# A Quantitative Competence Model for e-Recruiting and Team Building in Safety Critical Domains

Franz Nirschl[1], Manfred Fuchs[2] and Jürgen Dorn[3],

[1]*Austro Control GmbH, Schnirchgasse 11, 1030 Vienna, Austria, franz.nirschl@austrocontrol.at*

[2]*ÖBB-Personenverkehr AG, Wagramer Straße 17-19, 1220 Vienna, Austria, manfred1.fuchs@pv.oebb.at*

[3]*Vienna University of Technology, Favoritenstrasse 9-11, 1040 Vienna, Austria, dorn@dbai.tuwien.ac.at*

**Abstract**

An information system model is presented, that enables quantification of competencies which are used to determine the suitability of candidates for a certain job and of experts to be part of a team in safety critical domains. Qualification (in the sense of acquired knowledge) and experience are seen as the basic competence-components which are measured in hours. Further competence build-up and competence-loss is determined by other parameters that are relevant in the job-recruiting and team building processes. The model can be used in competence management systems where the quantitative competence levels provide the basis for further use-cases. Competencies in safety critical domains were used for the design of the model to focus on these particular areas. In addition to a standard e-recruitment process which can be used for recruitment of aviation personnel, the model is extended to build teams for carrying out risk assessments in an aviation context. The team can be optimised based on the determined competence levels and required team sizes.

**Keywords**

Competence Management System, Competence Quantification, e-Recruiting, Team building, Aviation, Safety Critical Domain

## 1 Introduction

Today's knowledge based markets are subject to accelerating changes, which require efficient and effective recruiting methods to satisfy the demand of organisations to react to the new and growing challenges with competency based products by getting the right employees into the right jobs.

In addition, safety critical businesses require risk assessments to be carried out to avoid accidents with human losses. Risk assessment in the aviation industry is a business and legal requirement which will become increasingly important in the near future. In distinction to e-recruiting, team building for a risk assessment involves setting up a temporary team with highly specialised competencies in specific fields, in order to identify hazards of a given system and to assess the risks of such hazards.

In response to these demands, we are presenting an information system model that uses competencies of persons and compares these to competency profiles which are defined by recruiting experts. This allows a ranked list of potential candidates to be created for a specific job. The model has been extended and can also be used for team building. We use the team building process for risk assessments in the aviation business, where team profiles are defined by safety experts.

The model is intended for implementation in competence management systems for e-recruiting in recruiting organisations when dealing with a larger number of candidates. The existing

competence ontology of the Vienna University of Technology, Institute of Software Technology and Interactive Systems will be complemented with the results of our work.

# 2 Relation to Existing Theories and Work

## 2.1 Related Work

Dittmann (2003) discusses in his work the effects of the application of competence management systems on the actors within an organisation. The acceptance depends highly on the type of system integration and the applied processes.

Lindgren et al (2004) describe in their study design principles including development and testing for competence management systems. In a wide study, 6 Swedish organisations are participating. The goal of the study is the development of a competence model that integrates competencies from an organisational and an individual viewpoint considering technological aspects.

Dorn and Pichlmair (2007) elaborate in their work on a university competence management system that enables students to systematically build up their competencies. With the use of a gap analysis to a dedicated job profile the students can specifically plan their courses at the university. The representation of the competencies is done with HR-XML, to enable data exchange with other entities. Reference competencies are defined in an ontology and the existence including the degree of a competence can be shown with a defined set of possible evidences. If the owner of a competence (student) approves the access of his profile for others, organisations can use those profiles for the recruitment process. Due to the privacy issue of personal data, the data is encrypted.

## 2.2 Competence

The term competence is used in literature in the context of ability for self organisation. According Heyse and Erpenbeck (2004), competencies are characteristic abilities of persons to orient themselves in open and manageable as well as complex and dynamic situations.

According North and Reinhardt (2005) competencies are manifested, when knowledge is transposed into actions. In a vast sense this happens in the moment, when challenges are complied with abilities and respectively potentials. Competence is therefore the ability to act accordingly in a certain situation.

For the purpose of our work, competence is composed of the basic components *knowledge* and *experience* in the same field. The variation of the existing types of competence is simply consolidated into hard-skills and soft-skills.

Standardised representation forms of competencies minimise the barriers in exchanging HR-data with other entities along the recruitment process. HR-XML serves the needs of transferring inter-organisational personnel data (Allen et al. 2007).

## 2.3 Mathematical Methods for Decision Making

In business practice, decision making situations are often unclear and unstructured, making it difficult to obtain and analyse the required inputs. Instead of making decisions on the basis of a few or even a single criteria, it is necessary to base decisions on multiple criteria. The nature of multiple criteria problems is, that there is a large amount of complex information of conflicting nature which cannot easily be resolved in one's head (Belton 2002).

In science, various models exist to serve that purpose. One of the main problems is to find the right model for the decision situation which poses a greater challenge rather than calculating the result.

Three different decision making methods are analysed in our work to choose an appropriate basis for building the competence model: Bayesian Networks, Fuzzy-Method and Multiple Criteria Decision Making (MCDM)

The focus is set on MCDM, where many sub-methods exist in literature. One way to classify them is according the type of data they use which categorises them into deterministic, stochastic and fuzzy MCDM methods. In addition there may be situations which involve a combination of all above data types. Three basic steps utilise any decision-making technique involving numerical analysis of alternatives: (1) determination of the relevant criteria and alternatives, (2) attachment of numerical measures to their importance and (3) processing numerical values to determine a ranking of each alternative (Triantaphyllou 2000).

Due to the given advantages, including explicit consideration of multiple criteria, good structuring ability and a transparent and traceable decision making steps, a deterministic MCDM method is chosen as the basic decision making model for the quantification model for competencies.

# 3 Model for Quantification of Competencies

## 3.1 Scope and Approach

In developing the model for quantification of competencies recruiting experts, safety experts from different companies and organisational units as well as scientists and experts in the personnel management area have been involved in empirical and structured interviews to collect information to formulate the requirements for an information system applying the quantitative competence model. In a two step approach, requirement data was collected and analysed for defining requirements.

The first step mainly concentrates on the recruitment process for air traffic controllers, which is chosen as a representative example for recruiting personnel in safety critical areas. Derived from a standardised recruiting process it can be described in 4 basic steps (ACG 2005)

- selection according basic requirements (filtering of applicants according the prerequisites)
- preselection and main selection: testing performance based basic hard-skills, soft-skills and working attitudes
- assessment centre: testing of social skills
- final selection with interviews

Along those 4 basic steps, the model aims to accompany the different process stakeholders – client, recruitment expert, psychological expert and assessor – in determining the best suitability of job candidates.

The second part of the model focuses on the team building process for risk assessments in aviation segments, where legal compliance requires analysis and manageability of risks for new systems and changes to existing systems or parts thereof. It includes the quantitative assessment of risks, the development of systematic mitigation strategies and a confirmation of those. Teams are particularly important to identify and assess the risks. The quality of the assessment result is based and highly depends on the competence of the team members. An analysis of the competency requirements and a selective distribution of the competencies is a prerequisite that is carried out by a safety-peer in the planning phase of the risk assessment. The team building process is led by a *safety-peer*, who is an expert with methodical skills in carrying out risk assessments. The process can be described in three steps: (1) pre-analysis of the system under consideration to determine the necessary roles, (2) determination of the competence distribution and (3) selecting the team members after a possible optimisation of the team size (Nirschl 2006).

## 3.2 Stakeholder Perspectives

In designing a model for the quantification of competencies for e-recruiting and team building, we use four modules of which each concentrates on a different perspective. The modules are dedicated to different stakeholders, by summarising their needs and interests in the recruiting process from their view.

The client, who is interested in the allocation of a job or in setting up a team, defines the job profile or the team profile respectively. The modules 'job profile' and 'team profile' are therefore the requirement modules from the client perspective. Figure 1 shows the modules at the very left and right.

Candidates and recruiters interest in collecting data as input to the recruiting process are represented in the candidate database on top of Figure 1.

The quantification model, as shown centrally in Figure 1, serves the purpose to calculate comparable competence levels based on the input data from the candidate database and the job profile or the team profile. The module consists of a calculus, that computes the competence levels by using the algorithm based on MCDM methods. Additional parameters represent the calculation boundaries, and allow more specific calculation patterns. The parameters are to be adjusted by recruitment experts using best knowledge and special recruitment experience.

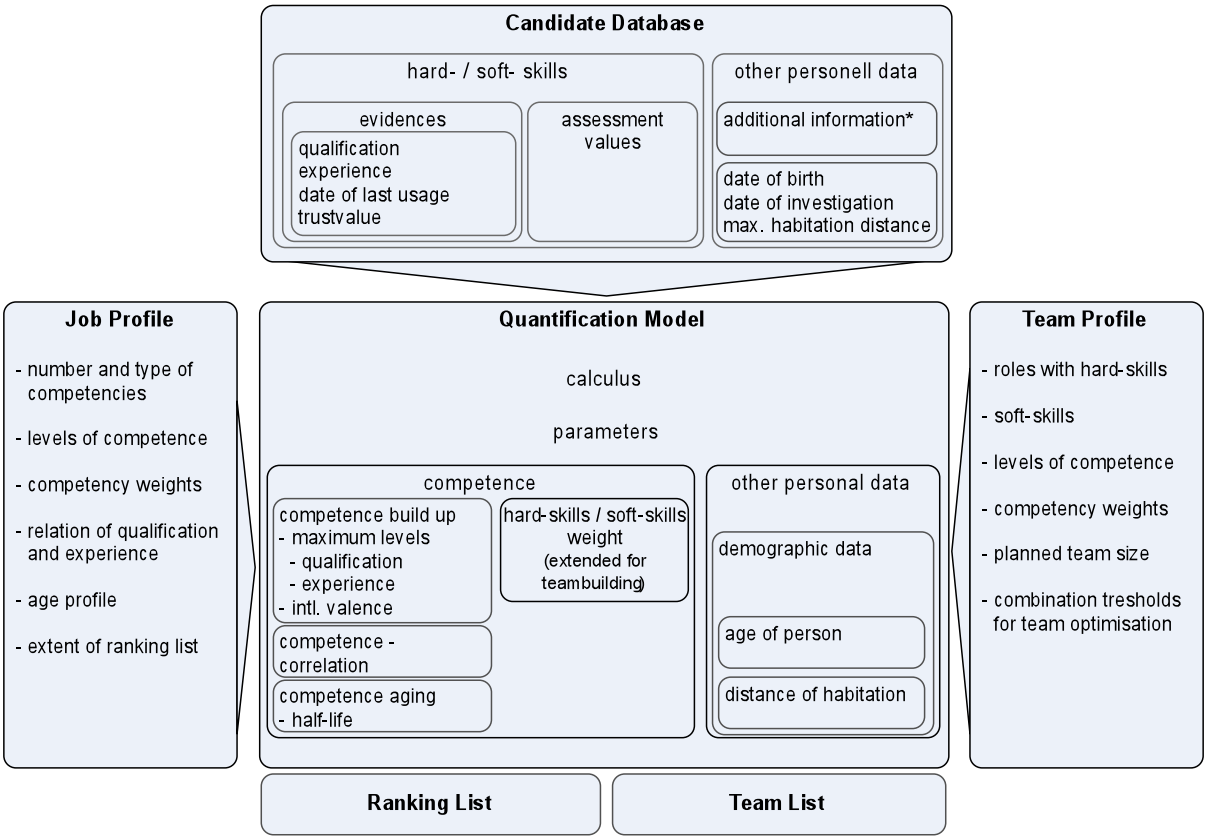


Figure 1: Model for Quantification of Competencies for e-Recruiting and Team building

## 3.3 Job Profile

With the job profile the client defines – typically in close cooperation with the recruitment expert – the competence based requirements for a job. In addition, other personnel data can be specified.

The number and type of competencies can be chosen from a competency catalogue where proposed job profiles provide a quick way to give orientation on existing profiles. Levels of competence give the client the option to define a more specific profile for each required

competence. The specification can be described with minimum, optimum and maximum levels. Competency weighting can be used to distribute the importance of competencies within a specific job profile. Distribution is specified with the help of percentage levels.

Relation of qualification and experience indicates whether the client searches for a person which is more theoretically or more practically oriented. With the help of the age profile, the client may express his – non competence based – expectation for a certain age that is required for a job. Minimum, maximum and optimum descriptors are used to specify the age profile.

The extent of the ranking list indicates the amount of potential candidates that should be presented to the client after the preselection of the candidates for the final selection, which is usually carried out in the form of hearings and personal talks between the client and the candidates.

## 3.4 Team Profile

In contradiction to the recruitment process of single candidates for a job, the composition of a team involves the definition of roles which are assigned to experts. The quantification model can be used to determine competence levels of team members including combination of dedicated soft skills with each required hard-skill. Levels of competence are used to set the minimum, optimum and maximum competence levels for roles. Competency weights are an essential input to the model to indicate the importance of skills and to serve as the distribution mechanism of the competencies as derived from the system criticality, which is determined by the safety expert in cooperation with the change owner (responsible person for a change project). The planned team size is used as the starting point for the determination of the real team size, which is usually smaller when experts combine more than one required competence. The combination thresholds (limits) are the basis for the team optimisation step in the calculus. Figure 2 shows a sample screenshot from the prototype validation instrument, pointing out the competence distribution and the combination level of a defined team profile. In case of competence 7, the competence weight is lower than the combination limit, which leads to a take-over of that role by an existing team member covering competence 1 to competence 6.

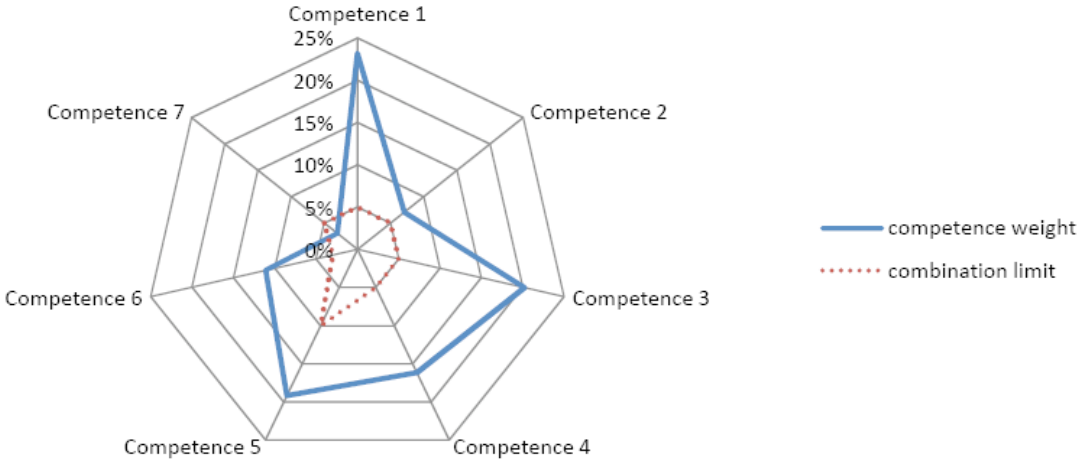


Figure 2 - Competence distribution and combination limits for a selected team profile

## 3.5 Candidate Database

The candidate database contains required data for computation of the competence levels. In addition, other personnel data and additional information can be used to provide decisive orientation along the recruiting process. Evidence for a competence is given in the form of hours for qualification and experience, the date of the last usage and a trust level which gives the recruitment expert the option to value validity of competence components from the recruiter's perspective. Evidence is usually given for hard-skills whereas soft-skills typically cannot be

described with hourly based evidences in learning or experience environments. The model therefore considers the option of using assessed competence levels, which are usually provided by the recruitment expert or an assessment centre. The consideration of assessment levels can also be used for hard-skills where evidence is difficult to provide.

Other personnel data like date of birth, date of investigation and maximum habitation distance is used by the calculus later in the quantification model.

## 3.6 Quantification Model

We see hard-skills typically composed of the basic competence elements *knowledge* and *experience* which each can be quantitatively described with hours. Qualification is usually gained in a learning environment that uses – next to other descriptors – hours to give an indication of the qualification level. Our model considers the amount of hours in qualification in a non-linear relation to the degree of the qualification level (see Figure 3). The non-linearity reflects a flattened increase of competence towards longer learning periods, where qualification build up is slowed down. The build up of experience as the second basic competence element is seen accordingly.

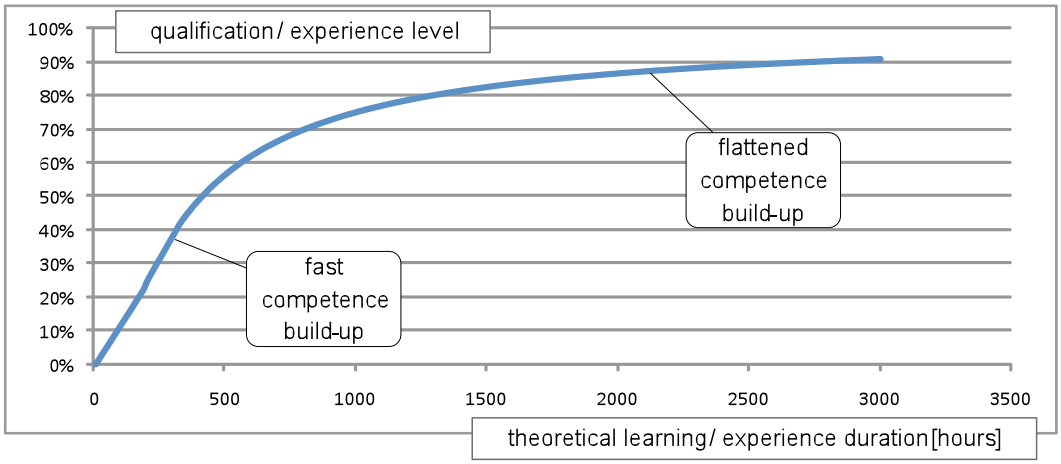


Figure 3: Build-up of the competence components qualification and experience

The calculation steps in determining the quantitative competence levels consider the input of the job profile and the team profile respectively, the basic competence data from the candidate database and the parameters of the quantification model which are typically adjusted by the recruitment or safety expert. The parameters of the quantification model are likely to be adjusted for category groups of jobs and need therefore not to be adjusted for each single job since these parameters are valid for job domains to describe the context of a job (e.g. aviation). The team optimiser, an additional major step, is added for team building to optimise the team size to smaller but equally competent groups.

Competence parameters are categorised in build-up, correlation and competence loss parameters. For the build-up of a competence the maximum levels for qualification and experience are to be defined. The international experience valence is used to specify the increased (theoretically also decreased) valence of the competence from the perspective of an organisation when a candidate used to work internationally in a certain job related field. Competence correlation is used to determine a certain closer relationship amongst competencies. Lower values in a certain competence can be increased with higher competence values in a close related neighbouring competence. With the help of the half-life value of a competence, the competence loss can be determined in case the applicant didn't use the competence for some time.

For the purpose of using the quantification model for team building, the additional weighing parameter for hard- and soft-skills is introduced. This parameter reflects the fact, that for team building roles are usually defined which are assigned to separate experts. This parameter gives

the option to consider the combinability of the expert hard-skills with some selected soft-skills to certain extend.

Other personnel data parameters are used to calculate whether the applicant meets the age requirements according the clients age specification and the distance of habitation to the working location. In the latter, recruiting experts can specify the maximum allowable distances based on experience with applicants in a certain job field.

The output of the calculus is the ranking list of the best candidates that is provided to the client or the recruitment expert to invite candidates to a final hearing. In case of team building, the team list with the optimised team naming their roles is presented to the safety expert.

### 3.7 Model Validation

A prototype of the model, including the input modules, is set up in form of a spreadsheet which serves as the instrument for validation with the help of recruiting and safety experts. The prototype consists of simulated interfaces for the input of data according the above module descriptions. All model parameters, except the competence build up, can be used on an optional basis to reduce complexity and increase transparency to the user.

The expert judgement serves as one form of validation of the model which has to be supplemented with additional validation methods. These methods split into two directions where the first one concentrates on field validation for job recruitments. The second method focuses on the validation via a comparison of safety assessment results which have been carried out. The aviation expert groups have to be sampled with the help of the quantification model to determine their competence distance from the ideal ones of the calculus. To be able to correlate the competence distance with the results of the safety assessments, quality descriptors have to be defined.

Model validation is currently in progress and highly dependent on the amount of available data and cooperation ability of organisations.

## 4 Findings

During the design of the model and in the validation phase it has been observed that additional perspectives have to be considered when implementing the model in a real life environment.

Special consideration has to be applied when personnel data is stored in the candidate database that can be used by other individuals in an organisation by having access to such data. These privacy concerns can be solved with state of the art encryption methods and access limitations to authorised users. Users show higher acceptance to a voluntary rather than a prescribed participation on a competence management system. Air traffic controller representatives even see additional benefits in entering skills in a competence management system, by gaining chances to participate in projects according their skills and in developing their own competence profile further in a structured way.

Collection of data, which is a natural process step in job recruitment but not a typical one for existing personnel (experts) in an organisation, poses an issue that has to be developed further. Validation interviews with safety experts revealed basically to ways of data collection. A simple and fast way to enter data is by the experts themselves, who have best knowledge about their evidences. A simple and transparent input HMI (human machine interface) is a prerequisite to avoid entering of non-harmonised data. In case of entering soft-skills or hard-skills that can't be presented by evidences, a self assessment of the soft-skill can be carried out with the help of a standardised questionnaire. Self-assessed data can be supplemented by a manager-assessment during the appraisal interview.

When using the model for job-recruitment, a change in the method of data collection has to take place in an organisation. Collecting of hours as evidence seems difficult to recruitment experts in

a first attempt, but turns out as equally simple as collecting other data after some practice. This change should be supported by a short training and introduction to the basic model to build up trust to recruitment experts.

## 5 Conclusions and Outlook

One limiting factor to the model when it is applied to a smaller number of candidates is the acquisition of the competencies, as this relies on a formal standardised approach which could be more time consuming compared to traditional recruiting methods. In such cases, recruiting experts are usually more efficient than applying the process required by the model.

The model proves to be efficient when used with a recruiting process of 10 or more candidates. Team building for risk assessments is not limited by a number since competence profiles of experts are well formulated once and stored for a longer time period. The strength of the model is unveiled when there are a number of well formulated competencies required for a job.

The standardized HR-XML schema which is used as in- and output to the candidate database, eases the interoperability amongst organisations. Exchange of standardised competence profiles enlarges the number of potential candidates in the recruiting process. Team building amongst a large group of experts raises the quality of the risk assessment results and is a key-fact in aviation safety. Data privacy is essential on a legal basis and has to be considered when the model is implemented, but is not in the focus of our study.

As an outlook for further development work, we see our model as an inspiration and the basis for processing a standardised competence-balance for an organisation, which can be used for competence development in a certain field according the market situation. Additionally, our model can be further developed to be used as an instrument for systematic, competence based layoffs in case of business breakdowns and for reorganisations of organisations.

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