Organizational Modeling in CommonKADS: The Emergency Medical Service

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Modeling organizations or enterprises is closely related to a modeler’s goals. Consequently, the chosen modeling approach and techniques also should reflect these goals. Generally, two related but distinct approaches are available:

- **Behavior-oriented modeling**: The modeler builds a model that exhibits dynamic behavior through simulation of the organization.
- **Analysis-oriented modeling**: The modeler uses a set of related descriptors that enables a structured representation of an organization’s salient features, but that excludes simulation of the organization’s behavior. The emphasis is on analysis and diagnosis. (The best term is probably “diagnostic modeling.”) However, to avoid confusion with medical diagnosis, which is another major topic in this article, we’ll use “analysis-oriented modeling.”

From an AI perspective, the first approach is more interesting, because it requires dynamic reasoning about organizational processes. Behavior-oriented modeling uses computer simulation to systematically investigate how changes in organizational parameters affect organizational processes. Unfortunately, this approach often takes a long time to develop a validated dynamic model. Validation is cumbersome, because distinguishing between a flaw in the model and autonomous organizational change is not easy. Also, the “black box” nature of the dynamic model sometimes makes understanding and accepting outcomes of model simulation difficult for the uninitiated. Analysis-oriented modeling is common in fields such as organizational sociology, organizational psychology, and organizational development. Its advantage lies in the relative ease and speed with which somewhat-inexperienced people can apply it. Also, it allows incorporation of intuitive aspects (such as the power relations, individual preferences, and attitudes), which are notoriously hard to capture in behavioral models. Its “glass box” nature facilitates inspection by outsiders, which can enhance their understanding of the model and the associated conclusions. The disadvantages are the subjective nature of the analysis and the impossibility of verifying the effect of changes through dynamic simulation.

Nonetheless, both approaches can use almost the same set of concepts and relations (the ontology). Both also face the problem of identifying the real-world counterparts of the elements of the abstract ontology they provide.

The context typically determines which approach to choose. In this article, we look at the problem of adequately equipping an emergency medical service to diagnose and treat heart attacks. This project required building a knowledge-based system. For application projects such as this, the time and resources for developing an organization model are typically limited. Only rarely can a full and valid behavioral model be developed. Therefore, having no simulation model at all appears to be better than having an incorrect one. Thus, analysis-oriented mod-
eling is probably preferable to behavior-oriented modeling.

We’ve applied the CommonKADS organization model, an analysis-oriented model, to the EMS project. Organizational modeling in the CommonKADS framework helped identify several solutions to the problem, and aided the selection of the most feasible solution from an organizational viewpoint.

CommonKADS

The CommonKADS organization model supports

- identification of promising areas for KBS applications in organizations (localization of problems and bottlenecks, and possible solutions), and
- detection of how the KBS might affect the organization.

It can also help those who are developing a KBS to get a feeling for the organization in which the prospective system will be deployed.

The pieces. The organization model consists of five basic components:

Organizational context. An organization’s context includes the constraints on a problem’s solution space, such as legislation, tradition, or finances.

Problem definition. This component has two subcomponents:

- Problems and opportunities—a description of the problems and opportunities in the organization for which a KBS might provide a solution.
- The current problem—the specific problem or opportunity that a project will address.

Organization description. This is the largest component. Its subcomponents are

- Structure. An organization is built from structural units.
- Function. Each structural unit carries out one or more business functions.
- Process. Functions are related in time through processes.
- People. People play roles in the organization. They fill positions in the structure; they sponsor certain solutions to problems; they possess knowledge that is required for a function; they have responsibilities; and so on.
- Power. People derive power from their role in the organizational structure and from the knowledge they possess. Power plays a role in defining the problem and assessing a solution’s feasibility.
- Resources. Computing resources (both hardware and software) and other resources (for example, telephones and a library) also determine a solution’s feasibility.
- Knowledge. This subcomponent is especially relevant for KBS-oriented organizational analysis. Knowledge is an organizational asset and can be described by knowledge items. A knowledge item is a collection of knowledge fragments used to perform the tasks that are defined by one or more functions. Knowledge items characterize the knowledge in the organization at a fairly general level of description, mainly for managerial purposes. The organization model also contains a list of an organization’s possible knowledge bottlenecks.

Possible solutions. The characterization of the context, the problem definition, and the organization description enable the generation of solutions.

Impact analysis and the feasibility of solutions. Gaining insight into a solution’s possible impacts is important. These impacts will influence whether crucial people in the organization will sponsor the solution. For an accepted solution, this insight will provide information that is useful for managing the project (for example, people might fear losing their jobs) and for designing the system (for example, human-computer interaction might need special attention). The method provides a checklist of possible impacts.

Putting the pieces together. CommonKADS provides a template for the organization model. This template provides a set of classes and relations that elaborate the components discussed above. Figure 1 gives a graphical overview of this template. The subcomponents in the large dotted box are used for the organization description. The template is a specification of the organization ontology underlying the
The EMS organization model

Our case concerns the introduction of a KBS at Amsterdam’s Emergency Medical Service, which covers the largest area in the Netherlands. The 1,015.34 km² service area includes 17 municipalities and approximately 1,250,000 citizens. The EMS handles approximately 400 calls daily, 250 to 300 of which require transport to a hospital. Approximately 40% of these calls involve heart problems. The organization model broadly follows the five components of the CommonKADS model. (Developing the organization model for this case was a highly iterative process. For brevity, we have swept this under the carpet. So, our order of presentation does not necessarily reflect that of the model-building process.)

Organizational context. The domain is acute myocardial infarction (a heart attack), one of the major causes of early death (15.0% for men, 11.7% for women). Reducing deaths from AMI will increase life expectancy significantly.

The most effective treatment for AMI is coronary reperfusion, which opens the blocked artery, restoring blood flow to the heart. This treatment can decrease both morbidity (the number of people that are ill) and mortality (the number of people who die) by 20 to 40%. The effect of this intervention, however, strongly depends on the time elapsed since the onset of the symptoms. After approximately nine hours, the therapy will be useless. Starting treatment as early as possible produces the best results. Thus, speed in detecting symptoms and starting therapy is crucial.

Therefore, major gains in reducing mortality from AMI must come from improvements during emergency management. For the EMS, the options might be to

- **Reduce patient delay.** This could be achieved by encouraging patients to ask earlier for medical assistance. Recognizing a cardiac problem is essential. The Netherlands Heart Foundation distributes educational material to citizens. Unfortunately, psychological defense factors strongly reduce the effects of trying to improve self-assessment. Also, most people are hesitant to contact a general practitioner (GP), especially outside office hours, if they are not sure that something serious has occurred.

- **Reduce physician delay.** Speed up the GP’s arrival. In the Dutch city of Enschedé, GPs can be reached through the EMS. The GPs have made an agreement with this service that the GP on duty can be ordered to visit the caller immediately.

- **Avoid transport.** Let the GP perform triage by telephone. (Triage, in the EMS context, is the process of making selections for treatment.) The disadvantage is that such triage depends only on verbal information from either the patient, the caller, or another bystander. Also, the hesitation to call the GP remains.

- **Bypass the GP.** The EMS carries out triage by telephone. For all cases, the delay between the first symptoms and treatment in the hospital averages 2.5 hours. However, for those cases that bypass the GP, the delay is only 1 hour and 25 minutes—a gain of more than an hour.

- **Avoid prehospital triage.** Patients go to the hospital by their own means, and triage occurs in the hospital. This still leaves the problem of how a patient can recognize a serious cardiac problem.

For our case, “bypass the GP” was the best strategy. At the same time, the solutions had to meet the constraint of budget neutrality (that is, they had to fit in the current budget). As we’ll show in the next section, this simultaneously posed a problem and provided an opportunity for the EMS.

**Problem definition.** Our description follows the two subcomponents mentioned earlier.

**Problems and opportunities.** Bypassing the GP will probably increase the calls to the EMS, many of which will be for nonurgent problems. Therefore, triage of really urgent cases will become more difficult. Cardiac expertise is necessary for diagnosing and treating acute myocardial infarction but is only available at the hospital. We can safely assume that the EMS staff has insufficient knowledge for proper triage of acute myocardial infarction by telephone.

The organization also has problems regarding the knowledge that is involved in assessing emergencies by telephone. Most knowledge is heuristic. Dispatchers say they can “feel” when something is wrong. This vague notion of an emergency prevents the knowledge from being similar among the dispatchers. It also complicates the evaluation of emergency handling. A strong need for protocols exists, for both the dispatchers and management.

**The current problem.** Therefore, we define the current problem as

The EMS is not sufficiently equipped for the triage of acute myocardial infarction by telephone.

**Organization description.** Our description follows the seven subcomponents listed earlier.

**Structure.** The EMS is a part of General and Social Health Care, which is a main section of the Municipal Medical and Sanitary Service (see Figure 2). The EMS contains two units: the dispatch center and the ambulance service, which are physically separate.

**Functions.** The EMS performs two basic functions: emergency management and support. Emergency management consists of three subfunctions: communication and coordination, emergency medical care, and the ambulance service. The support subfunctions are archiving, evaluation, policy making, and supervision. Figure 3 illustrates the full functional decomposition and the...
tasks that realize these functions (strictly speaking, the part below the white divide belongs to the CommonKADS task model).

Let’s look at the emergency-management functions in more detail:

- **Communication and coordination** consists of two subfunctions: *Triage* is realized by the emergency-call-handling task. This consists of the identification of the patient, telephone triage (gathering initial data, problem identification, and making a decision), and reporting. *Arranging and coordinating transport* is realized by the ambulance-dispatching task. This includes locating the patient, scheduling and selecting the ambulances, maintaining radio contact with ambulance personnel, communicating with the hospital, and guiding transport (verifying that bridges are closed, tunnel lanes are free, and so on).

- **Emergency medical care** consists of two subfunctions: *Triage* is realized by the ambulance-triage task. This is concerned with history taking, physical examination, initial diagnosis, monitoring, and reporting. *Treatment* is realized by the initial (on the spot) treatment task.

- **Ambulance** also consists of two subfunctions: *Transport* is realized by ambulance-transport tasks such as driving the ambulance, carrying the patient, and maintaining radio contact. *Delivery* entails handing the patient over to the hospital.

**Process.** Figure 4 depicts the time dependencies between the functions. Support functions and emergency-management functions operate in parallel. An emergency situation starts with triage. Based on the information obtained, the decision can be to send an ambulance. The paramedic at the ambulance performs triage on the spot and might provide some treatment. If necessary, the patient is transported to a hospital, where handing over takes place. The dispatching actions and the paramedic’s actions are reported and archived. Based on this information, the actions are evaluated. The evaluation is input for policy making, which guides the supervision.

**People.** The dispatch center is equipped with dispatchers, who carry out communication and coordination. At the ambulance service, each ambulance unit consists of a paramedic, who carries out emergency medical care, and a driver, who is responsible for the ambulance (transport and delivery). A system manager is responsible for archiving. The managers of both the dispatch center and the ambulance service carry out evaluation, policy making, and supervision.

**Power.** As is common for hierarchically structured organizations, the dispatch-center manager holds power over the system manager.
and over the dispatchers; the manager of the ambulance service holds power over the paramedic and the drivers. The paramedic is higher in the hierarchy than the driver. The manager of General and Social Health Care heads both departments.

At the dispatch center, one dispatcher is in charge of handling medical emergencies and, in this role, controls those who perform the ambulance function, without being formally in charge of them. This leads to an informal power relation of all dispatchers over the ambulance personnel. One indicator of this is that ambulance personnel and dispatchers do not socialize.

Computing resources. The EMS uses IBM RISC/600/320 machines under Unix to run an information-support system that handles online emergency calls and offline reservations, reviews, finance, statistics, and so on. The Information Services Department of the Municipal Medical and Sanitary Service maintains this system. The system does not use graphical terminals.

Knowledge. Three knowledge items are very important for the EMS: history-based triage knowledge, physical examination-based triage knowledge, and cardiac diagnosis.

Cardiac triage is difficult: 55% of the ambulances dispatched for “free calls” (calls direct to the EMS from a patient or bystander) regarding adults who have chest problems or who are unconscious (not owing to injury) were in retrospect unnecessary from an emergency point of view.7

As we mentioned before, when handling emergency calls, dispatchers use knowledge that is informal and idiosyncratic, and therefore difficult to manage. What is missing is sufficient knowledge about cardiac diagnosis. Figure 5 describes this knowledge item. As the figure shows, this knowledge resides at the hospital and has a limited availability for the dispatcher.

Possible solutions. Having analyzed the EMS, we need to identify solutions to the problem. As we mentioned before, they should be budget-neutral. In the EMS, the costs of new solutions can be paid for only by increased efficiency—for example, by the savings from not sending an ambulance without a “proven” necessity.

The knowledge item described in the knowledge component provides the answer to the problem: the organization needs expertise on cardiac diagnosis. Six possible solutions exist:

Solution I is to introduce a new agent at the dispatch center who possesses the required knowledge. The EMS could employ medical experts to perform triage, but replacing all dispatchers with experts is too expensive. However, a realistic alternative is to use a back-office in which an expert, such as an emergency physician, stands by to handle difficult cases. The EMS of Montreal, Canada, for instance, uses both nurse and physician emergency-call handlers. When a nurse is in doubt about a call, the call is transferred to the physician.7

Solution II is to aid dispatchers with written guidelines or protocols for cardiac diagnosis during emergency-call handling. A precondition for protocols is their usability: they should be flexible and explicit. For complex domains, this requirement is difficult to realize, and protocols are often difficult to handle in the current work context.

Solution III is to train the dispatchers. One possibility is to build an intelligent teaching system to support this teaching. This has been carried out for telephone triage at Montreal’s Urgence Santé.7

Solution IV is to use a KBS with cardiac-diagnosis expertise to support emergency-call handling during telephone contact with the caller. This KBS can guide the dispatcher through the interview and can support decision making based on the information collected. The teaching system at the Montreal EMS, mentioned above, was originally developed for telephone triage. However, the dispatchers did not accept this first-generation expert system because of its rigid user interface. Also, the development costs were high, and the estimated yearly system-maintenance costs were a quarter of the development costs.

Solution V is always to send an ambulance and let the paramedic perform triage on the spot. The paramedic has an advantage over the dispatcher because he or she can physically examine the patient. One study found that the paramedic dispatches at the Amsterdam EMS cover 92% of all cardiac-emergency free calls, so this solution would increase the number of dispatches by 8%.7 A way to redistribute the resources to finance this solution is to replace several paramedics with more emergency technicians, who are less skilled and less expensive. They should be dispatched only to perform basic life-saving support. In this case, the dispatch task should be extended with a triage task to choose between these two types of medical emergency care. This type of system is common in the US.

Solution VI is to introduce at the ambulance service a new agent who possesses cardiac expertise: the emergency physician. This is, for example, the case in Germany, where sometimes a Notarzt (emergency physician) is sent. The funding for this solution might be the same as proposed for Solution V.

Impact and the feasibility of solutions. Using the possible impacts of the potential solutions, we can analyze the feasibility of solutions in terms of organizational support.

For brevity’s sake, we won’t show all the impacts of all the solutions. However, we will include them into an overview of the attitudes of the possible sponsors for the different solutions. We’ll also detail the impacts of the selected solution.

Solution I, to use a back-office at the dispatch center, lacks support by the management and dispatchers, because they prefer to work with the dispatch center’s current personnel. The ambulance personnel is neutral.

Solution II, to use paper protocols, is sponsored by the management, because it could take into account the other problems and opportunities in the organization—the informal character of the knowledge of emergency-call handling and the lack of standards. The dispatchers recognize the need for standardization, and they will sponsor the protocols if they can retain sufficient control of the process. The system manager is neutral about protocols. The paramedic is in
favor of triage protocols at the dispatch center, because he can be prepared before he reaches the scene.

Solution III, to train the dispatchers, is favored by the dispatcher and the paramedic. The manager is neutral. Although training increases the quality of dispatching, the manager argues that training is a wasted investment because of the frequent turnover of personnel.

Solution IV, to introduce a KBS during emergency-call handling, is sponsored by the manager of the dispatch center, for three reasons. First, a KBS entails standardization that solves not only the current problem, but also other problems in the organization. Second, it provides a means for registration that can be used to improve the evaluation of emergency-call handling. Third, the solution is relatively insensitive to personnel turnover. The system manager favors this solution because he expects an extension of his sphere of influence. Although the dispatchers favor standardization, they feel slightly threatened by systems that possess artificial intelligence and that might take over their jobs. The ambulance personnel sponsor a KBS, because a better assessment of a case enables them to prepare themselves better.

Solution V, to perform triage on the spot, is favored by no one at the dispatch center. The manager has recently been confronted with the inspector’s policy to reduce the number of dispatches that do not result in patient transport to the hospital. The dispatchers are against this solution because they expect a decrease in work satisfaction. In contrast, the paramedics expect an increase in work satisfaction, and therefore sponsor the solution. In addition, the ambulance personnel expects an increase of employment.

Solution VI, to introduce an emergency physician at the ambulance, is opposed by the managers, because they prefer to work with the current personnel. The system manager is neutral. Dispatchers expect decreased work satisfaction. The paramedics fear losing their jobs because the physician will take over their work. Only the drivers sponsor this solution, because they expect an increase in employ-

Table 1. Estimated sponsoring for the six possible solutions and the status quo. “+” indicates in favor of, “-” against, and “o” neutral to the solution.

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Table 2 summarizes the major impacts associated with this solution.

The aftermath

Wilfried Post built the KBS for providing cardiac-diagnostic knowledge for dispatchers. However, lack of money greatly delayed...
its deployment. In the meantime, two important events occurred:

- The solution, which was originally only local to the Amsterdam EMS, became entangled in a national discussion about how and where to carry out emergency-call handling. This discussion caused more delay.
- At the EMS (and nationally), the use of information technology for emergency-call handling accelerated substantially. This acceleration made necessary the integration of the KBS with other information systems, which caused even more delay.

Consequently, the system is still not operational at the EMS. We could lay this “failure” at the feet of the organization model, because it is precisely what we want to prevent by building the model. On closer inspection, the organization model isn’t responsible for failing to cope with the first event. Neither a behavior-oriented nor an analysis-oriented approach can perfectly predict the future in a social context. We would have detected the second event by investigating the computer-resources component, if we had repeated the analysis after the delay occurred. This stresses the need to maintain the model after its completion, which is a key principle of the CommonKADS methodology.

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**References**


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HE EMS CASE STUDY REVEALED some strengths of the analysis-oriented modeling approach, as embodied in the CommonKADS Organization Model:

- It gives a coherent framework and terminology for thinking about organizations.
- It supports an open-minded identification of problems and solutions; that is, it tries to prevent a bias toward predefined interpretations.
- It does not require a time- and effort-consuming comprehensive behavioral model of the organization or require training in computer-modeling environments.
- It provides a transparent picture of the organization, its problems, the possible solutions, and their estimated impacts. This transparency makes it easier for participants to discuss these topics.

Of course, the approach has some drawbacks:

- Its subjective character and the highly iterative and informal building process makes replication by others difficult.
- Impacts are based on judgments. Analysts can mentally perform an impact analysis such as the one in Table 2, but such analyses depend totally on the analyst’s insights and implicit assumptions.
- The CommonKADS organization model alone is often insufficient. Elements of a task model and an agent model are also needed, which raises questions about the model template’s completeness.
- Establishing whether the model builder has covered everything relevant is difficult; no clear stopping rule exists.
- Over time, updating the model is imperative. However, this updating will consume additional effort and time, which are not always freely available.

Although this article describes only one case, the analysis-oriented modeling approach embodied in the CommonKADS organization model has been applied in at least 15 other cases. A summary of those cases is outside this article’s scope, but the lessons learned in pre-Hospital Emergency Management, PhD thesis, Univ. of Amsterdam, Faculty of Psychology, Amsterdam, 1996.

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