are: 1. Identify tasks that are necessary to operate the proposed system. 2. Identify the operators to system. 3. Assign tasks to operators. 4. Estimate workload values using the scales.

When combined with task analysis, simulation models give the best results (Wickens, 2002). With the help of these simulation models, the system designer can predict task and procedure execution and mental workload. These models contain the tasks needed to accomplish a particular process, the amount of time it takes each task to perform in the process, the sequence of the tasks, and the person who performs each task. Nevertheless, the time and effort needed for inputs (e.g. tasks, operators, time, and resources) are high. Also, validation of the simulation model is a major issue. So, an addition of a task-personnel assignment optimization module (as mentioned in the previous section) would assist the analyst in narrowing down the range of acceptable task assignments within the work team and work process.

In general, we see the application of mental workload analysis in military and health-care environments for critical processes that require immediate attention and decision making. However, since mental workload measures is not dependent on time, it is also applicable to a business environment (tasks that require longer time). Mental workload expresses the relation between the (quantitative) demand for resources required by a task and the ability to supply those resources by the operator (Wickens, 2002).

Carayon and Gürses (2005) proposed a conceptual framework of intensive care units nursing workload that defines causes, consequences and outcomes of workload. They identified four levels of nursing workload: unit level, job level, patient level, and situation level and discuss measures associated with each of the four levels. Holden et al.

(2011) states that reviews of nursing workload measurement show that workload is most often defined in terms of staffing ratios and added these ratios are not clearly representative of nurses' actual or perceived workload. Both Carayon and Gürses (2005) and Holden et al. (2011) concluded suggesting using situation level (subjective) workload measures since errors may be best describes by task level workload. Also, they are reliable and transferable to new system or new task conditions.

Mitchell (2009) used mental workload analysis to evaluate changes in a combat system by using a special human-performance modeling tool called Improved Performance Research Integration Tool (IMPRINT). She claims that when the program managers add new technologies, these technologies have the potential to change the Soldiers' tasks. The tasks Soldiers perform determine the Soldiers' workload level and their performance. Too little or excess workload decreases their performance. The design goal for optimum Soldier performance is to have an evenly distributed, manageable workload. To meet this design goal, they evaluated the impacts of new technologies on Soldier tasks, workload and performance. Mitchell, Samms, Henthorn, and Wojciechowski (2003) examined the mental workload to determine best allocation of some combat functions among two versus three soldier crews. Another application is made by Samms and Mitchell (2010) on tank crewmembers. They also mentioned the importance of defining workload threshold level in mental workload analysis.

Exhibit 3. Summary of metal workload analysis methods and applications

Method	Description	Application	Reference
Conceptual Framework	They identified four levels of nursing workload: unit level, job level, patient level, and situation level and discuss measures associated with each of the four levels.	-	Carayon and Gürses (2005)
Survey	A study carried out at six nursing units at two pediatric hospitals provided interesting possibilities for how different types of workload may relate to common patient and employee problems in pediatric clinical settings.	To test this model, they analyzed results from a cross-sectional survey of a volunteer sample of nurses in six units of two academic tertiary care pediatric hospitals.	Holden et al. (2011)
Multiple resource theory-simulation modeling	They evaluated the impacts of new technologies on Soldier tasks, workload and performance	They used IMPRINT as the simulation software. The model has a crew of four personnel Soldiers operating the system (Abrams V2 SEP).	Mitchell (2009)
VACP	They examined the mental workload to determine best allocation of some combat functions among two versus three soldier crews	The objective of this trade study was to examine the mental workload of the crew to determine the best allocation of the combat functions among two- and three-soldier crews.	Mitchell, Samms, Henthorn, and Wojciechowski (2003)
Multiple resource theory-simulation modeling	They propose a technique that can be applied in any workload analysis.	They applied the technique on a case with tank crewmembers.	Samms and Mitchell (2010)

A summary of the approaches in mental workload analysis can be found in Exhibit 3. Subjective methods are the mostly used methods in human engineering evaluation to evaluate the employee's rating of a task. These methods, especially those with rating scales, have various advantages in measuring workload relative to other approaches. They have good face validity and general applicability. Lately, the VACP method is the most preferred one because it is based on MRT, its workload predictions are task-based predictions, and it is applicable through commercial simulation software such as IMPRINT.

Proposed Method

As the literature review shows, in general, work processes consist of different tasks which require different expertise. Personnel usually have various degrees of qualifications and their performance may vary for different tasks. So, the performance outcome of an organization depends greatly on which tasks are assigned to which employees. Moreover, using human factors engineering knowledge, approaches and measurement methods of workload can improve the performance of employees, as well.

Optimized assignments may result in overload conditions for highly qualified employees while the rest remain underloaded. For instance, in extreme cases a person could get highly loaded, and as a result cannot perform well even with the best qualifications. On the contrary, even distribution of workload without taking into consideration the qualification of the employee may cause unproductive employee-task matching and as a result low performance of employees. Accordingly, there is a tradeoff between optimized assignment of employees to tasks and even distribution of workload between employees. To overcome this problem, a model that optimizes task-employee assignment and balances the mental workload together could result in better performance outputs.

Similarly in business, military, or health-care organizations, the employee allocation process can be optimized by finding the set of skills that provide the optimal candidate for a particular task. We claim that the right matching of employee-task is as important as the balance of workload between employees. Whichever approach is preferred, the aim should be to optimize performance by optimizing the workload as well. Optimal workload level can be defined as a situation in which the person feels comfortable, can deal with the task demands wisely, and continue with the good performance (Huey & Wickens, 1993; Wickens, 2002).

It has generally been found that task assignment problems for business environments are solved with deterministic optimization, while mental workload analyses for military environments are studied by simulation models. Deterministic optimization relies on linear algebra and is fast in converging to a solution. In deterministic optimization, we ignore the uncertainty in order to come up with a unique and objective solution. However, the nature of a business environment that embraces work processes is stochastic. Given that simulation approximates reality, it also permits the inclusion of various sources of uncertainty and variability into tasks that impact work process outcomes. However, simulation generally answers "what if" questions and it is not possible to find optimal solutions in reasonable time. In situations where uncertainty is at the center of the problem, a different strategy is essential. A “Simulation Optimization” method can resolve these issues by merging deterministic optimization and simulation (Kelly, 2002).

To provide a simulation optimization environment with which to study task assignment and mental workload balance tradeoffs in a work process with a work team, we suggest a two-step model (Exhibit 4). The first step will be the deterministic part and used to assign the most qualified employee to the tasks. The second step will be the stochastic part and used to balance mental workload between employees with a simulation model based on Multiple Resource Theory and VACP approach. It should be noted that The output of this two-step model will show the mental workload of each employee and if they accomplished the tasks on time. Then, the results can be used to test hypotheses and perform sensitivity analysis based on optimized employee-task assignment and the impact on performance of employees in cases of even distribution of workload between employees.

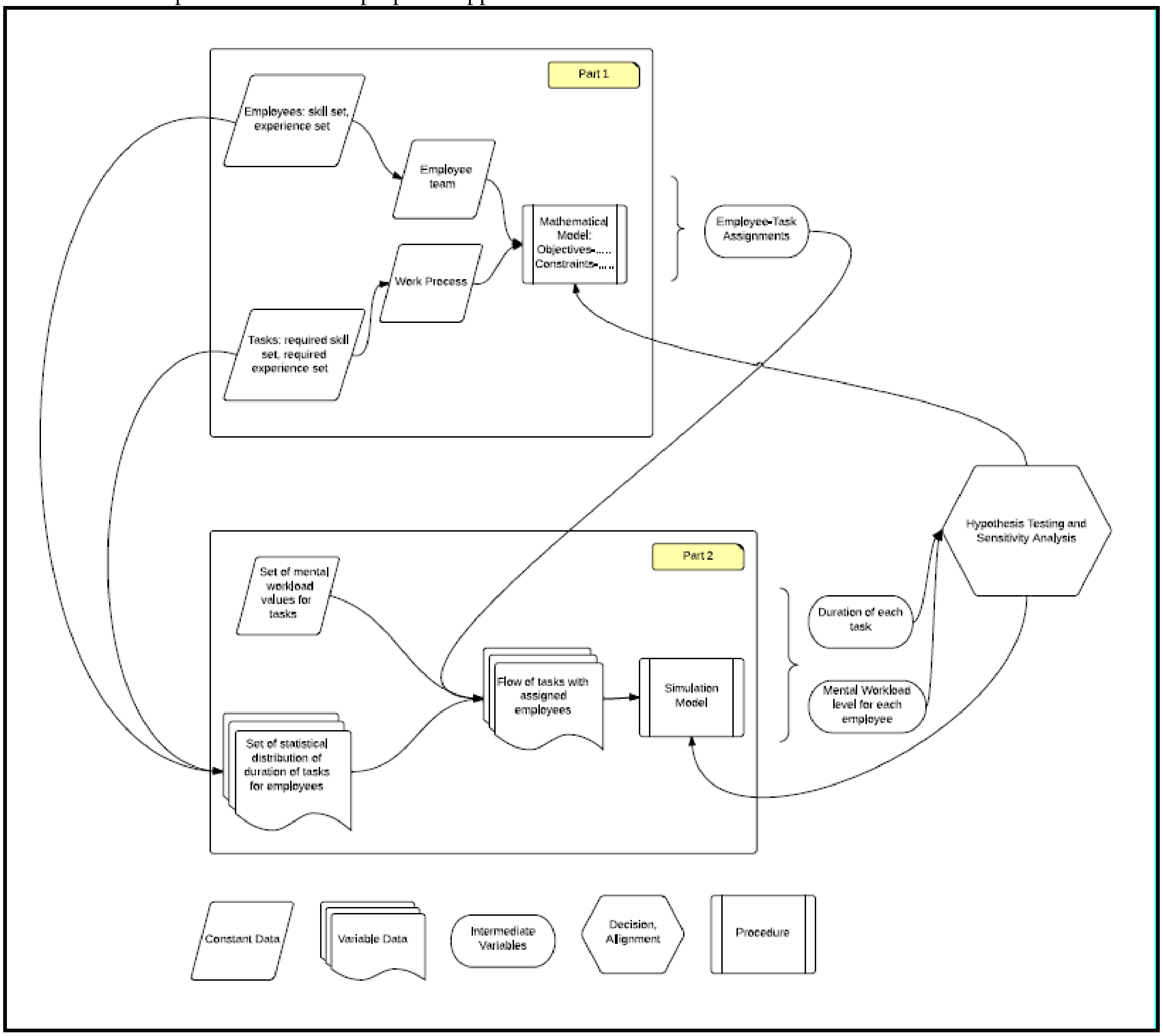
This two-step model will contribute to the literature in several ways. First, the current literature provides limited evidence of mental workload analysis within the business environments. This model will help addressing mental workload analysis for work processes in business environment, especially, in critical time junctions. Second, the results of this study will help organizations address task assignments and employees’ workload balancing problems using a new methodological approach. A merged optimization-simulation approach, a feasible technique, for efficiently managing and planning the employee allocation process in different type of organizations such as military, business or health-care may help researchers gain insights into the effectiveness of this research design. The outcome of the virtual experiments will provide guidance on the tradeoffs between task assignment and workload balance and identify the region where both goals can be met successfully in order to increase performance.

Conclusions

Current literature has provided clear evidence that within organizational science in particular, many scientists and practitioners are beginning to utilize computational modeling and analysis. Simulation and mathematical modeling has especially gained popularity in use for employee alignment for organizational modeling and design.

In this study, task-employee assignment problems in organization modeling are reviewed with their applications. Since it is heavily dependent on the personnel; mental workload analysis approaches in organizational modeling are pointed out. Moreover, an approach to improve personnel performance by optimizing the task-personnel assignments while balancing the mental workload among the work team is proposed. This simulation optimization approach will provide increased performance by balancing workloads and making more efficient task assignments. Additionally, it will help to identify the region where both goals can be met effectively. The outcome from these results would provide input to both organizational design and engineering management fields.

Exhibit 4. Conceptual model of the proposed approach



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