NPS-AM-10-070

EXCERPT FROM THE PROCEEDINGS

OF THE

SEVENTH ANNUAL ACQUISITION RESEARCH SYMPOSIUM THURSDAY SESSIONS VOLUME II

Acquisition Research
Creating Synergy for Informed Change
May 12 - 13, 2010

Published: 30 April 2010

Approved for public release, distribution unlimited.

Prepared for: Naval Postgraduate School, Monterey, California 93943

The research presented at the symposium was supported by the Acquisition Chair of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

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Service-Oriented Architectures and Project Optimization for a Special Cost Management Problem Creating Synergies for Informed Change between Qualitative and Quantitative Strategic Management Processes

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Abstract

Mobility plays a central role in the support of military staff of the German Federal Armed Forces. This demand most often is fulfilled by a central organizational unit which allocates needed vehicles out of a local car pool of the military facility.

One essential maxim is to meet the “approved” demand for mobility for any military employee of that facility at any time.

This paper is based upon the experience out of an optimization project that has been conducted at a large German military facility with about 3000 employees.

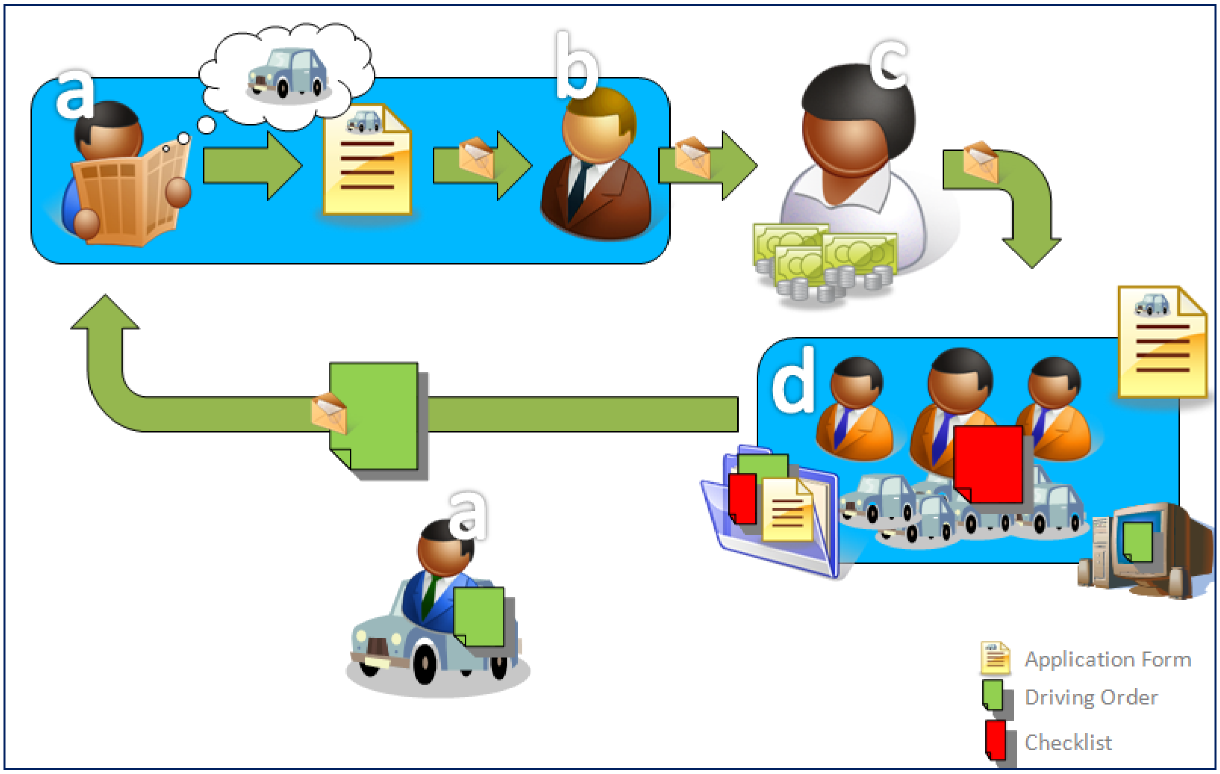
The optimization effort aimed at two dimensions:

- Optimization at business process level (qualitative)
- Optimization at the cost level (quantitative)

A short introduction is given into the overall process from the application for a vehicle to the allocation of the needed vehicle. After analyzing the old process and its inefficiencies, a proposal for an improved process design supported by a service oriented software approach is given.

The second part of this paper is focused on potential mathematical optimization approaches that can be chosen to reduce cost and make “intelligent” allocations to the given demands.

The demanding goal was a user-friendly decision support system that is able to make intelligent allocations.



The Former Inefficient Process

The overall application process for a car starts with an application form (yellow document icon in Figure 1) that has to be filled out by the demanding person (a). Each department has an authorized person (b) who decides if the need for the car is appropriate and if the application can be granted. After having granted the application form, person (b) transfers the application form to the cost center (c) to ensure the funding of the car demand. If the funding is ensured the form is transferred to the local car pool management department (d). Here, the allocation of the car is conducted which includes the creation of a driving order (green document icon in Figure 1) and a checklist (red document icon in Figure 1).

The local car pool consists of a number of vehicles in short term and long term rent; if the request for a car cannot be satisfied out of the local car pool, (e.g., because of the unavailability of the same or a higher classed car), the request is escalated to a decentralized mobility centre which has access to a larger car fleet. Only if this mobility centre is not able to answer this demand either, an external car rental company is contacted to provide the desired car.

The driving order is the official document to certify that a certain typed vehicle has been assigned to a certain driver respectively group of drivers. This document is sent to the driver and confirms him officially to receive a car from the local car pool. On the day when the rental period starts, a person from (d) hands over the car to (a) and completes a checklist that contains information about the mileage, fuel tank level, potential damages, and additional equipment inside of the car. The driver's obligation is to document each (sub-) trip that he undertakes during the rental period; this information is captured on the driving order form (green document icon, Figure 1) and contains information about the driver (important when a group of drivers are given), the number of kilometers, and the starting and end time of the trip. When the car is returned by the driver, a person from (c) checks the car for damages, mileage and fuel level and completes the checklist. The driving order which contains information about the trips made as well as the checklist remains with the local car pool department. The global process ends when the car is returned and the complete and consistent documents were handed in to the local car pool department.

One essential process step is the allocation of the car. Here, several parameters have to be taken into account in order to facilitate a cost-efficient and "intelligent" allocation that considers a balanced utilization of the car pool in terms of e.g. rental time and mileage. The task of "intelligent" allocation is fulfilled by a person of the car pool department (d) and is based on his experience in this field. The only it-based support so far consisted of an Excel-sheet that listed all the different types of vehicles with their corresponding performance-/statistical data (type, mileage …) and a software tool which generated the driving order. When the car is returned, the Excel-sheet is updated with the trip data that has been collected by the driver on his driving order.

A more detailed reflection on the quantitative optimization methods that are needed for an intelligent disposition of a car as well as for the optimal mixture of rental types (short-/long term) is given in the second part of this paper.

Looking at the global process in Figure 1 in terms of process efficiency and usability, it becomes clear that this process is neither efficient nor user-friendly; documents are only handled manually, they are sent by internal post mail or they are faxed, (equal) data is gathered at several points of the process and very often redundantly, and the quality of data is very poor. All these factors lead to a very inefficient, time-consuming, and error-prone process.

Assuming that each postal service step (depicted by the brown envelopes in Figure 1) needs approximately two working days to reach its destination, the overall processing time consumes up to two weeks in order to provide the official driving order to the person requesting a car. This implies that urgent and short-term requests have nearly no chance to be granted in time so that induced by the given inefficiencies the requesting person might get into trouble to accomplish his task he needed the car for.

Description of Improved Global Car Demand Process

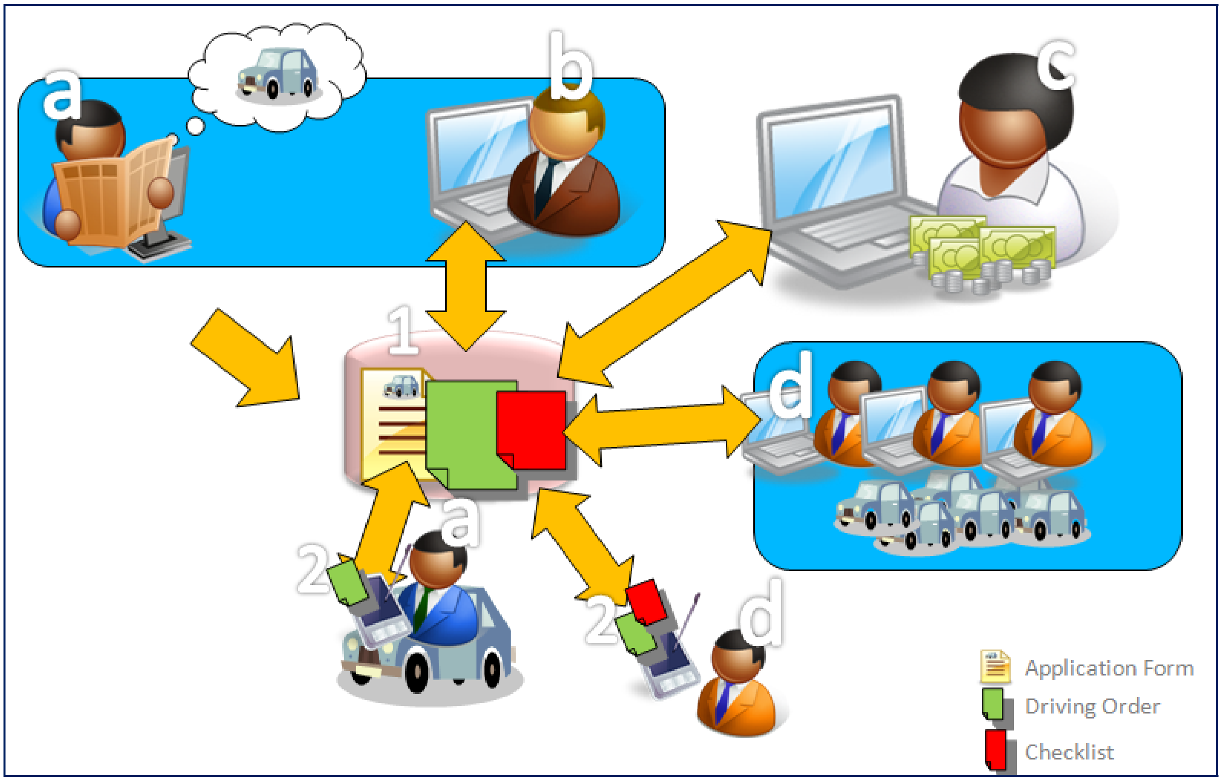


Figure 1. The Improved Process

In order to improve the process efficiency and the usability, it is indicated to introduce a software-based approach with a centralized data management and to define a workflow that supports the overall process from the application for the car until the return of it.

Central objectives should be a user-friendly, non-hardcopy document handling as well as a short processing time and an increased data quality in order to establish optimized decision making.

The introduction of a central database ("1" in Figure 2) that can be accessed by all organizational units that are involved into the global process, hard-copy documents become superfluous and the processing time can be minimized through the elimination of the postal document handling. The central data management minimizes redundant data collections which can now be stored in a controlled way into the database.

Another improvement, which leads to an increase of the data quality, is the introduction of a mobile device (as e.g., PDA or Smartphone) combined with an integrated gps-component and an optional GSM- or WiFi-module ("2" in Figure 2) for data transmission. This device supports the car pool service assistant in storing the checklist data into the central database. The device can then be handed over to the person that rented the car. For the trip-management, a special mobile application is running on the device and supports the driver in collecting the needed data. The driver-process that is support by the mobile application includes the authorization of the driver, indicating the start of the trip ("start-trip" button when starting trip), automatic registration of the number of kilometers driven, indication of the end of the trip ("end-trip" button at finish). When the car is returned, the device data is stored into the central database. Another option would be the real time transmission of the data using the GSM-Module—but as this option might contradict to privacy policies it is not taken into further account.

A Flexible Service Oriented Architecture Approach

As it can be seen from the description of the old process, the legacy system implied many unnecessary steps and no databases or electronic forms were used.

An improvement can be reached in the development of a software solution given above that would use Service Oriented Architecture (SOA) concepts and principles. Additionally a SOA based approach would allow easily for further extensions and integration of complementary applications.

Figure 3 gives a more formalized presentation of the improved global process using the notion of event driven process chains (Scheer, 1998; Balzert, 2008).

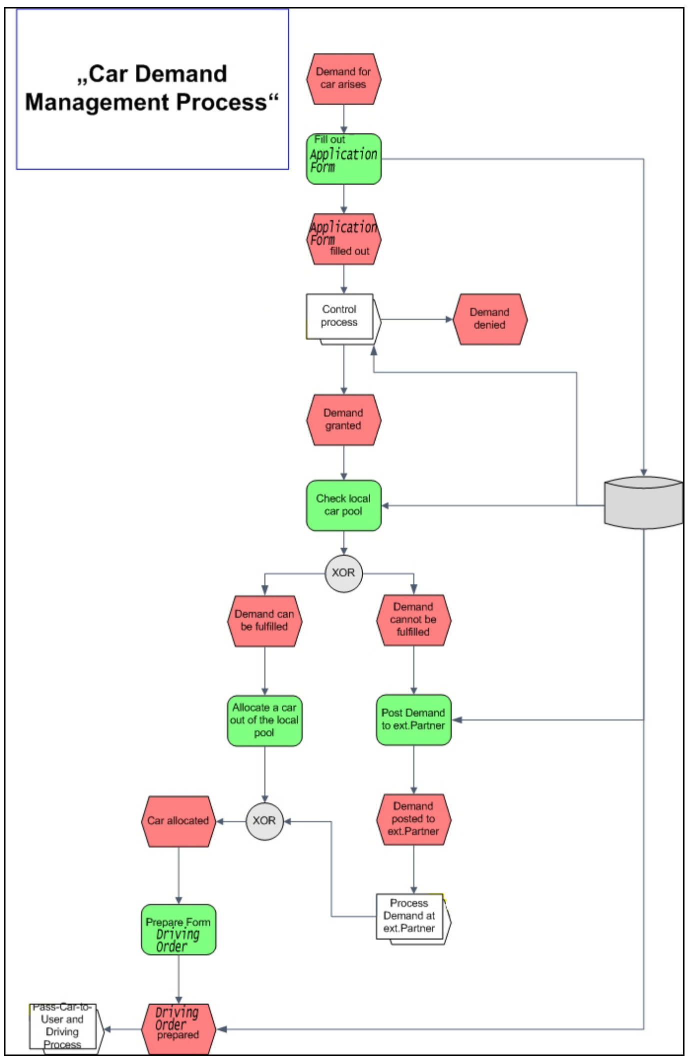


Figure 3: Event Driven Process Chain of Improved Process

Following the paradigm of matching business services to web services (WS)—assuming the use of web services as means of service oriented design patterns (see e.g., BPEL 2007; Drawehn 2008)—the following major services can be identified:

- Application Form WS
- Control Process WS
- Local Car Pool Allocation WS
- External Partner Allocation WS
- Driving Order Generation WS
- Car Handling WS

The Application Form WS handles the application form and supports the user in requesting a car by collecting all relevant data including consistency checks. etc.

The Control Process WS works on the application form data stored in the central database and supports the controller in handling the request.

The Local Car Pool Allocation WS is the “intelligent” component that is in charge of a cost efficient and balanced allocation of a car to the given request.

As mentioned above there may be situations in which the request cannot be satisfied out of the local car pool; in these cases, the External Partner Allocation WS is activated.

The Driving Order Generation WS generates the necessary driving order for the specific request.

When the car is picked up at the local car pool centre, the driving order is handed to the driver and the Car Handling WS is processed; this service initializes the mobile device with the needed data and manages the data handling of the checklist and trip data (at rental period start and finish).

A service oriented software approach enables an agile, efficient and user-friendly realization of the described “Car Demand Management Process” and it supports the flexible adaption of single services to the demand of the involved organizational units as well as the integration of external business partners (Krafzig, 2007).

Key aspect of the contribution is the connection of the service-oriented framework ("architecture") with the classical optimization approach. As the problem describe an actual challenge within acquisition research an integral solution might support in an holistic and comfortable way the policy-making process for Department of Defense officials.

In the following we characterize the several optimization problems which are central. It might be observed that such approaches exist so far in several units but integration is missing and required. Furthermore, our contribution proposes an IT-based decision support tool which is characterized by an actual state of the art SOA-based framework.

In the following the different optimization "units" which should be integrated will be presented.

Description of the Problem

The overall optimization intent is to minimize the cost of the car fleet while several constraints have to be fulfilled. One constraint is that each driving job has to be served. As soon as the whole car fleet is busy an additional driving job creates the need of a new car. While the base fleet is present anyway, thus producing no reducible cost, each additional car creates extra costs. The additional cars are the main source of cost of the present optimization problem. Nevertheless the inability of the existing fleet to cover all driving jobs might not be the only reason to go for more cars. There's another cost factor. All cars of the fleet are rent for a certain time frame—usually two years—and a certain mileage. If that mileage is exceeded an additional gradual charge is to be paid. Contrariwise an under-run mileage leads to a gradual rebate. That system could produce situations where an additional car would be the cheaper solution although the existing car fleet could cover the demand of driving jobs. As an additional difficulty, the driving jobs are categorized in certain classes of different types and qualities of cars.

In all models there are two main types of question to be answered. The first one is: "What car should execute what driving job?". Of course one car cannot deal with two overlapping jobs and the car has to be available in the fleet during all time frames of the driving jobs it runs. Second question to be answered is: "Are there better/cheaper solutions to the problem when more cars are added to the fleet?". The second question seems to be even more difficult to answer since there's no preset given for the number of cars to rent and rent time. It's also possible to rent an additional car in advance without even knowing the jobs it has to run. This adds the wide field of probability, prediction and uncertainty to the present problem.

Problem Categorization

To solve an optimization problem, it's often beneficial to categorize it. Finding the right problem category can be a tremendous step to solve the problem since with the problem category the algorithms and methods used to solve such a problem or the non-existence of such become apparent. The following sections will discuss possible categories and categorization factors. When modeling the present optimization problem there are several options selectable that will not only affect accuracy but also the complexity of the model. In some cases, it might be beneficial to reduce accuracy in favor of analyzability.

Linear versus Non-linear

One categorization factor is the linearity or non-linearity of the objective function on one side and of the constraints on the other side. For linear systems, there's in general a wider and better performing selection of algorithms and methods available to solve the problem. Therefore, linearity can be a decisive attribute of a problem. Unfortunately, the present optimization problem is apparently non-linear, since the distance constraints for the mileage of individual cars create non-linear gradual cost steps. Nevertheless, the main core of the problem can be modeled in a linear way omitting the mileage constraints. This leads to a less accurate but maybe better analyzable reduced model. Therefore the present problem is—depending on the analysis needs—either non-linear or linear. Thus for now no limitations are raised based on the linearity of the problem.

Integer versus Continuous

Most decision variables in the present problem are integers. Theoretically, the lease times for additional cars could be modeled as non-integers. But since the driving jobs are bound to a fixed length cycle a more flexible lease time for additional cars is of no use. Therefore, the present problem is an integer problem. Following that result, most of the discussed problem categories in the following chapter originate from the combinatorial optimization.

Deterministic versus Probabilistic

Next to the already mentioned problem of assigning the right car of the fleet to the right driving job, including the option of adding new cars to the fleet, there's another optional addition to the problem. In order to improve the decisions made based on the model it might be beneficial to predict future driving jobs. This adds the whole complexity of randomness and decision under uncertainty to the present problem. As already explicated the added complexity might circumvent detailed enough analysis. Therefore, careful judgment is required whether driving job prediction is needed and useful.

Another kind of randomness comes into play when watching the mileage of the fleet cars. An incoming driving job comes with a very rough driving schedule that can be used to derive a prediction for the amount of kilometers the car will drive for the job. This prediction will again add a lot of complexity to the problem. But even without predicting the distance the car will drive, after its return the number of driven kilometers is a random parameter to the problem. Thus, as soon as mileage is included, the present problem becomes probabilistic.

Possible Problem and Solution Categories

Regarding the results from the previous chapter some promising candidates for the right problem category are discussed. Beside a short discussion of the solution strategy in general the pros and cons of the respective category in regard to the present problem are illustrated.

Exhaustive Enumeration

Omitting probability the most direct approach is exhaustive enumeration. This could be implemented as a simple back-tracking algorithm utilizing a depth-first search. Sadly the amount of possible combinations grows tremendously with the number of cars in the fleet and the number of driving jobs. In the worst case scenario the amount of combinations to check is

$$\sum_{k=0}^{n}\left[\frac{1}{k!}\cdot\sum_{i=0}^{k}\left[(-1)^{i}\cdot\binom{k}{i}\cdot(k-i)^{n}\right]\cdot(F+1)^{k}\right]$$

where n is the number of driving jobs and F is the number of cars in the Fleet. This grows terrible. A small example with only five cars and ten driving jobs already produces over 4.8 billion possible combinations to check. This is without additional cars and without predictions for future driving jobs in consideration. Without further improvements exhaustive enumeration is not feasible for real world scenarios.

Branch & Bound

One possible improvement to the exhaustive search is the branch and bound algorithm. It also tries to implement a depth-first search but it's looking for clever shortcuts to avoid as many branches of the search tree as possible. To achieve this, the algorithm tries to predict upper and lower bounds for all branches. With better upper/lower bounds the algorithm gains speed. Finding a good function for the upper/lower bounds is main challenge of the algorithm. First attempts to utilize Branch & Bound for the present problem have shown that finding adequate bounds is very difficult. So far in most example situations the calculation time of the bounds exceeded the time advantage of the Branch & Bound algorithm compared to the exhaustive search. This is not because the calculation took so long but because the calculated bounds only removed very few branches from the search tree. Unless better functions for upper/lower bounds are found Branch & Bound is no improvement to the solution of the problem.

Scheduling Problem (Job Shop Scheduling)

It's possible to model the problem as a scheduling problem with the following attributes. The cars of the fleet translate into the machines of the scheduling problem. Machines of certain types can substitute certain other types, others can't. The driving jobs represent the tasks. The jobs have a fixed start and end time and therefore a fixed length. All jobs have a type or class defining on what type of machine they can be run. If no feasible schedule with existing machines can be found, new machines are added. Also, if feasible schedules can be found, there might be cheaper schedules with more machines taking mileage into account. That demonstrates the difference of the present problem to usual scheduling problems. A usual scheduling problem seeks the fastest completed feasible schedule while here the cheapest feasible schedule is to be found.

Summary and Outlook

Building flexible structures that combine qualitative measures of e.g. business process design with quantitative optimization approaches proof to provide very effective and efficient solutions in real-world problems of the daily military work. The Service-Oriented Architecture Approach serves as an excellent connector and enabler between these two "worlds." This approach offers a reasonable chance to be successfully transferable also to further domains of every-day military problem solving.

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