WORKING PAPER SERIES

Personnel Planning and Leadership as Central Personnel Economic Instruments

Kim Michelle Siegling/Thomas Spengler/Sebastian Herzog

Working Paper No. 09/2023

OTTO VON GUERICKE
UNIVERSITÄT
MAGDEBURG

FACULTY OF ECONOMICS
AND MANAGEMENT

Impressum (§ 5 TMG)
Herausgeber:
Otto-von-Guericke-Universität Magdeburg
Fakultät für Wirtschaftswissenschaft
Der Dekan

Verantwortlich für diese Ausgabe:
K. M. Siegling, T. Spengler, S. Herzog
Otto-von-Guericke-Universität Magdeburg
Fakultät für Wirtschaftswissenschaft
Postfach 4120
39016 Magdeburg
Germany

http://www.fww.ovgu.de/femm

Bezug über den Herausgeber
ISSN 1615-4274

Personnel Planning and Leadership as Central Personnel Economic Instruments

Kim Michelle Siegling, Thomas Spengler and Sebastian Herzog[1]

Abstract

Economic activity always involves the allocation of scarce goods to competing uses. Among these scarce goods is also the personnel of the enterprise. Personnel economics therefore also has to make such allocation decisions with respect to the availability of personnel and with respect to the functionality of personnel. For this purpose, two sets of instruments are used, namely personnel planning and leadership. This article is dedicated to a selection of such instruments. Beyond selected relevant basics of personnel planning and leadership, this article introduces hierarchical personnel planning and the conception of fuzzy rule systems for the selection of appropriate leadership styles.

JEL: A20, A22, A23, C60, M12, M21, M50, M51

Keywords: (fuzzy) linear programming, fuzzy logic, (hierarchical) personnel planning, leadership, leadership styles, leadership style choice models, management by … concepts, productivity factors, rule based systems

[1] Thomas Spengler, Prof. Dr., thomas.spengler@ovgu.de; Chair of Management and Organization, University of Magdeburg, P.O. Box 4120, 39016 Magdeburg (Germany), Phone: +49 391 67 58440; Kim Michelle Siegling, M. Sc., kim.siegling@ovgu.de; Chair of Management and Organization, University of Magdeburg, P.O. Box 4120, 39016 Magdeburg (Germany), Phone: +49 391 67 52626; Sebastian Herzog, M. Sc., sebastian.herzog@ovgu.de; Chair of Management and Organization, University of Magdeburg, P.O. Box 4120, 39016 Magdeburg (Germany), Phone: +49 391 67 50176.

Contents

1 Preliminary remarks

Human resources problems arise when business owners are unwilling or unable to carry out all the activities required to achieve the purpose of the business themselves and therefore wish to delegate activities to agents. Those agents who are provided with employment contracts are referred to in their entirety as the personnel of the business. The two main personnel management problems are the availability problem and the functionality problem.

To solve availability problems, one chooses measures of personnel planning and to solve functionality problems, one chooses those of leadership. Personnel planning methods deal with availability problems, whereas functionality problems are faced within leadership.

In Chapter 2, we look at personnel planning. To this end, we first explain general and formal basics. We then formulate various models for optimizing personnel and personnel assignment in crisp situations. We place particular emphasis on hierarchical planning. Subsequently, we construct hierarchical planning models for the fuzzy case.

Chapter 3 is devoted to leadership. Here, too, we first deal with terminological and systematical basics, addressing, among other things, effective, efficient and optimal leadership. We then look at selected concepts of leadership. These include various models for leadership style selection and so-called management by ... concepts. At the end of the third chapter, we outline a new fuzzy rule system for leadership style selection.

The paper ends with a short conclusion (chapter 4).

2 Personnel planning

2.1 Basics of personnel planning

2.1.1 General principles of personnel planning

The availability problem is about creating and securing the availability of personnel. In the context of this problem, it is therefore a matter of having the right employees at the right time and in the right place to a sufficient extent to cover the company's personnel demands. This in turn means that personnel are adequately provided and that the personnel provided are adequately used. The most rational solution possible to the availability problem requires appropriate (personnel) planning. The term "personnel planning" can be defined in different ways. However, we do not want to present them here in their breadth, but rather define personnel planning in a narrower sense, namely as an ordered, information-processing procedure, in the course of which the characteristics of personnel variables are determined with foresight in such a way that desired operational goals are achieved. In principle, all potential design alternatives in the area of personnel availability problems - such as the hiring, release, training, promotion or assignment of employees - can be considered as personnel variables. Furthermore, we consider here the so-called categorial and not the individual level, i.e. we deal with categories of work forces on the one hand and with categories of activities on the other hand, whereby work force categories can be differentiated e.g. according to qualification types or (service) age groups and activity categories e.g. according to activity types or job types. One speaks then also of the so-called collective personnel planning.

The problem areas of personnel planning are personnel demand, personnel and personnel assignment. Personnel demands are defined as the type and number of workers needed in a given period and location, while personnel is defined as the type and number of workers available in a given period and location. Personnel assignment is the allocation of the labor force available in a given period and location to organizational units or activities. It should be explicitly emphasized here that personnel demand and personnel must be kept neatly apart, because there is sometimes a significant difference between the staff needed and the staff available. The difference between needing personnel and having personnel can be as serious as the difference between needing money and having money. Four dimensions are relevant for the three problem areas, because in each case it must be clarified which manpower (qualitative dimension), to what extent (quantitative dimension), when (temporal dimension) and where (local dimension) is needed, provided and used (see figure 1).

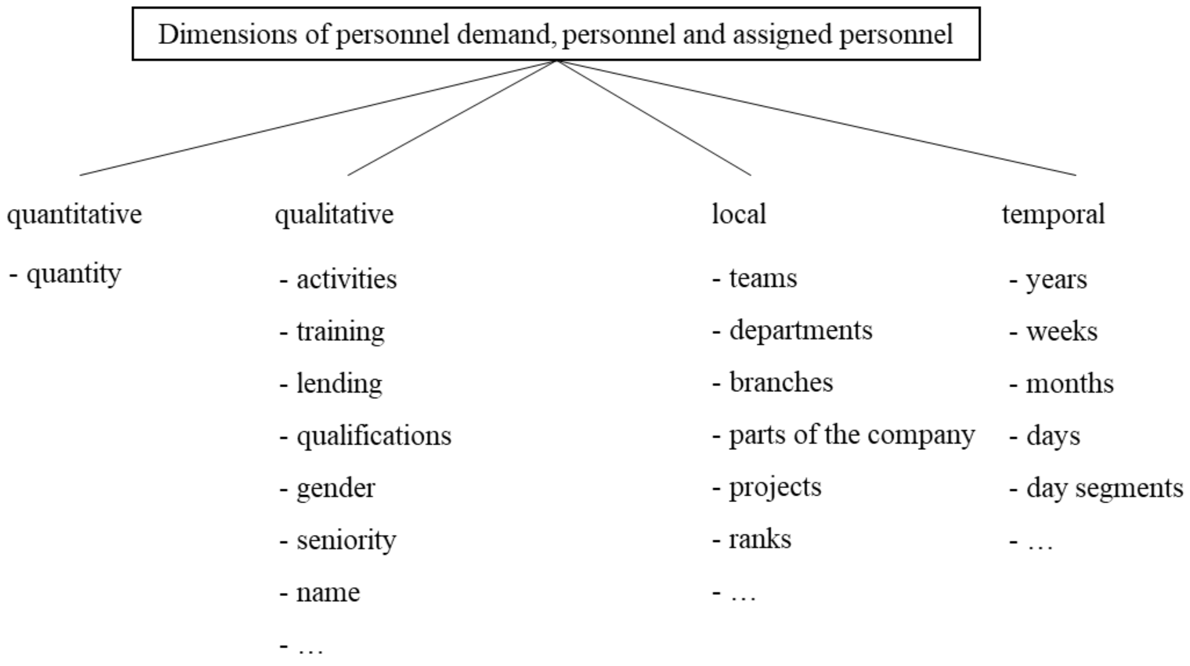

Figure 1: Dimensions of personnel planning and examples of differentiation

The three problem areas of personnel demand (PD), personnel (P) and assigned personnel (AP) must be coordinated with each other. For this purpose, the so-called implicit and the so-called explicit approach of personnel planning are basically two procedures to be considered. If the implicit approach is used, the personnel demand and the personnel are directly coordinated with each other by requiring that the personnel demands can at least be covered by the provision of a sufficiently suitable workforce ($PD \leq P$). The explicit approach, on the other hand, takes place in two steps and explicitly takes into account personnel levels. In the first step, it is required that all personnel demands are exactly covered by the assignment of sufficiently qualified personnel ($PD = AP$); over- and under-coverage of personnel demands are thus excluded (for economic reasons), e.g., to avoid productivity losses in the case of over-coverage (because too "many cooks spoil the broth") or contractual penalties in the case of under-coverage. In the second step, personnel assignment and personnel are coordinated with each other. Here it is required that at least as much suitable personnel must be available as is planned for assignment or that no more personnel can be assigned than is available ($AP \leq P$).

Let us now consider four exemplary cases in which the following applies: There are two types of activity to be performed ($q = 1$ and $q = 2$). The company employs workers of three categories ($r = 1, r = 2$ and $r = 3$), which are differentiated by qualifications. Workers of type $r = 1$ can only perform activities of type $q = 1$, workers of type $r = 2$ can only perform activities of type $q = 2$ and workers of type $r = 3$ can perform both types of activities. For both types of activities, a total of thirty workers are required and a total of thirty workers are available in the company. If one designates the personnel demand for the completion of activities of the kind q with PD_q and the personnel with workers of the kind r with P_r, then $PD_1 + PD_2 = P_1 + P_2 + P_3 = 30$ applies obviously.

If, for example, the personnel demands are $PD_1 = 20$ and $PD_2 = 10$, then according to the constraint system of the explicit approach, a personnel configuration with $P_1 = 18$, $P_2 = 11$ and $P_3 = 1$ is inadmissible and a personnel configuration with $P_1 = 20$, $P_2 = 5$ and $P_3 = 5$ is permissible. If, however, $PD_1 = 19$ and $PD_2 = 11$ apply to the distribution of personnel demands, the (in)admissibility of the personnel levels is reversed (see table 1), whereby, of course, only in the cases of admissibility, permissible personnel assignment plans can be found.

		$PD_1; PD_2$	
		(20;10)	(19;11)
$P_1; P_2; P_3$	(20;5;5)	permissible	inadmissible
	(18;11;1)	inadmissible	permissible

Table 1: Inadmissible and permissible personnel

The permissible personnel assignment schedules for which the constraints both of type $PD \leq P$ and $PD = AP$ as well as $AP \leq P$ are fulfilled are listed in table 2a and table 2b. For the other two constellations, no assignments of the AP variables are found that satisfy these constraints.

	$r = 1$	$r = 2$	$r = 3$	PD_q
$q = 1$	20	-	0	20
$q = 2$	-	5	5	10
P_r	20	5	5	

Table 2a: Permissible personnel assignments

	$r = 1$	$r = 2$	$r = 3$	PD_q
$q = 1$	18	-	1	19
$q = 2$	-	11	0	11
P_r	18	11	1	

Table 2b: Permissible personnel assignments

To conclude the introductory considerations, we would like to briefly discuss the necessity of personnel planning. Personnel planning problems arise in a non-trivial way whenever ambiguities exist with respect to at least one of the above-mentioned dimensions. They arise, for example, when several categories of workers can be provided for the completion of one and the same type of activity and/or when one and the same type of worker can be used for the completion of several types of activity. Such ambiguities concerning the qualitative dimension are called deployment ambiguities in the first case and use ambiguities in the second case. However, personnel planning problems also arise, for example, if - and this is the rule in many companies - several workers or types of workers are deployed in several shifts or according to several shift patterns (temporal dimension) or if they can be assigned to several branches (local dimension).

2.1.2 Formal basics of personnel planning

As already stated, in personnel planning, three problem fields must be coordinated: personnel demand, personnel and assigned personnel. We understand personnel (demand) as type and number of available (required) employees, and assigned personnel as the number of employees of type r who cover personnel demands of type q. We define the following symbols:

$$\overline{Q} := \{q | q = 1,2, \ldots, Q; q \text{ is a personnel demand type, e.g. a category of jobs}\}$$

$$\overline{R} := \{r | r = 1,2, \ldots, R; r \text{ is a personnel type, e.g. a type of qualifications}\}$$

$R_q :=$ {r|personnel types r are capable of covering personnel demand type q}

$Q_r :=$ {r|personnel demand type q can be covered by personnel type r}

$PD_q :=$ personnel demand of type $q \in \overline{Q}$

$P_r :=$ personnel of type $r \in \overline{R}$

$AP_{rq} :=$ assigned personnel of type $r \in \overline{R}$ for covering personnel demand of type $q \in \overline{Q}$

$\mathfrak{P} :=$ power set

$\emptyset :=$ empty set

The explicit or implicit approach of personnel planning can be applied to coordinate these three problem fields. The explicit approach explicitly takes into account the assignment of personnel and ensures that the personnel demands are exactly covered by the assigned personnel (1) and that the number of assigned personnel cannot be greater than the personnel (2):

$$PD_q = \sum_{r \in R_q} AP_{rq} \;\; \forall\, q \in \overline{Q} \tag{1}$$

$$\sum_{q \in Q_r} AP_{rq} \leq P_r \; \forall\, r \in \overline{R} \tag{2}$$

The so-called implicit approach does not explicitly consider the assignment of personnel, but only implicitly. At least one permissible personnel schedule can be derived from it (if there exists one at all). It requires that every partial personnel demand and any combination of partial personnel demands can at least be covered by sufficiently suitable employees (3):

$$\sum_{q \in \hat{Q}} PD_q \leq \sum_{r \in \bigcup_{q \in \hat{Q}} R_q} P_r \;\; \forall\, \hat{Q} \in \mathfrak{P}(\overline{Q}) \backslash \emptyset \tag{3}$$

2.2 Optimization of personnel and assigned personnel in deterministic situations

2.2.1 Basic models

Optimization models always consist of (at least) one objective function and several constraints. The constraint space of the models to be formulated here always contains either the implicit or the explicit approach. In a first model, the goal is to minimize the personnel costs that depend on r. We define w_r as labor cost for a worker of type r. In addition, we use the implicit approach.

Model I:[2]

$$\sum_{r \in \overline{R}} w_r \cdot P_r \rightarrow \min! \tag{4}$$

subject to:

$$\sum_{q \in \hat{Q}} PD_q \leq \sum_{r \in \bigcup_{q \in \hat{Q}} R_q} P_r \ \ \forall \ \hat{Q} \in \mathfrak{P}(\overline{Q}) \backslash \emptyset \tag{3}$$

$$P_r \geq 0 \quad \forall \, r \in \overline{R} \tag{5}$$

We formulate the objective function to minimize personnel costs. With a total of $2^Q - 1$ constraints of type (3) we guarantee the coverage of the personnel demands. Since the different activities are to be carried out simultaneously, we must guarantee the coverage of all single personnel demands and all their combinations. Model I leads to the same optimal values of the personnel variables as the following Model II, in which the explicit approach is used.

Model II:[3]

$$\sum_{r \in \overline{R}} w_r \cdot P_r \rightarrow \min! \tag{4}$$

subject to:

$$PD_q = \sum_{r \in R_q} AP_{rq} \ \ \forall \ q \in \overline{Q} \tag{1}$$

$$\sum_{q \in Q_r} AP_{rq} \leq P_r \ \forall \ r \in \overline{R} \tag{2}$$

$$P_r \geq 0 \quad \forall \, r \in \overline{R} \tag{5}$$

$$AP_{rq} \geq 0 \quad \forall \, r \in \overline{R}, q \in Q_r \tag{6}$$

When using Model II, we receive additional information. This model additionally generates the optimal personnel assignment plan. The Q constraints of type (1) guarantee the exact coverage of the personnel demands by the personnel assignment for all activities $q \in \overline{Q}$. The other type (2) constraints require that no more employees can be used than are available.

[2] See the example in the appendix.
[3] See the example in the appendix.

2.2.2 Introduction to hierarchical structured models

Planning models (not least in personnel planning) can very quickly become very complex, so that their optimizing solution requires immense effort or even becomes impossible. It is then necessary to solve the complex decision problem not simultaneously in a total model, but to sequentialize it and to formulate partial models. If one has to solve for example a complex procurement planning, production planning and sales planning problem, one can make possibly first the procurement, then the production and only at the end the sales planning. Or, if one has to solve a multi-period decision problem, one could plan first the first, then the second and so on and at the end the last period. The problem with such a successive approach, however, is that it cuts the interdependencies between the sub-areas and does not take them into account simultaneously, which usually destroys the overall optimum. Models of so-called hierarchical planning, on the other hand, are so cleverly formulated that such negative effects of partialization are avoided (Anderson/Joglekar 2005, Schneeweiß 1998).

It is obvious that the explicit and the implicit approach of personnel planning and their combination can be used for exactly such problems. Using the implicit approach, the optimal personnel is generated, which is then used as a datum in the explicit approach. The fact that no overall optimum is destroyed corresponds to the basic idea of hierarchical planning. In the further course of this chapter, we will now formulate corresponding models for different planning situations.

We first determine the optimal personnel $\overline{P}_r^{opt}$ by solving Model I. This solution is then integrated as data into Model III in the next step.

Model III:

$$\sum_{q \in \overline{Q}} \sum_{r \in R_q} w_r \cdot AP_{rq} \rightarrow \text{min!} \tag{7}$$

subject to (1), (6) and:

$$\sum_{q \in Q_r} AP_{rq} \leq \overline{P}_r^{opt} \; \forall \, r \in \overline{R} \tag{8}$$

Since no personnel variables are used in this model, we have to apply objective function (7), which is based on personnel assignment variables. We get the same solution via Model III as via Model II. Especially in situations with multi-period problems and different possibilities to change the personnel (e.g. by hiring and firing), such hierarchical planning can be very useful to reduce the model size.

2.2.3 Hierarchical structured models including productivity factors

2.2.3.1 Single period models

2.2.3.1.1 Productivity factors depending only on the skills of the employees

We now vary the above problem definition in such a way that the employee categories are characterized by different productivity factors that depend on the employee capabilities. Such factors take values close to 1. We assign them the symbol α_r. For example, if α_r = 0.8 (1.1), this means that employees in category r are 80% (110%) productive compared to an average capable employee. In this case, we can derive the optimal personnel and the optimal personnel assignment from a combination of Models IV and V below. Model IV includes an extended version of the implicit approach and leads to the optimum of the personnel variables.

Model IV:[4]

$$\sum_{r \in \overline{\overline{R}}} w_r \cdot P_r \rightarrow \min! \tag{4}$$

subject to (5) and:

$$\sum_{q \in \hat{Q}} PD_q \leq \sum_{r \in \bigcup_{q \in \hat{Q}} R_q} \alpha_r \cdot P_r \ \ \forall \, \hat{Q} \in \mathfrak{P}(\overline{Q}) \backslash \emptyset \tag{9}$$

As already stated, we now denote the optimal specifications of the personnel variables by $\overline{P}_r^{opt}$. They are into account as data in Model V:

Model V:[5]

$$\sum_{q \in \overline{Q}} \sum_{r \in R_q} w_r \cdot AP_{rq} \rightarrow \min! \tag{7}$$

subject to (6), (8) and:

$$PD_q = \sum_{r \in R_q} \alpha_r \cdot AP_{rq} \ \ \forall \, q \in \overline{Q} \tag{10}$$

---

[4] See the example in the appendix.
[5] See the example in the appendix.

In such simple cases, where personnel is not restricted in any way (e.g. by hiring limits), constraint (8) is redundant. One can then generate the optimal personnel only by solving Model V (without (8)) and inserting it into the following equation:

$$\sum_{q \in Q_r} AP_{rq} = P_r \quad \forall\, r \in \overline{R} \tag{11}$$

We have demonstrated this procedure of hierarchical planning in this section of the study, since it is still very simple and the principle does not need to be changed even in more complex situations (e.g., in the dynamic case or when the personnel variables are restricted).

2.2.3.1.2 Productivity factors depending on the skills of the employees and on the assigned activities

Now, we assume, that the productivity factors (α_{rq}) depend on the personnel categories *r* as well as on the types of activities q. These factors effect, that the implicit approach is not still available. Nevertheless we can generate the optimal solution using a hierarchical structured process. This process bases on a special version of Model III (Model VI) with an inserted checking criterion. This checking criterion (12) deduces the personnel (for all categories r) one can get in the worst case, that is when activities of type q are carried out by employees of (only) one category *r* completely:

$$\overline{P}_r^* = \sum_{q \in Q_r} \frac{1}{\alpha_{rq}} \cdot PD_q \quad \forall\; r \in \overline{R} \tag{12}$$

After calculating the worst case personnel, we bring $\overline{P}_r^*$ as a datum into Model VI and compare it with the upper recruitment limit H_r^{max} (14).

Model VI:

$$\sum_{q \in \overline{Q}} \sum_{r \in R_q} w_r \cdot AP_{rq} \rightarrow \min! \tag{7}$$

subject to (6) and:

$$PD_q = \sum_{r \in R_q} \alpha_{rq} \cdot AP_{rq} \;\; \forall\, q \in \overline{Q} \tag{13}$$

$$\sum_{q \in Q_r} AP_{rq} \leq \min\left(\overline{P}_r^*, H_r^{max}\right) \;\forall\, r \in \overline{R} \tag{14}$$

If $\overline{P}_r^*$ is smaller than or equal as H_r^{max} for any r, the regarding constraint (14) is redundant. We only have to take (14) into account, if H_r^{max} is a real bound. The optimum for the personnel we however get by calculating equation (11) in the last step.

2.2.3.2 Multi period models

Now, we consider a planning situation, which concerns more than one period. The set of periods we denote with

$\overline{T} \coloneqq \{t | t = 1,2, \dots, T; t \text{ is a single period in the planning horizon}\}$

If the productivity factors depend only on the skills of the employees, we can generate the optimal personnel and personnel assignment by applying the same process as in the static case. First we solve a model based on the implicit approach (Model VII), then we bring the optimal personnel (as data $\overline{P}_{rt}^{opt}$) into a model based on the explicit approach (Model VIII).

Model VII:

$$\sum_{t \in \overline{T}} \sum_{r \in \overline{R}} w_r \cdot P_{rt} \to \min! \tag{15}$$

subject to:

$$\sum_{q \in \hat{Q}} PD_{qt} \leq \sum_{r \in \bigcup_{q \in \hat{Q}} R_q} \alpha_r \cdot P_{rt} \;\; \forall\, \hat{Q} \in \mathfrak{P}(\overline{Q}) \backslash \emptyset \,, t \in \overline{T} \tag{16}$$

$$P_{rt} \geq 0 \quad \forall\, r \in \overline{R} \,, t \in \overline{T} \tag{17}$$

Model VIII:

$$\sum_{t \in \overline{T}} \sum_{q \in \overline{Q}} \sum_{r \in R_q} w_r \cdot AP_{rqt} \to \min! \tag{18}$$

subject to:

$$PD_{qt} = \sum_{r \in R_q} \alpha_r \cdot AP_{rqt} \;\; \forall\, q \in \overline{Q} \,, t \in \overline{T} \tag{19}$$

$$\sum_{q \in Q_r} AP_{rqt} \leq \overline{P}_{rt}^{opt} \;\forall\, r \in \overline{R} \,, t \in \overline{T} \tag{20}$$

$$AP_{rqt} \geq 0 \;\; \forall\, r \in \overline{R}, q \in Q_r \,, t \in \overline{T} \tag{21}$$

While in this case the deduction of the optimal solution is very simple, the next case, where the productivity factors depend on the skills of the employees and on the activity types, is more complicated. In dynamic situations, the personnel can be computed by calculating the following equation:

$$P_{rt} = \sum_{t'=1}^{t} (h_{rt'} - f_{rt'}) \ \forall\, r \in \overline{R}\,, t \in \overline{T} \tag{22}$$

with $h_{rt} :=$ number of employees of type *r* hired at the beginning of period *t*

$f_{rt} :=$ number of employees of type *r* fired at the beginning of period *t*

If neither hiring nor firing of employees leads to any cost, we can generate the solution by application of an extended version of Model VI (Model IX). The following equation serves as an upstream check criterion:

$$\overline{P}^{*}_{rt} = \sum_{q \in Q_r} \frac{1}{\alpha_{rq}} \cdot PD_{qt} \quad \forall\, r \in \overline{R}\,, t \in \overline{T} \tag{23}$$

Model IX:

$$\sum_{t \in \overline{T}} \sum_{q \in \overline{Q}} \sum_{r \in R_q} w_r \cdot AP_{rqt} \rightarrow \min! \tag{18}$$

subject to (21) and:

$$PD_{qt} = \sum_{r \in R_q} \alpha_{rq} \cdot AP_{rqt} \ \forall\, q \in \overline{Q}\,, t \in \overline{T} \tag{24}$$

$$\sum_{q \in Q_r} AP_{rqt} \leq \min\left(\overline{P}^{*}_{rt}, H^{max}_{rt}\right) \ \forall\, r \in \overline{R}, t \in \overline{T} \tag{25}$$

If $\overline{P}^{*}_{rt} \leq \sum_{t'=1}^{t} H^{max}_{rt'}$ for any *r* and for any *t*, the regarding constraint (25) is redundant (see (14) in Model VI). Computing the following equation

$$\sum_{q \in Q_r} AP_{rqt} = P_{rt} \ \forall\, r \in \overline{R}, t \in \overline{T} \tag{26}$$

we get the optimal personnel. But in situations where hiring and firing incur costs, this multistep process can generate optimal personnel only by accident, because neglecting costs synchronizes personnel and personnel demands. This implies that this type of sequentialization is unsuitable for such situations. Then we must either use the explicit approach in the original version or the powerful concept of fuzzy sets, where the productivity factors α_{rq} are transformed into fuzzy factors $\tilde{\alpha}_r$.

2.3 Hierarchical structured models in fuzzy situations

2.3.1 Introduction

2.3.1.1 Basics

In real situations the decision maker often has to deal with a fuzzy environment, that is fuzzy data (terminological vagueness) and fuzzy relations (relational vagueness) must be processed. Due to this we construct personnel planning models in situations by the above mentioned assumptions, but no more in the deterministic case.

A fuzzy set is defined as follows (Zadeh 1965, Zimmermann 1987): If $\overline{X} = \{x | x = 1, \ldots, X\}$ is a classical set, then a fuzzy set $\widetilde{A}$ in $\overline{X}$ is a set of ordered pairs:

$$\tilde{A} = \left\{\left(x, \mu_{\tilde{A}}(x)\right) | x \in \overline{X}\right\} \quad \text{with } \mu_{\tilde{A}}: \overline{X} \to \mathbb{R}_0^+$$

$\mu_{\tilde{A}}$ is the so-called membership function, $\mathbb{R}_0^+$ is the membership space. $\mu_{\tilde{A}}(x)$ is the degree of membership of x in $\tilde{A}$. Afterwards we only use normalized fuzzy sets, which are characterized by $\mu_{\tilde{A}}(x) \in [0,1] \quad \forall\, x \in \overline{X}$.

Now we modify the situation by assuming that the personnel demands and the productivity factors (only depending on *r*) are fuzzy data. We also assume, that both are defined as so-called flat fuzzy numbers (fuzzy intervals) of *LR*-type (Dubois/Prade 1978). This assumption is usually made in literature, because the computation of this type of fuzzy intervals is very easy (Rommelfanger 1989a, 1989b). We now define the following symbols:

$\widetilde{PD}_q = \left(\underline{PD}_q; \overline{PD}_q;\ \underline{\beta}_q; \overline{\beta}_q\right) :=$ fuzzy personnel demand of type $q \in \overline{Q}$; $\underline{PD}_q$ $\left(\overline{PD}_q\right)$ is the left (right) support point on the $1-$ membership level; $\underline{\beta}_q$ $\left(\overline{\beta}_q\right)$ is the left (right) spread (*LR*-fuzzy interval) [6]

$\tilde{\alpha}_r = \left(\underline{\alpha}_r; \overline{\alpha}_r;\ \underline{a}_r; \overline{a}_r\right) :=$ fuzzy productivity factor of employee type $r \in \overline{R}$; $\underline{\alpha}_r$ $(\overline{\alpha}_r)$ is the left (right) support point on the $1-$ membership level; $\underline{a}_r(\overline{a}_r)$ is the left (right) spread

[6] The degree of membership between the supporting values is 1. Below and above the spreads it's 0.

(LR-fuzzy interval)

x_{PD_q} ≔ Characteristic of personnel demand PD_q

$\mu_{\widetilde{PD}_q}$ ≔ Membership function of fuzzy personnel demand of $\widetilde{PD}_q$

x_{α_r} ≔ Characteristic of productivity factor α_r

$\mu_{\tilde{\alpha}_r}$ ≔ Membership function of fuzzy productivity factor $\tilde{\alpha}_r$

The membership functions may be visualized graphically as follows:[7]

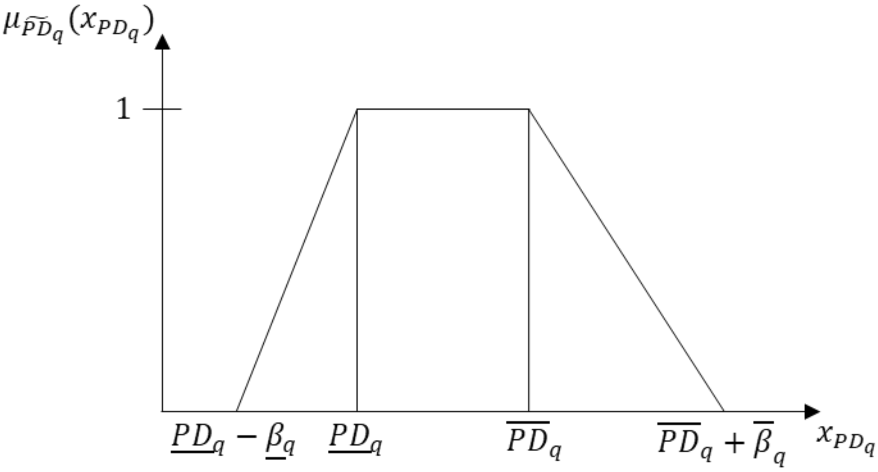

Figure 2: Membership function $\mu_{\widetilde{PD}_q}$

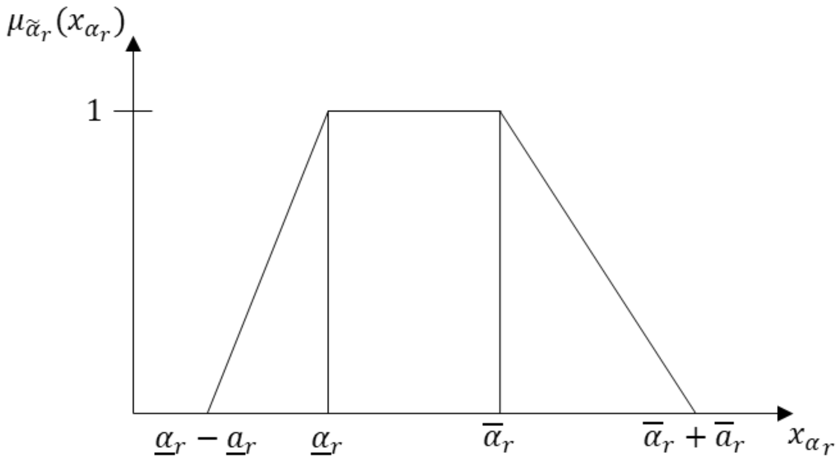

Figure 3: Membership function $\mu_{\tilde{\alpha}_r}$

[7] For the sake of simplicity we only use fuzzy sets with linear membership functions in the present paper (Garcia-Aguado/Verdegay 1993, Rommelfanger 1990).

In the described situation we have to solve Model X, which is based on the fuzzy explicit approach. A suitable fuzzy implicit procedure doesn't exist, because it would lead to a valid and optimal personnel assignment-plan only by accident.

Model X:

$$\sum_{q\in\overline{Q}}\sum_{r\in R_q} w_r \cdot AP_{rq} \rightarrow \text{min!} \tag{7}$$

subject to: (2), (6) and

$$\widetilde{PD}_q \cong \sum_{r\in R_q} \tilde{\alpha}_r \cdot AP_{rq} \;\; \forall\, q \in \overline{Q} \tag{27}$$

To process constraint (27) we have to replace it by (27a) and (27b):

$$\widetilde{PD}_q \;\widetilde{\leqq}\; \sum_{r\in R_q} \tilde{\alpha}_r \cdot AP_{rq} \;\; \forall\, q \in \overline{Q} \tag{27a}$$

$$\widetilde{PD}_q \;\widetilde{\geqq}\; \sum_{r\in R_q} \tilde{\alpha}_r \cdot AP_{rq} \;\; \forall\, q \in \overline{Q} \tag{27b}$$

Both constraints claim, that the fuzzy personnel demand is satisfied as well as possible. If we would generate a solution which deviates from the support values on the 1-level than we had to evaluate this deviation. In prominent fuzzy linear programming procedures this evaluation is made by constructing a 'fuzzy utility function' (Rommelfanger 1989a, 1989b). For this purpose we create two fuzzy sets denoted by $\widetilde{U}_q^{lb}$ and $\widetilde{U}_q^{ub}$. Their membership functions are denoted by

$\mu_{\widetilde{U}_q^{lb}}\left(\sum_{r\in R_q} \underline{\alpha}_r \cdot AP_{rq}\right)$ and $\mu_{\widetilde{U}_q^{ub}}\left(\sum_{r\in R_q} \overline{\alpha}_r \cdot AP_{rq}\right)$.

They are expressions for the evaluation of utility in the case, that the personnel demand is satisfied by the quantity $\sum_{r\in R_q} \underline{\alpha}_r \cdot AP_{rq}$ resp. $\sum_{r\in R_q} \overline{\alpha}_r \cdot AP_{rq}$. We now define

$$g_q^{lb} \coloneqq \sum_{r\in R_q} \underline{\alpha}_r \cdot AP_{rq}$$

$$g_q^{ub} \coloneqq \sum_{r\in R_q} \overline{\alpha}_r \cdot AP_{rq}$$

$d_q^{lb}, d_q^{ub} \coloneqq$ deviation tolerance parameters chosen by the decision maker, with $d_q^{lb} \leq \underline{\beta}_q$ and $d_q^{ub} \leq \overline{\beta}_q$

$$\mu_{\tilde{U}_q^{lb}}\left(g_q^{lb}\right) = \begin{cases} 0 & \text{if } g_q^{lb} < \underline{PD}_q - d_q^{lb} \\ \dfrac{g_q^{lb} - \left(\underline{PD}_q - d_q^{lb}\right)}{d_q^{lb}} & \text{if } \underline{PD}_q - d_q^{lb} \leq g_q^{lb} < \underline{PD}_q \\ 1 & \text{if } \underline{PD}_q \leq g_q^{lb} \end{cases}$$

If $\sum_{r \in R_q} \underline{\alpha}_r \cdot AP_{rq}$ is higher than or equal as (smaller than) $\underline{PD}_q$ $\left(\underline{PD}_q - d_q^{lb}\right)$, this leads to complete (none) satisfaction of the decision maker (at all).

$$\mu_{\tilde{U}_q^{ub}}\left(g_q^{ub}\right) = \begin{cases} 0 & \text{if } g_q^{ub} > \overline{PD}_q + d_q^{ub} \\ 1 - \dfrac{g_q^{ub} - \overline{PD}_q}{d_q^{ub}} & \text{if } \overline{PD}_q + d_q^{ub} \geq g_q^{ub} > \overline{PD}_q \\ 1 & \text{if } \overline{PD}_q \geq g_q^{ub} \end{cases}$$

If $\sum_{r \in R_q} \overline{\alpha}_r \cdot AP_{rq}$ is smaller than or equal as (higher than) $\overline{PD}_q$ $\left(\overline{PD}_q + d_q^{ub}\right)$, this leads to complete (none) satisfaction of the decision maker (at all).

Each constraint of type (27a) ((27b)) is now replaced by a new constraint (28) ((30)) and by a goal (29) ((31)):

$$\sum_{r \in R_q} \left(\underline{\alpha}_r - \underline{a}_r\right) \cdot AP_{rq} \geq \underline{PD}_q - \underline{\beta}_q \quad \forall\, q \in \overline{Q} \tag{28}$$

$$\mu_{\tilde{U}_q^{lb}}\left(\sum_{r \in R_q} \underline{\alpha}_r \cdot AP_{rq}\right) \to \max! \tag{29}$$

$$\sum_{r \in R_q} \left(\overline{\alpha}_r + \overline{a}_r\right) \cdot AP_{rq} \leq \overline{PD}_q + \overline{\beta}_q \qquad \forall\, q \in \overline{Q} \tag{30}$$

$$\mu_{\tilde{U}_q^{ub}}\left(\sum_{r \in R_q} \overline{\alpha}_r \cdot AP_{rq}\right) \to \max! \tag{31}$$

Now we can replace Model X with the Multi-objective Optimization Model XI:

Model XI:

$$\begin{pmatrix} -\left(\sum_{q\in\overline{Q}}\sum_{r\in R_q} w_r \cdot AP_{rq}\right) \\ \mu_{\tilde{U}^{lb}_{q=1}}\left(\sum_{r\in R_1} \underline{\alpha}_r \cdot AP_{r1}\right) \\ \vdots \\ \mu_{\tilde{U}^{lb}_{q=Q}}\left(\sum_{r\in R_Q} \underline{\alpha}_r \cdot AP_{rQ}\right) \\ \mu_{\tilde{U}^{ub}_{q=1}}\left(\sum_{r\in R_1} \overline{\alpha}_r \cdot AP_{r1}\right) \\ \vdots \\ \mu_{\tilde{U}^{ub}_{q=Q}}\left(\sum_{r\in R_Q} \overline{\alpha}_r \cdot AP_{rQ}\right) \end{pmatrix} \to \max! \tag{32}$$

subject to (2), (5), (6), (28), (30)

2.3.1.2 Preparatory models

To generate an optimal compromise solution of Model XI[8], not the objective function (7), but a corresponding utility assessment of the decision maker is used. For this purpose we define the fuzzy set $\tilde{G} = \{(w, \mu_{\tilde{G}}(w))\}$ of satisfying values of (7) (denoted by w). First, we solve two preparatory models (XII and XIII). Model XII leads to the absolute best solution $\underline{w}$ and Model XIII to the absolute worst solution $\overline{w}$:

Model XII:[9]

$$\sum_{q\in\overline{Q}}\sum_{r\in R_q} w_r \cdot AP_{rq} \to \min! \tag{7}$$

subject to (2), (5), (6), (28), (30)

Model XIII:[10]

$$\sum_{q\in\overline{Q}}\sum_{r\in R_q} w_r \cdot AP_{rq} \to \min! \tag{7}$$

[8] Here we use the algorithm FULPAL by Rommelfanger (1989a,1989b, 1990).
[9] See the example in the appendix.
[10] See the example in the appendix.

subject to (2), (5), (6), (28), (30) and

$$\sum_{r \in R_q} \underline{\alpha}_r \cdot AP_{rq} \geq \underline{PD}_q \quad \forall\, q \in \overline{Q} \tag{33}$$

$$\sum_{r \in R_q} \overline{\alpha}_r \cdot AP_{rq} \leq \overline{PD}_q \quad \forall\, q \in \overline{Q} \tag{34}$$

Since Model XIII is more restrictive than Model XII, the relation $\underline{w} \leq \overline{w}$ is valid.

2.3.1.3 Compromise solution

In Model X, we aim to achieve three goals ((7), (29), (31)) simultaneously. This implies the search for a compromise solution if these three goals are in conflict. By applying Models XII and XIII, we obtain reference points for possible wage costs. Solutions that result in costs that are lower (higher) than $\underline{w}$ ($\overline{w}$) lead to complete (to none) satisfaction of the decision maker (at all). Now we can define the membership function for $\tilde{G}$ as follows:

$$\mu_{\tilde{G}}(w) = \begin{cases} 0 & \text{if } w > \overline{w} \\ 1 - \dfrac{w - \underline{w}}{\overline{w} - \underline{w}} & \text{if } \underline{w} \leq w \leq \overline{w} \\ 1 & \text{if } w < \underline{w} \end{cases}$$

With reference to the relevant literature (Bellman/Zadeh 1970, Negoita/Sularia 1976) the compromise model is shaped as follows, where λ denotes the compromise value, which is normalized from 0 to 1 (λ is the minimum utility):

Model XIV:[11]

$$\lambda \rightarrow \max! \tag{35}$$

subject to (2), (5), (6), (28), (30) and

$$\lambda \leq \mu_{\tilde{G}}(w) \tag{36}$$

$$\lambda \leq \mu_{\tilde{U}_q^{lb}}\left(\sum_{r \in R_q} \underline{\alpha}_r \cdot AP_{rq}\right) \quad \forall\, q \in \overline{Q} \tag{37}$$

$$\lambda \leq \mu_{\tilde{U}_q^{ub}}\left(\sum_{r \in R_q} \overline{\alpha}_r \cdot AP_{rq}\right) \quad \forall\, q \in \overline{Q} \tag{38}$$

[11] See the example in the appendix.

$$\lambda \geq 0 \tag{39}$$

With reference to the membership functions mentioned above we can substitute (36), (37) and (38) by (40), (41) and (42):

$$\left(\overline{w} - \underline{w}\right) \cdot \lambda + \sum_{q \in \overline{Q}} \sum_{r \in R_q} w_r \cdot AP_{rq} \leq \overline{w} \tag{40}$$

$$d_q^{lb} \cdot \lambda - \sum_{r \in R_q} \underline{\alpha}_r \cdot AP_{rq} \leq -\left(\underline{PD}_q - d_q^{lb}\right) \quad \forall\ q \in \overline{Q} \tag{41}$$

$$d_q^{ub} \cdot \lambda + \sum_{r \in R_q} \overline{\alpha}_r \cdot AP_{rq} \leq \overline{PD}_q + d_q^{ub} \quad \forall\ q \in \overline{Q} \tag{42}$$

2.3.2 Hierarchical structures

Of course, the insights from section 2.2.3.1 can also be used to exploit hierarchically structured models in fuzzy situations. The size of Models XII and XIII and the size of Model XIV can be reduced by applying an adapted checking criterion. To derive the worst-case personnel, one calculates equation (43), which is similar to equation (12):

$$\overline{P}_r^* = \sum_{q \in Q_r} \frac{1}{\underline{\alpha}_r - \underline{a}_r} \cdot \sum_{q \in \overline{Q}} \left(\underline{PD}_q - \underline{\beta}_q\right) \quad \forall\, r \in \overline{R} \tag{43}$$

Instead of constraint (2), one can then use constraint (14) in Models XII, XIII, and XIV. If the expression '$\underline{\alpha}_r - \underline{a}_r$' in equation (43) is replaced by '$\underline{\alpha}_{rq} - \underline{a}_{rq}$', the procedure can also be used in situations in which the productivity factors also depend on q. Moreover, fuzzy sets can be usefully applied in the dynamic case when the productivity factors depend on both r and q. In such situations, one is able to construct fuzzy coefficients $\tilde{\alpha}_{rq}$. With these, one can then also apply the implicit method in a first step and the explicit method in a second step.

3 Leadership

3.1 Basics of leadership

3.1.1 Preliminary remarks

The functionality problem is about creating and ensuring the effectiveness of personnel. This lies in the production and safeguarding of the functionality of personnel, and to solve it, the behavior of the workforce must be adequately controlled. In addition to self-control (which is only effective to a limited extent) by the employees, three variants of external control can be considered for controlling behavior. One of these variants is the determination of organizational measures, a second is the so-called informal leadership. This is carried out by persons who are not (officially) designated and appointed as supervisors by management, but who are accepted (informally) by one or more employees as (secret) leaders. The third variant is leadership. While organizational measures are of a structural nature, leadership measures are dispositive or situational measures. They are taken by the supervisor in concrete action situations, who must observe the organizational framework structure. In companies, neither organization nor leadership can be dispensed with. Both sets of measures can be substituted for each other, but not in their entirety. Thus peripheral substitutionality is present. Thus it is valid that with increasing degree of organization of an enterprise - even if in borders - one can do without leadership increasingly and vice versa. We define leadership as a complex of measures which are intended by supervisors (and not carried out by chance) in order to influence the work behavior of their subordinate employees in the interest of the company. In the course of leadership, social interaction processes take place in which both parties influence each other. However, we only count the actions of the supervisor as leadership; he or she has the greater power compared to his subordinates and only he or she is legitimized to issue instructions to them (and not vice versa).

3.1.2 Effective, efficient and optimal leadership

Business management decisions are required not only to be rational and legitimate, but also effective and, ideally, efficient and optimal. This naturally also applies to leadership when viewed from an economic perspective.

Effectiveness goes back to the Latin word “effectivus” (effecting) and ultimately refers to the achievement of goals or the degree to which goals are achieved, neglecting input-output ratios. Effectiveness is defined as the suitability of a means to contribute to the achievement of a set goal. For example, if a supervisor leads his or her employees by granting incentive *A* or incentive *B* in such a way that they meet the set behavioral norms, then both incentives are effective with respect to the goal of norm compliance. If the above definition is interpreted narrowly, the degree of goal achievement is only recorded dichotomously, i.e. the set goal is either achieved or not achieved. If one wants to measure the degree of goal achievement in numbers, then it is, for example, equal to one in the first case and zero in the second. However, if the above definition of effectiveness is interpreted less narrowly, then degrees of goal achievement between perfect goal achievement and perfect non-achievement of the goal can also be specified (e.g., in the amount of 0.2 or 0.7). The narrow interpretation of the term means that a decision is either effective or not effective, there is nothing in between. A broad interpretation, on the other hand, allows measures to be ranked in terms of effectiveness in a more finely graded order. For example, measure *A* can be characterized as not very effective, measure *B* as moderately effective and measure *C* as very effective. In this case there are thus gradation forms for the effectiveness term (effective, more effective, most effective).

To assess effectiveness, the relationship between actual output (AO) and targeted output (TO) is evaluated. If $AO < TO$, the measure is ineffective; if $AO \geq TO$ it is effective. This relation can be measured as a function of a difference or as a function of a quotient. In the first case, the effectiveness is ET:

$$ET = f(AO - TO) \text{ with } \begin{cases} ET = 0 \text{ for } AO < TO \\ ET > 0 \text{ for } AO \geq TO \end{cases}$$

and in the second case holds:

$$ET = f(AO/TO) \text{ with } \begin{cases} ET < 1 \text{ for } AO < TO \\ ET \geq 1 \text{ for } AO \geq TO \end{cases}$$

Since the actual output can in principle also be zero (Koopmans 1951), and the division by zero is not defined, the actual output must be in the numerator in the quotient formation. Effectiveness in the narrower sense is when $ET \in \{0,1\}$, while effectiveness in the broader sense is $ET \in [0,1]$.

Effectiveness is oriented only to the achievement of a given goal (output). Efficiency, on the other hand, takes into account not only the output *O* but also the input *I*. Efficiency *EC* is then measured as the input-output ratio: A measure is efficient if, for a given input, the output is maximized and no input is wasted (maximum principle). A measure is also efficient if a given output is achieved with a minimum input and no output is wasted (minimum principle). From these two definitions, it follows that a measure is efficient if there is no other measure that achieves the same or more output with less or the same input. It also holds that a measure is efficient if it is not dominated by any other measure. Dominant measures are efficient and dominated measures are inefficient. These considerations apply both when inputs and outputs are valued only at the quantity level and when they are valued (e.g., with prices, units of utility, etc.), i.e., enter the calculus at the value level. The concept of efficiency can also be interpreted more narrowly or more broadly. With a narrow interpretation of the term, a measure is either efficient or not efficient (inefficient) and it exists if $EC \in \{0,1\}$. In the case of efficiency in a broader sense, this can be graduated, and the following applies: $EC \in [0,1]$.

Let us return to the above example, first of all for the narrow definition of efficiency: If the manager achieves the same degree of compliance with the standard by the employees using both incentive *A* and incentive *B*, but incentive *A* is more cost-effective than incentive *B*, then according to the minimum principle the use of incentive *A* as opposed to incentive *B* is efficient. If, however, both incentives incur the same costs and incentive *B* results in a higher level of compliance than incentive A, then the efficiency ratio is reversed according to the maximum principle.

Following the definitions of effectiveness and efficiency, we will now turn to their relationship. In principle, effective measures can be efficient or inefficient. Ineffective measures, on the other hand, cannot be efficient; they are always inefficient, no matter which interpretation of the term is used. This is justified as follows: If a measure is completely ineffective, its degree of target achievement (output) is zero. If this is put in relation to the input, the result is always inefficiency. Thus, effectiveness is always the necessary prerequisite for efficiency. However, if the concept of effectiveness is interpreted broadly, less effective measures (i.e. those that are neither completely effective nor completely ineffective) can also be efficient.

We have established above that a measure is efficient if it is not dominated by any other measure, i.e. if there is no other measure that leads to higher output with the same input (maximum principle) or that produces the same output with lower input (minimum principle). This relationship is explained graphically in figure 4:

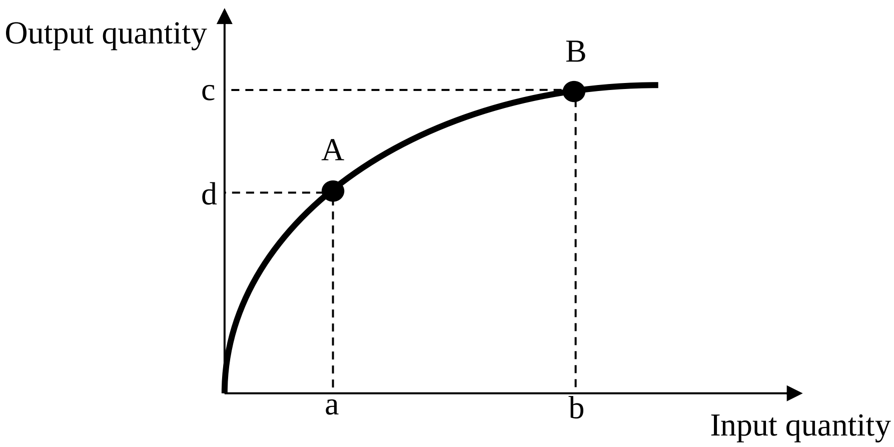

Figure 4: Efficiency line

In this graph, input is plotted on the abscissa and output on the ordinate, each measured in units of quantity. If we compare points A and B, we can see that the input quantity at point A is lower than at point B, while the output quantity at point B is higher than at point A. If you want to increase the output quantity from d to c, the input quantity increases from a to b. If you want to reduce the input quantity from b to a, the output quantity decreases from c to d. The bold line represents the so-called efficiency line. All points along this line are (equally) efficient, all points below are inefficient. Compared to the points on the efficiency line, they produce a lower output for a given input and require a higher input for a given output. We call such constellations dominated, the points along the efficiency line dominant or efficient.

At the end of this section, we would like to talk about the concept of optimality, in distinction to efficiency. The Latin word “optimum” means the best. The optimum can be either the smallest (minimum) or the largest (maximum) or, in other words, the best (optimal) solution is always either the smallest (minimum) input or the largest (maximum) output. Now what does this mean for the relationship between optimality and efficiency? We have seen above that all points along the efficiency line are (equally) efficient. However, it is possible that only one of them is optimal. For this to be the case, we need to introduce an additional criterion. In the example of figure 4, we then no longer only consider the respective quantities, but multiply them by their respective prices and thus arrive at the revenues (output) and costs (input). It may then turn out that among all the efficient points only one turns out to be revenue maximum or cost minimum. This means in the generalization that efficient measures can be optimal (but do not have to be), optimal solutions however are necessarily efficient. Nevertheless, not always only one point on the efficiency line has to be the optimal one. There are definitely cases in which several (to the same extent) optimal solutions are also available.

The effects of leadership on the profit of the company are predominantly partial and indirect. This means on the one hand that there are other operational measures (e.g. from the areas of procurement, production and marketing) which also have an effect on profit. In addition leadership affects predominantly over several further factors and not directly on the profit. This leads both to the fact that one can measure the profit emanating from leadership instruments usually only over substitute criteria.

3.1.3 Instruments of leadership

Leadership is a complex of instruments, including measures of (a) behavioral guidance, (b) behavioral evaluation and (c) behavioral compensation, which in turn can be differentiated into various individual instruments. Their choice depends on the instruction, motivation, qualification and preparation of the employees.

To (a): The individual instruments of behavioral guidance include (a1) the specification of behavioral norms, (a2) the enabling (prevention) and the support (hindrance) of behavior, and (a3) the communication of control and incentive perspectives. To (a1): Through (functional) behavioral norms, supervisors express their ideas about how employees should behave in completing tasks. There is a wide range of differentiation possibilities in the scientific literature, including the distinction between implicit and explicit norms. In the case of explicit behavioral norms, the employee is explicitly told how he or she should behave, so that he or she is not given any leeway in decision-making. In the case of implicit behavioral norms, on the other hand, the employee is merely given a goal and has to decide for himself or herself how he or she wants to achieve this goal. To (a2): The behavior of the employee can be enabled and supported by the supervisor in positive cases and hindered and prevented in negative cases. Enabling behavior includes, among other things, providing resources and information. In the case of behavioral support, the supervisor can, for example, provide helpful tips for solving problems. It does not take much imagination for one to envision corresponding condrance and hindrance tools. To (a3): In the course of behavioral guidance, there is not yet any control or stimulation. Nevertheless, appropriate perspectives must already be granted here, because if the employee were not given the prospect of incentives, he or she would not become active for the company and if he or she were not told that he or she would have to reckon with controls in the course of completing his or her tasks, there would be a danger of uncontrolled and collusive behavior. In the context of behavioral guidance, target-theoretical approaches (Locke et al. 1981) are relevant, among others.

To (b): By directing behavior, the supervisor formulates a behavioral target for the employee. In the context of behavioral evaluation, this targeted behavior is compared with the actual behavior. Such a target/actual comparison can result in the target and actual being the same or deviating from each other. In the event of such deviations, the supervisor must assess their significance and the relevant causes must be identified and attributed to the causers. Particularly in the case of negative target/actual deviations, the concept of behavior guidance must be reviewed and possibly corrected in order to avoid such deviations in the future. In the context of behavioral evaluation, attribution theory approaches (Weiner 1985) are relevant, among others.

To (c): The third set of measures is for behavioral compensation. It is therefore a matter of rewarding or punishing the employee in accordance with the behavioral evaluation. To this end, (positive and negative) incentives must be formulated and granted, and incentive criteria (measurement bases) and criterion-incentive relations must be constructed and applied. In the context of behavioral compensation, neo-institutionalist, agency theory and equity theory approaches are relevant (Adams 1965, Akerlof 1970, Coase 1937, Demsetz 1967, Pratt/Zeckhauser 1985, Ross 1973, Shavell 1979, Williamson 1975).

The following figure 5 shows the described relationships graphically. The dashed lines represent feedback loops. They indicate that, based on the respective results of behavioral evaluation and behavioral compensation, modified control measures can be taken in a next guidance sequence in the course of the steering concept. This is important, for example, if the supervisor determines in connection with the deviation analysis that the behavioral standards he or she set were too imprecise or not comprehensible to the employees. Behavior guidance, evaluation and compensation trigger pulse, control and incentive expectations on the part of the employee. At the same time, the supervisor also has corresponding expectations, so that the leadership instruments cause personnel behavior and the personnel behavior determines the supervisor's choice of instruments.

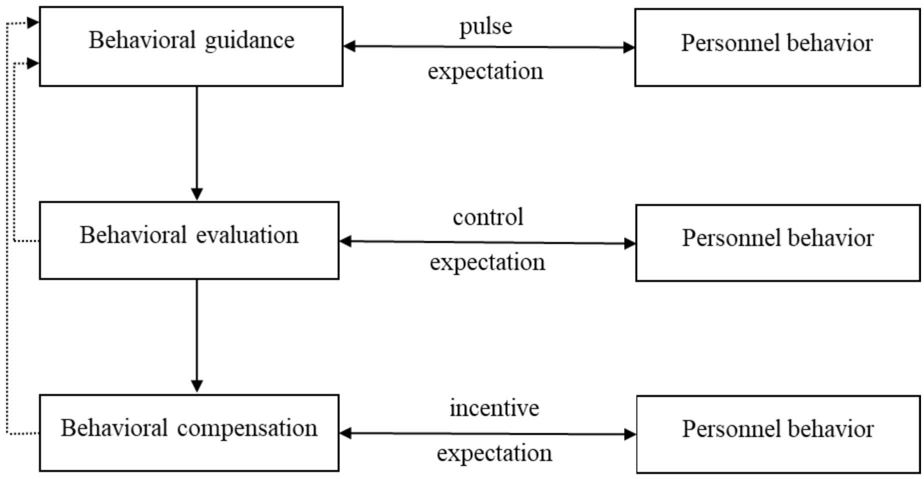

Figure 5: Measures for influencing personnel behavior

3.1.4 Legitimation bases of leadership

As already outlined above, leadership represents an intended and (at least positionally) legitimized behavioral influence based on interaction in order to achieve predefined organizational goals.

Although in many contexts an intended exertion of influence by one person on another can be interpreted as negative manipulation, in the context of leadership the use of power in the sense of an intended, social exertion of influence is legitimized insofar as it serves the achievement of corporate goals. Thus, there is an unequal distribution of influence or an excess of influence on the part of a supervisor between supervisor and employee. However, since on the one hand the unequal distribution is recognized by both parties and thus a consensus exists in this regard and on the other hand there is a necessity or expediency of the influence, we speak of a legitimacy basis of personnel behavior influence by the leadership behavior of a supervisor (French/Raven 1959). In this context, Weber (1947) distinguishes between different bases of legitimacy, each of which justifies the exercise of power. These include traditional authority, bureaucratic authority, and charismatic authority. The traditional Weberian conception is subsequently developed further by French & Raven (1959), Katz & Kahn (1966), Peabody

(1964) and Presthus (1963) and among others, by distinguishing between (a) positional authority, (b) functional authority and (c) personal authority.

To (a): positional authority is also called official authority and is equivalent to bureaucratic authority according to Weber (1947). The ones influenced recognize the rules and norms of the influencers because there is a need or interdependence, as is classically the case in companies between supervisors and employees.

To (b): Functional authority is also referred to as specialist authority, as the recognition of the surplus of influence is based on a higher, specific expertise. However, this professional superiority can regularly be called into question, so that this type of authority must always be reacquired.

To (c): Personal authority is very similar to the charismatic authority concept according to Weber (1947). On the basis of a person's integrity of character and exemplary character, this person's influence potential is recognized and his or her influence actions are accepted.

For leadership, the legitimation basis of positional authority is fundamental. It is used to pursue the goal of influencing employees in such a way that corporate goals can be achieved effectively and efficiently. However, functional and personal authority can also be effective.

3.2 Selected conceptions of leadership

3.2.1 Preliminary remarks

The concepts of leadership include (a) so-called management by ... concepts and (b) models of leadership style selection.

To (a): The so-called management by ... concepts postulate leadership principles aimed at effectiveness and thus recommendations for action to supervisors. The list of these often trivial and deficiently operationalized concepts (such as management by exception, by delegation, by results, by communication) is quasi infinite, a differentiated elaborated and serious concept, however, is the so-called Management by Objectives (MbO). This was introduced into the literature by Drucker (1954). Later, Odiorne (1973) and Humble (1973) were responsible for the widespread use of this concept in science and business practice. MbO means leading with goals. In the authoritarian variant of the concept, it is about leading by setting goals. However, we want to outline the participative variant here, in which the goals are not simply given to the employee, but are agreed with him or her in the course of a negotiation process.

The MbO process has three core stages: In the first stage, both parties (separately) make a preliminary selection of possible performance and development targets. In this process, the supervisor is guided by the overarching corporate objectives. In the second phase, which serves to guide behavior, the target agreement is negotiated (target agreement meeting). After a specified or agreed deadline has expired, the third phase follows, which serves to evaluate the objectives. In this phase, the extent to which the objectives have been achieved is reviewed (behavioral evaluation). In addition, consequences are derived (including behavioral compensation) and the process begins again.

In the course of agreeing on objectives, the supervisor and the employee agree on at least one common objective. As a rule, however, this is a system of objectives consisting of several main objectives, which may have to be broken down into various sub-objectives and for which it is necessary to define series (keyword: prioritization in terms of time) and ranking relationships (keyword: preference in terms of content). It is advisable to carefully balance the target system and to define it in writing. In addition, the SMART rule derived from the goal theory of Locke et al. (1981) should be applied: SMART is an acronym for "Specific-Measurable-Achievable-Relevant-Timely" and thus postulates requirements for meaningful target agreements.
This is based on the following considerations: If goals lack sufficient specificity and operationalization, this leads to orientation problems for the actors. If goals are not sufficiently measurable, no (sufficiently) precise degree of goal achievement can be determined ex post, which leads to difficulties in compensating for behavior. A lack of specificity and measurability of goals can also lead to hiding behind the openness of the goal formulation, to pretending to have achieved a goal that has not in fact been achieved, or to leaving the achievement of the goal to others (keyword: free-rider behavior). Furthermore, only ambitious goals lead to satisfactory performance motivation and unrealistic goals will be abandoned sooner or later (keyword: "fighting windmills"). If no clear deadlines are set or agreed for the desired achievement of (interim) goals, there is a risk of arbitrariness in terms of time and thus of dawdling, delaying or procrastinating in the achievement of goals.

To (b): By leadership style we mean the way in which supervisors guide, evaluate and compensate their employees - in short: influence them. On the one hand, a leadership style can represent a personality trait of the supervisor, whereby it is assumed that the manager has a leadership style and therefore leads his or her employees in a corresponding (recurring) manner regardless of various situational factors. On the other hand, the leadership behavior pattern can also (and this is the idea we are discussing here) be defined as situationally selectable (and not as a personality constant). In this case, a supervisor decides, depending on the situation, which leadership style to apply in order to effectively influence his or her employees. There is no finite number of selectable leadership styles. Rather, there are different dimensions by which leadership styles can be described and agglomerated. In so-called one-dimensional leadership style concepts, leadership styles are differentiated on a bipolar continuum. This includes, for example, differentiation according to the participation rate, whereby a distinction is made between authoritarian and participative leadership styles. In the relevant literature, there are often so-called pairs of opposites between which leadership behavior can be localized: These include, for example, the conceptual pairs autocratic and democratic as well as authoritarian and cooperative. Tannenbaum & Schmidt (1958), Likert (1967) and Vroom (1959, 1964) present corresponding one-dimensional considerations for the classification and choice of a leadership style. Tannenbaum & Schmidt differentiate seven leadership styles (from the sole decision of the supervisor to the group decision with limited leeway for decision-making) and Likert distinguishes four different leadership styles on a continuum from strongly setting the tone (autoritative leadership style) to cooperative (participative leadership style).

In multidimensional leadership style concepts, (at least) two dimensions that are regarded as independent are used for differentiation. This view is based primarily on the results of the Ohio State Leadership Studies (Halpin 1957, Stogdill 1963, Stogdill/Coons 1957). In the course of these studies, a large number of independent dimensions were first identified. These included group behavior, company-related characteristics, economic, social, and political environmental factors, and task orientation (concern for production) and relationship orientation (concern for people) (Shartle 1979, Stogdill/Coons 1957). Further research and factor analyses in the Ohio State Leadership Studies subsequently reveal two clearly dominant dimensions in the form of task orientation and relationship orientation. According to the results of the Ohio State Leadership Studies, these two dimensions are orthogonally related to each other. Their assumed independence is undoubtedly debatable, but will not be further problematized in this paper. In task orientation, the focus of leadership behavior is on the fulfillment of factual tasks. The supervisor tells the employees what, when, where and how they should do something. He or she sets their goals and defines their areas of responsibility. Another characteristic of a strongly pronounced task orientation is the focus on the structured and efficient completion of various activities to achieve the company's goals. Relationship orientation, on the other hand, refers among other things to two-way communication, including listening and support from the manager, but also to human warmth in the leadership process. It is characterized, for example, by consideration for the individual preferences and needs of employees. To operationalize task and relationship oriented leadership styles, Halpin (1957), Fleishman (1960) and Stogdill (1963), among others, develop questionnaires such as the Leadership Opinion Questionnaire (LOQ) and the Leader Behavior Description Questionnaire (LBDQ).

The scientific literature provides a wide range of basic models for leadership style selection, of which we outline four selected approaches in the following section: the managerial grid by Blake & Mouton, the situational leadership theory by Hersey & Blanchard, the 3D model by Reddin and the normative decision model by Vroom & Yetton.

3.2.2 Basic models for leadership style selection

3.2.2.1 The Managerial Grid by Blake & Mouton

Blake & Mouton (1964) design a so-called behavioral grid, which is determined by the two orthogonal main factors of the Ohio State Leadership Studies, task orientation and relationship orientation. The two authors develop a nine-level scale for each dimension and thus fan out a grid with a total of 81 different possible combinations. Of the 81 possible combinations, only five relevant ones are explained in more detail by the authors and evaluated in terms of their leadership effectiveness (see figure 6).

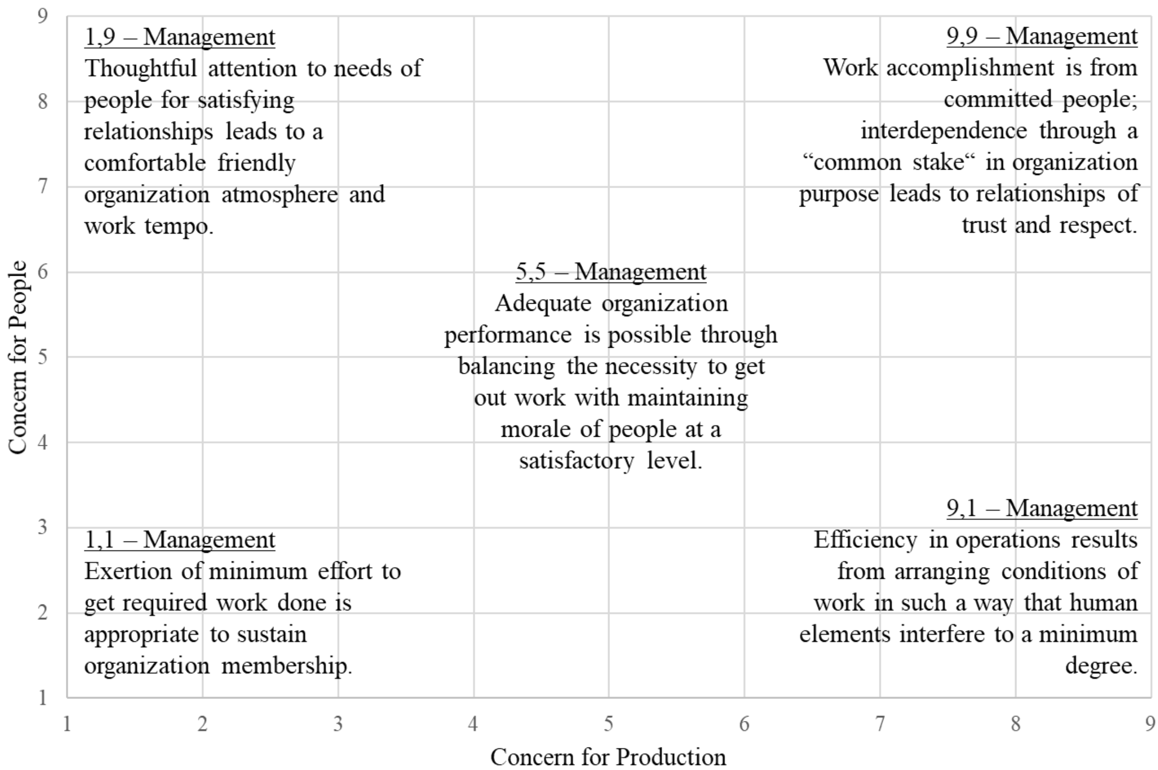

Figure 6: Managerial Grid by Blake/Mouton (1964, p. 10)

These five leadership styles are described below:

9.1-Leadership style (high task and low relationship orientation): A supervisor who practices this leadership style is referred to as an "exact task manager." While the structuring of the tasks is in the foreground with this leadership style, the optimal organization of the working conditions in the sense of the coworkers is disregarded.

1.9-Leadership style (low task and high relationship orientation): A leader who practices this management style tries to avoid decisions concerning production and the associated conflicts. He or she fears that pressure to perform can lead to resistance on the part of employees, which is why he or she prevents such pressure. Pleasant working conditions and his or her function as a role model are at the center of this management style, since the supervisor expects to gain the favor of the employees and on the basis of this the tasks are gladly completed.

1.1-Leadership style (low task and relationship orientation): This approach is rarely found in organizational situations with non-recurring actions, where each situation poses a different set of problems to be solved. It is far more common in routine operations where the situation allows for complete withdrawal of the supervisor, as is the case here.

5.5-Leadership style (medium task and relationship orientation): A supervisor who practices this leadership style avoids extremes and assumes that moderate levels of both dimensions cause a balance between effort as a leader and employee performance results, creating a more acceptable trade-off.

9.9-Leadership Style (high task and relationship orientation): In contrast to the other basic approaches, the 9.9-Leadership style assumes that there is no conflict between task completion and employee needs. The supervisor achieves an almost perfect integration of the pursuit of corporate goals and the consideration of individual employee needs.

Blake & Mouton leave little doubt as to which of these five leadership styles they prefer. The authors are clearly in favor of the 9.9-Leadership style, as it successfully combines both dimensions and thus allows the expected corporate goals to be optimally achieved while at the same time fully taking into account the concerns and needs of the employees. In the context of the 1.1-Leadership style the supervisor is said to have already resigned himself or herself to defeat and therefore not to want to exert any more effort (Blake/Mouton 1964, Blake et al. 1962). The relationship and task orientation should be chosen by the supervisor to the maximum extent possible, but are not completely independent of a specific leadership situation. Blake & Mouton (1964) postulate which leadership style should be chosen tendenially, but they also refer to organizational framework conditions and limiting circumstances, which is why it may be necessary to switch to other leadership styles.

In an extension of the original model written by Blake & Mouton (1964), the independence of the dimensions of task and relationship orientation is rejected and interdependence is assumed. Thus, the expression of one dimension (e.g., 1-9) is no longer to be considered alone, but always gains its significance in the leadership context only in combination with the respective other dimension expression. In the 9.9-Leadership style, for example, the 9 of relationship orientation stands for productive task completion in a team, while the high relationship orientation in the 1.9-Leadership style can rather be seen as a comfortable (and thus rather ineffective) working atmosphere.

In a later paper, Blake & Mouton (1985) point out that a leadership style must be chosen to suit a situation in order to achieve leadership effectiveness. As relevant influencing factors they name the organizational structure, the leadership situation, value concepts of the supervisor and the employees, personality characteristics of the supervisor as well as the knowledge about alternative leadership styles. Based on this, Blake & Mouton have extended their assumption regarding the dominance of the 9.9 style. The authors argue that every leader should be able to apply the 9.9 leadership style. However, in this context it is a leadership strategy consisting of a bundle of leadership measures which can be selected on the basis of the situation determinants, so that a maximum degree of task and relationship orientation does not have to be selected in every case.

3.2.2.2 The 3D-Model of the leadership by Reddin

Reddin (1970) is also oriented to the two dimensions of task and relationship orientation and adds a third dimension, leadership effectiveness. He concretizes and emphasizes the situational dependence of the leadership behavior to be selected. This means that no leadership style is declared to be dominant across all situations. It is therefore necessary to find the leadership style that is effective in a leadership situation. This is based on effectiveness in the narrower sense (a leadership style is therefore either effective or ineffective). Reddin formulates four basic styles (see figure 7).

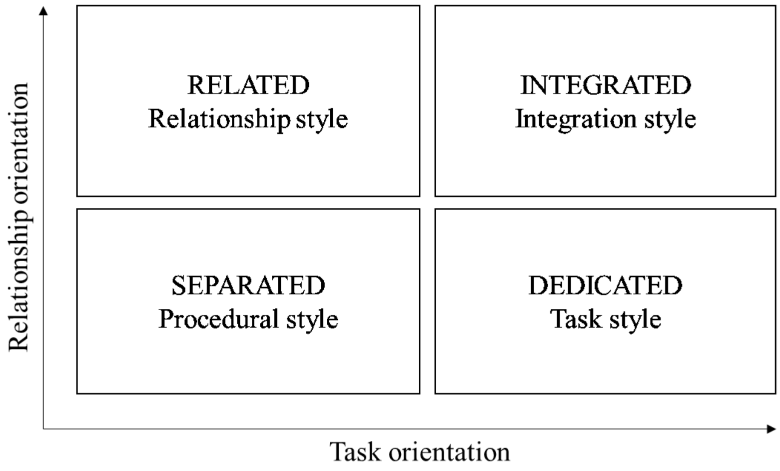

Figure 7: Basic styles by Reddin (1970, p. 12)

He distinguishes between the "procedural style" (separated, with low relationship and task orientation, corresponds to approximately 3.3 in the Managerial Grid), the "relationship style" (related, with strong relationship orientation and low task orientation, corresponds to approximately 3.7 in the Managerial Grid), the "task style" (dedicated, with a low degree of relationship orientation and a high degree of task orientation, corresponds to approximately 7.3 in the Managerial Grid), and the "integration style" (integrated, with a high degree of relationship and task orientation, corresponds to approximately 7.7 in the Managerial Grid) (Blake/Mouton 1964). These four basic styles are then assessed in terms of target extent (leadership effectiveness). In doing so, Reddin uses metaphorical language: In negative cases, the procedural style results in the behavior of a “deserter”, the relationship style in the behavior of a “missionary”, the task style in the behavior of an “autocrat”, and the integration style in the behavior of a “compromiser”. In positive cases, on the other hand, the procedural style results in the behavior of a “bureaucrat”, the relationship style in the behavior of a “developer”, the task style in the behavior of a “benevolant autocrat”, and the integration style in the behavior of an “executive”. None of the four basic styles is inherently more or less effective. The leadership situation is decisive at this point and ultimately determines whether the corresponding leadership style applied is effective (see figure 8).

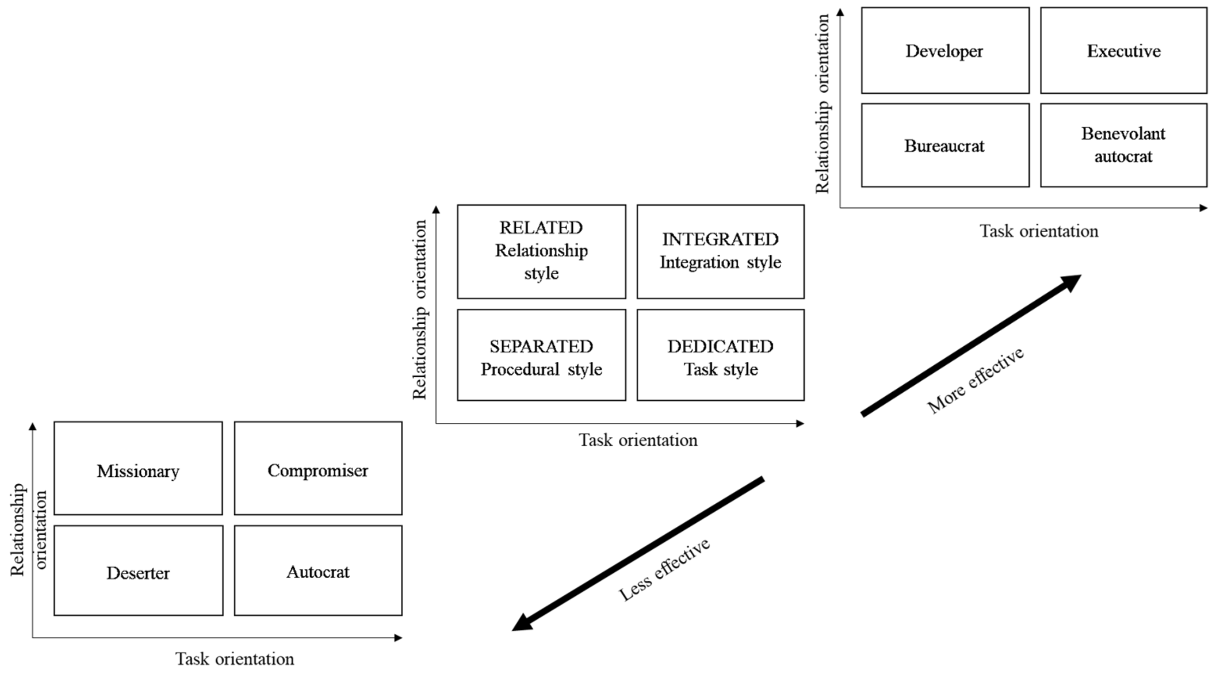

Figure 8: Adding the third dimension "effectiveness" following Reddin (1970, p. 13)[12]

A leader who opts for the procedural style initially relies on existing and established methods and processes in the company and prefers stable environmental situations. As a "bureaucrat", he or she masters routine processes, follows rules and orients himself or herself to organizational guidelines. In contrast, the procedural style is described negatively in the form of a "quitter" ("deserter") who meticulously insists on rules and does not disregard regulations even when a situation makes it urgently necessary.

A supervisor who is strongly relationship-oriented and hardly task-oriented (integrative style) places a lot of value on interpersonal relationships and on taking employees' wishes into account. If this leadership behavior is selected in a situation-specific manner, Reddin (1970) speaks of a "developer" who leaves potentially delegable activities to the employees and pursues the goal of helping the employees to develop personally and professionally without losing sight of the organizational goals. In contrast, the author describes the relationship-oriented and hardly task-oriented supervisor as a "missionary" who neglects the company's prerequisites for taking employee needs into account and focuses only on the individual satisfaction of an employee. The actual operational consequences remain unconsidered.

---

[12] Note: The arrows in the figure are not to be understood in terms of increasing or decreasing degrees of effectiveness, since Reddin uses the narrow concept of effectiveness and thus effectiveness and ineffectiveness are dichotomous.

A supervisor who is strongly task-oriented and hardly relationship-oriented (task style) focuses on the performance and productivity of his or her employees. If the supervisor adapts to the situation accordingly, he or she is characterized as a “doer” (“benevolant autocrat”) according to Reddin. In contrast to the “autocrat”, the “doer” formulates realistic and at the same time challenging goals without overtaxing the employees.

An integration-oriented supervisor (integration style) exhibits both a high degree of task orientation and of relationship orientation. As an “integrator” (“executive”), the supervisor is able to make decisions in the interests of the company, taking into account diverse employee needs, and in doing so is both motivating and cooperative. A “compromiser”, on the other hand, shies away from conflicts and decision-making situations in which not all employee wishes can be taken into account.

The descriptions of the basic styles and effective or ineffective results show that the author does not prefer any of the four leadership styles. Rather, a prior analysis of the situation is necessary in order to be able to choose the appropriate leadership behavior. For this, the leader must be able to assess the situation validly, for which Reddin (1970) formulates up to 100 indicators for analysis. The situation indicators can be divided into the following elements:

- Work method or task requirements,
- Employees,
- Colleagues,
- Supervisors and
- Organizational structure or organizational climate.

For each of the four basic styles (see figure 8), there are five indicators per situation element. If, for example, an employee shows a high degree of independence, professional competence and intrinsic interest and the task to be completed is at the same time very simple, the procedural style is to be applied in such a situation. Instructions for appropriate situation assessment based on the above elements are described in detail by Reddin (1970).

3.2.2.3 The situational leadership theory by Hersey & Blanchard

Whereas Reddin takes leadership effectiveness dichotomously as a third dimension, Hersey & Blanchard (1969) focus exclusively on effective leadership styles. They name a multitude of relevant situational determinants which should be taken into account when choosing a leadership style. These include task structure, supervisor-employee relationships, time constraints, and organizational characteristics. However, the authors focus on the so-called task-relevant maturity level of an employee, which is determined by his or her motivation and qualification.

By means of a corresponding dichotomous recording, Hersey & Blanchard (1969) distinguish four levels of maturity (R_1 to R_4):

R_1 (low maturity): Both motivation and qualification of the employee are assessed as low.

R_2 (low to medium (moderate) maturity): The employee shows a high level of motivation and a low level of qualification.

R_3 (medium (moderate) to high maturity): The employee shows a low level of motivation and a high level of qualification.

R_4 (high maturity): The employee demonstrates both a high level of motivation and a high level of qualification.

Employees do not always have the same level of maturity everywhere, but can have different levels of maturity in relation to different tasks and situations. The manager must therefore be able to validly assess the maturity level of an employee in different situations in order to select and apply the appropriate leadership style in each case. According to the participation rate, Hersey & Blanchard (1969) differentiate four leadership styles (S_1 to S_4):

S_1 (low participation rate): The supervisor decides autocratically, solves the corresponding decision problem alone and communicates the solution to the employee.

S_2 (low to medium participation rate): The supervisor still makes the decision alone, but involves the employee to the extent that he or she explains how he or she arrived at the decision and why he or she made it and not another one.

S_3 (medium to high participation rate): The employee is involved in the decision-making process, but does not make it alone.

S_4 (high participation rate): The supervisor delegates the decision-making problem to the employee.

Figure 9 shows the correlations recommended by Hersey & Blanchard (1969) between maturity level and the leadership style to be selected. With R_1 one should choose S_1, with R_2 one should choose S_2, with R_3 one should choose S_3 and with R_4 one should choose S_4. Although the leadership styles are differentiated according to the participation rate, the authors also recommend different degrees of relationship and task orientation in the various leadership situations.

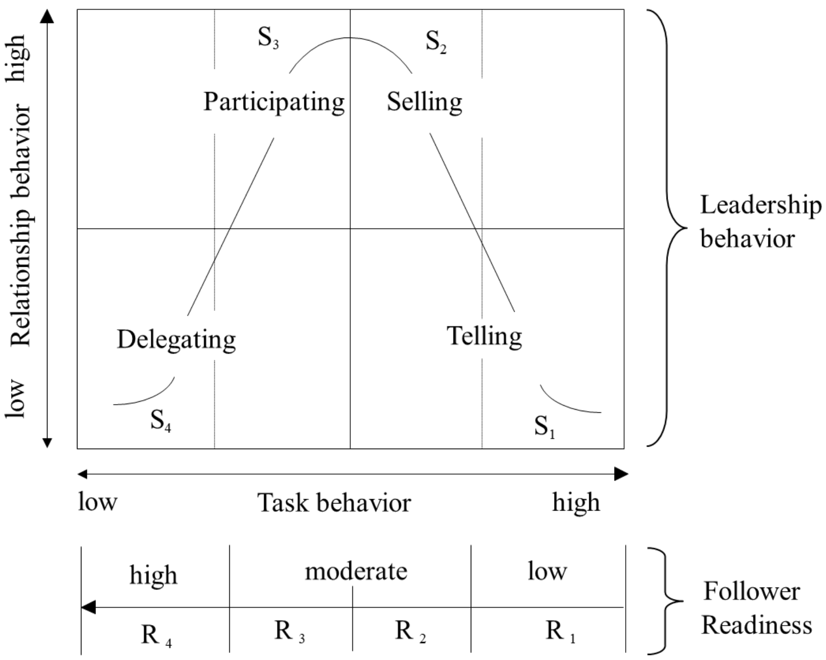

Figure 9: Situational Leadership Model by Hersey & Blanchard (1969, S. 19)

The leadership style recommendations are justified as follows:

R_1 (low maturity): Both motivation and qualification of the employee are assessed as low. The reference to the authoritarian leadership style in the case of low qualification and motivation seems understandable and conclusive. According to Hersey & Blanchard (1969), in such a situation the leader should focus on giving the employee precise instructions on how an activity and task must be completed, since the employee does not have the necessary qualifications and also lacks motivation to complete the task.

R_2 (low to medium maturity): The employee exhibits a high level of motivation and a low level of qualification. The assignment to S_2 is also plausible. Since the employee is willing but not sufficiently qualified, he or she should be shown how to make good decisions for development reasons.

R_3 (medium to high maturity): The employee exhibits a low level of motivation and a high level of qualification. This assignment of leadership style and maturity level is also plausible. If the supervisor were to delegate the decision in such situations, there would be a risk of collusive behavior on the part of the employee.

R_4 (high maturity): Since the employee here is both motivated and qualified, it can make a lot of sense to delegate the pending decision to him or her.

Hersey & Blanchard (1969) do not assume that the task-relevant maturity level of an employee can be regarded as unchangeable (as may be the case with other situational determinants), but that active promotion should be aimed at increasing or stabilizing the employee's maturity level.

The authors propose a two-stage process for the realization of this personnel development, whereby first a task delegation of a delimited area of responsibility is carried out. If successfully mastered, the employee's behavior is rewarded in the second stage and reinforced by further development measures. The successive expansion of the area of responsibility is thus the core of active maturity development and can be repeated as often as desired. This procedure explains the bell-shaped curve in figure 9. An employee is to be promoted by the supervisor in such a way that he or she moves further and further to the left on the curve.

3.2.2.4 The normative decision model by Vroom & Yetton

The participation rate is the extent to which employees are involved in the decision-making process and represents the central leadership style dimension in the model of Vroom & Yetton (1973, Jago/Ettling/Vroom 1985, Vroom/Jago 1988). The two authors distinguish between five leadership styles ($I_1, I_2, \ldots, I_5$):

I_1:= The supervisor makes the factual decision alone, based on his or her current level of information.

I_2:= The supervisor makes the decision on the matter alone after obtaining information from the employees.

I_3:= The supervisor makes the factual decision alone, after discussing the factual decision problem in individual meetings with the employees.

I_4:= The supervisor makes the factual decision alone, after discussing the factual decision problem with the group of employees.

I_5:= The supervisor presents the factual decision problem to the group of employees, everyone develops and evaluates alternative courses of action as a group and the group make a joint factual decision. The supervisor is an equal member of the group.

Provided, that one accepts the participation rate as a differentiation criterion for leadership styles - and there is nothing seriously wrong with that - this leadership style list is quite reasonable. However, one misses the complete delegation to the body (without co-decision by the supervisor) and the possibility of obtaining information from other persons (than one's own employees).

The leadership situation is analyzed according to a total of seven criteria in question form, whereby these are recorded dichotomously in each case and are to be answered with "yes" or "no" ($J_1, J_2, \ldots, J_7$):

J_1:= Is the quality of the decision important? (Note: Here we are asking about quality, not whether the decision itself is important).

J_2:= Does the supervisor feel sufficiently informed to make a quality factual decision?

J_3:= Does the supervisor think the factual problem is sufficiently structured?

J_4:= Is the acceptance of the factual decision on the part of the employees important for its implementation?

J_5:= Does the supervisor assume that a factual decision made in an authoritarian manner will be accepted?

J_6:= Will employees align their solution contributions with the organizational goal?

J_7 := Is it to be expected that employees will argue about the evaluation of the alternative actions?

Seven questions with two possible answers each result in a total of (2^7 =) 128 possibilities (leadership situations) to combine the answers (variations with repetition).[13]

For the purpose of selecting the leadership style, decision rules are to be applied. Vroom & Yetton (1973) propose the following seven decision rules ($DR_1, DR_2, \dots, DR_7$) in the version presented here, where ⌐ symbolizes negation, ∧ logical and (both ... and), and → implication:

<u>DR_1 (Information rule):</u>[14] $J_1 \land \neg J_2 \rightarrow \neg I_1$

Note: This rule is undoubtedly plausible, because if decision quality is important but the supervisor is not sufficiently informed for a good factual decision, it makes no sense for him or her to decide based on his or her current level of information.

<u>DR_2 (Trust rule):</u> $J_1 \land \neg J_6 \rightarrow \neg I_5$

Note: This rule is also plausible to a certain extent, because if the quality of the decision is important but conflicts are to be expected among the employees about the factual decision to be made, they should not be allowed to participate in the decision if it is assumed that conflict resolution is not possible or at least not possible with reasonable effort. In principle, however, they can then be used in upstream stages of the decision-making process. The fact that conflicts

[13] Siegling et al. (2023) list all 128 possible combinations.

[14] Read: If question J_1 is answered yes and question J_2 is answered no, then do not choose leadership style I_1.

can also have a negative impact in this process (e.g., through strategic information and consultation behavior) is apparently not considered relevant by Vroom & Yetton and therefore only I_5 is excluded here.

DR_3 (Structure rule): $J_1 \wedge \neg J_2 \wedge \neg J_3 \rightarrow \neg(I_1, I_2, I_3)$

Note: If the decision quality is important, but the supervisor is not sufficiently informed for a good factual decision and he or she considers the factual decision problem as unstructured, the supervisor should not decide authoritatively. This is plausible as far as it goes. Nor, according to Vroom & Yetton (1973), should he or she seek advice in one-on-one meetings. That - as assumed by Vroom (1967) – I_2 and I_3 are always too cumbersome, ineffective and inefficient here is questionable and whether group discussions can make up for the deficits is at least worth discussing.

DR_4 (Acceptance rule): $J_4 \wedge \neg J_5 \rightarrow \neg(I_1, I_2)$

Note: If the acceptance of the factual decision on the part of the employees is important but it can be assumed that an authoritarian decision will not be accepted by them, then it is logical that neither of the two authoritarian leadership styles is chosen here.

DR_5 (Conflict rule): $J_4 \wedge \neg J_5 \wedge J_7 \rightarrow \neg(I_1, I_2, I_3)$

Note: If it is important that the employees accept the factual decision, but an authoritarian factual decision is not likely to be accepted by them and conflicts over the order of preference are to be expected, then there is a case for not selecting I_1, I_2 and I_3. Whether, in this case, I_4 is actually better than I_3 is at least debatable.

DR_6 (Fairness rule): $J_4 \wedge \neg J_5 \wedge \neg J_1 \rightarrow \neg(I_1, I_2, I_3, I_4)$

Note: Vroom & Yetton consider it fair if the employees in the group (co-)decide, if the acceptance of the decision is important, an authoritarian decision is probably not accepted but the quality of the decision is irrelevant. It remains to be seen whether every employee actually considers it fair when he or she is called upon to make qualitatively irrelevant decisions.

DR_7 (Acceptance prioritization rule): $J_4 \wedge \neg J_5 \wedge J_6 \rightarrow \neg(I_1, I_2, I_3, I_4)$

Note: Here, Vroom & Yetton (1973) apparently assume that only a group decision can eliminate the presumed conflicting goals. However, this assumption is also debatable.

It goes without saying that leadership style selection can be made on the basis of these seven rules - the first three of which relate to decision quality and the other four to decision acceptance - by analyzing the current leadership situation and then applying the corresponding rule(s).

3.2.2.5 Critique

In all these models, the focus is on leadership effectiveness. Leadership efficiency and leadership optimality, on the other hand, are at best implicitly addressed. The Vroom/Yetton model offers a certain exception here, in which one arrives at the time-efficient or development-efficient leadership style through two alternative additional criteria, but without this being derived and discussed in a differentiated manner by the authors.

In Blake & Mouton, unlike the other models mentioned above, the leadership situation is not differentiated according to situation determinants. In addition, no measurement rules are mentioned or discussed for the two dimensions that are considered independent. Instead, five statements are given for each of six problem areas, e.g. such as effort, emotion, or persuasion, and the one that best characterizes supervisor behavior is to be selected from these. However, Blake & Mouton do not discuss the origins of the six problem areas or the five statements, nor the relationship between statements and leadership style. Although the model is known to many practitioners and is often discussed in management training courses, it cannot be rated very highly from a scientific perspective due to deficits in differentiation, operationalization and theoretical foundation.

Reddin's 3D-Model leaves room for interpretation in many places. For example, the situation elements are operationalized too weakly and vaguely to be able to formulate concrete recommendations for action. The inflationary use of metaphorical language (not least in the differentiation of leadership styles) is not necessarily conducive to understanding the explanations. In addition, the correlations between leadership style and leadership effectiveness are not explained in great detail. However, it is positive that Reddin emphasizes the situation-specificity of the choice of leadership style several times.

Hersey & Blanchard also emphasize that leadership styles must be chosen on a situation-specific basis. The leadership styles are plausibly differentiated, at least as far as they relate to the participation rate. However, it remains open whether all three dimensions are actually independent. The situation differentiation and the match between leadership situation and leadership style are also plausibly justified, although relatively simply structured.

The Vroom/Yetton-Model has been widely tested, evaluated, and criticized (Auer-Rizzi/Reber 2013, Duncan/LaFrance/Ginter 2003, Erffmeyer 1983, Field 1979, 1982, Field/Andrews 1998, Field/House 1990, Horgan/Simeon 1990, Gomolka/Mackin 1984, Margerison/Glube 1979, Pate/Heimann 1987, Samosudova 2017, Vignesh 2020, Vroom 2003, Vroom/Jago 2007, Wedley/Field 1984, Zimmer 1978). Provided that one accepts the participation rate as a differentiation criterion for leadership styles - and there is nothing seriously wrong with that - this leadership style list is quite defensible. However, one misses the complete delegation to the committee (without co-decision by the supervisor) and the possibility to obtain information from other persons (than the own employees). The list of situation determinants can also be accepted as reasonable, although the level of information of the employees could be taken into account, as provided in another model version by Vroom & Yetton (1973), but also the forecast qualification of employees and supervisors. Leadership costs and returns are also considered implicitly at best in both leadership styles and leadership situations. Moreover, the dichotomization of situation determinants is based on a simplifying and complexity-reducing assumption that is overturned in later work (Vroom/Jago 1988).

3.2.3 A fuzzy rule system for leadership style selection[15]

In considering the fuzzy case, we deliberately focus in this paper on fuzzy rule systems rather than fuzzy decision trees (see e.g. Hill/Schmitt 1977, Lunenburg 2010, Vroom 1967, Vroom/Jago 1995, Vroom/Yetton/Jago 2015), although such have already been constructed in the scientific literature (Baldwin/Xie 2005, Cintra/Monard/Camargo 2012, Hall/Lande 1998, Janikow 1998, Lertworaprachaya/Yang/John 2010, Olaru/Wehenkel 2003, Yuan/Shaw 1995). However, we consider our approach with continous input and output sets to be more promising. The initial model of Vroom & Yetton is based on Boolean (two-valued or binary) logic, which knows only two states, namely true or false, yes or no or 0 or 1. Thus an element x belongs either completely (or completely not) to a set. For the membership value of such a crisp set A holds $\mu_A(x) \in \{0,1\}$. In the context of the so-called fuzzy logic (Buckley/Eslami 2002, Gottwald 1993, Pedrycz 1993, Piegat 2001, Zadeh 1983, Zimmermann 1987, 1996) membership values can also be graduated, such that for the membership of an element x to a fuzzy set $\tilde{A}$ $\mu_{\tilde{A}}(x) \in [0,1]$ holds (Bellmann/Zadeh 1970, Dubois/Ostasiewicz/Prade 2000, Dubois/Prade 1980a, Pedrycz 1993, Piegat 2001, Wang/Chang 2000, Zimmermann 1996).[16] Since $\{0,1\} \subset [0,1]$ unambiguity is always a special case of fuzziness.

Crisp rule systems usually use the modus (ponendo) ponens as an inference rule (Dubois/Prade 1991, Mamdani 1981, Zimmermann 1987): it consists of (at least) two premises and one conclusion:

---

[15] We refer here to the basic model of Vroom & Yetton, for such situations in which several coworkers are subordinate to the supervisor (Vroom/Yetton 1973).

[16] See section 2.3 of this paper.

Premise 1: If A then C

Premise 2: A is present

Conclusion: It follows C

This inference mechanism is also used in fuzzy control systems:

Premise 1: If $\tilde{A}$ then $\tilde{C}$

Premise 2: $\tilde{A}$ is present

Conclusion: It follows $\tilde{C}$

In the context of fuzzy control (Driankov/Hellendoorn/Reinfrank 1993), linguistic variables (for $\tilde{A}$ and $\tilde{C}$) are often used. These represent quadruples (Dubois/Prade 1978, Spengler/Herzog 2023, Zadeh 1975, 1987). They consist of the name of the linguistic variable, of the set of linguistic terms, of the base set on which the linguistic variable is defined, and of a semantic rule that assigns a membership function to each linguistic term. The design of an expert system based on fuzzy rules (Hall/Kandel 1991, Zimmermann 1996) is basically carried out in three steps:

1. Step: Fuzzification of the rule input by constructing membership functions for the input variables.
2. Step: Fuzzy inference (Bouchon-Meunier 1991, Dubois/Prade 1980b, Dubois/Prade 1991, Fodor/Yager 2000, Klement/Mesiar/Pap 2004, Pap 2002, Piegat 2001, Schneider/Kandel 1991, Yager 1980, Yager 1991, Zadeh 1983, Zimmermann 1996) by formulating the rule base, applying the inference mechanism, and deriving the linguistic output variables (including construction of corresponding membership functions).
3. Step: Defuzzification of the fuzzy output.

In the original model by Vroom & Yetton (1973), the leadership styles I_1, I_2, I_3, I_4 and I_5 are discretely differentiated. Such a differentiation can also be implemented in the context of a fuzzy rule system by taking the effectiveness expressions $\tilde{E}$ of the different leadership styles as fuzzy conclusion variables of the rules in the form of singletons.[17] In the present work, however, the aim is not to make a discrete but a continuous differentiation of leadership styles on the basis of a bipolar continuum of the participation rate (x_{PR}). At the poles of this continuum,

[17] Singletons represent a special case of the fuzzy logic: These are one-element fuzzy sets for whose membership value $0 < \mu_{\tilde{A}}(x^*) \leq 1$ holds (Piegat 2001).

$x_{PR} = 0$ (completely authoritarian leadership) and $x_{PR} = 1$ (complete delegation of factual decision-making) apply. The participation rate is used here as a linguistic variable with the linguistic terms *low*, *medium* and *high*.

In the original model (see chapter 3.2.2.4), the leadership situation is analyzed according to a total of seven determinants (J_1, J_2, …, J_7) in the form of questions, each of which is recorded dichotomously and must be answered with "yes" or "no". J_1 is about the importance of the (factual) decision quality (DQ), J_2 about the adequacy of the supervisor's level of information (ILL), J_3 about the structuredness of the factual problem (PS), J_4 about the importance of the acceptance of an authoritative decision ($IAAD$), J_5 about the possibility of acceptance of an authoritatively made decision ($PAAD$), J_6 about the goal orientation of the employees (GO) and J_7 about the expectation of evaluation conflicts among the employees (CE). In the fuzzy rule model to be formulated here, the evaluation of the corresponding questions or, more precisely, their truthfulness or degree of true $x_d \in [0,1]$ is not dichotomous, but in bipolar continua $x_{DQ}, x_{ILL}, x_{PS}, x_{IAAD}, x_{PAAD}, x_{GO}$ and x_{CE}. We also model these as membership functions for the linguistic terms l for criterion d as follows (see figure 10):

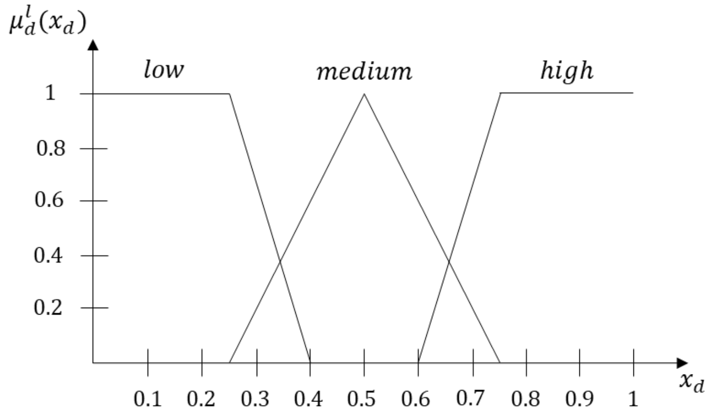

Figure 10: Graphs of the membership functions

We assume such shapes of the membership functions, although we can also model other (e.g., piecewise continuous, bell-shaped, and trapezoidal) ones.

For the purpose of leadership style selection, Vroom & Yetton bring a total of seven decision rules (DR_1, DR_2, …, DR_7) into play in the version presented in section 3.2.2.4. However, in the fuzzy rule system to be formulated here, these are not constructed as singular rules, but as rule blocks DR_k $(k = 1, 2, \dots, 7)$, each composed of several rules differentiated (according to the combinations of linguistic terms).[18] In the following, we use these symbols:

$\overline{K} \coloneqq \{k | k = 1, \dots, K; k \text{ is a rule block}\}$

$\overline{M}_k \coloneqq \{m = M_{k-1} + 1, M_{k-1} + 2, \dots, M_k \lceil m \in \overline{M}; m \text{ is a decision rule in block } k \in \overline{K}; M_0 = 0\}$

$\overline{M} \coloneqq \bigcup_{k \epsilon \overline{K}} \overline{M}_k$ (Set of all decision rules)

$\widetilde{PR}_k \coloneqq$ fuzzy participation rate of decision rule block k

$\widetilde{PR}_m^k \coloneqq$ fuzzy participation rate of decision rule $m \in \overline{M}_k$ in decision rule block $k \in \overline{K}$

$\widetilde{PR}_{total} \coloneqq$ total participation rate

$DOF_m \coloneqq$ degree of fulfillment of decision rule $m \epsilon \overline{M}_k$ $\left(k \in \overline{K}\right)$

$DOF_{total}^{l,k} \coloneqq$ total degree of fulfillment of linguistic term l in decision rule block $k \in \overline{K}$

Decision rule block $k = 1$:

The decision rule block $k = 1$ corresponds to the crisp information rule DR_1 from the basic model. This requires $J_1 \wedge \neg J_2 \rightarrow \neg I_1$. The fuzzy rule block $k = 1$ now demands:

$\widetilde{DQ} \wedge \widetilde{ILL} \rightarrow \widetilde{PR}_1$

Decision rule block $k = 2$:

The decision rule block $k = 2$ corresponds to the crisp confidence rule DR_2 from the basic model. This requires $J_1 \wedge \neg J_6 \rightarrow \neg I_5$. The fuzzy rule block $k = 2$, on the other hand, now requires:

$\widetilde{DQ} \wedge \widetilde{GO} \rightarrow \widetilde{PR}_2$

Decision rule block $k = 3$:

The decision rule block $k = 3$ corresponds to the crisp structure rule DR_3 from the basic model. This requires $J_1 \wedge \neg J_2 \wedge \neg J_3 \rightarrow \neg(I_1, I_2, I_3)$. The fuzzy rule block $k = 3$, on the other hand, now requires:

$\widetilde{DQ} \wedge \widetilde{ILL} \wedge \widetilde{PS} \rightarrow \widetilde{PR}_3$

Decision rule block $k = 4$:

The decision rule block $k = 4$ corresponds with the acceptance rule DR_4 from the basic model. This requires $J_4 \wedge \neg J_5 \rightarrow \neg(I_1, I_2)$. The fuzzy rule block $k = 4$, on the other hand, requires now:

[18] The rule system formulated by Siegling et al. (2023) comprises a total of 135 rules, which we cannot list individually here for reasons of limited space.

$\widetilde{IAAD} \wedge \widetilde{PAAD} \rightarrow \widetilde{PR}_4$

Decision rule block $k = 5$:

The decision rule block $k = 5$ corresponds with the conflict rule DR_5 from the basic model. This requires $J_4 \wedge \neg J_5 \wedge J_7 \rightarrow \neg(I_1, I_2, I_3)$. The fuzzy rule block $k = 5$, on the other hand, requires now:

$\widetilde{IAAD} \wedge \widetilde{PAAD} \wedge \widetilde{CE} \rightarrow \widetilde{PR}_5$

Decision rule block $k = 6$:

The decision rule block $k = 6$ corresponds with the fairness rule DR_6 from the basic model. This requires $J_4 \wedge \neg J_5 \wedge \neg J_1 \rightarrow \neg(I_1, I_2, I_3, I_4)$. The fuzzy rule block $k = 6$, on the other hand, requires now:

$\widetilde{IAAD} \wedge \widetilde{PAAD} \wedge \widetilde{DQ} \rightarrow \widetilde{PR}_6$

Decision rule block $k = 7$:

The decision rule block $k = 7$ corresponds with the acceptance prioritization rule DR_7 from the basic model. This requires $J_4 \wedge \neg J_5 \wedge J_6 \rightarrow \neg(I_1, I_2, I_3, I_4)$. The fuzzy rule block $k = 7$, on the other hand, requires now:

$\widetilde{IAAD} \wedge \widetilde{PAAD} \wedge \widetilde{GO} \rightarrow \widetilde{PR}_7$

For the purpose of explanation and in order not to go beyond the scope, we show an example rule set from block $k = 1$ below:

Given two linguistic input variables and three linguistic terms each, there are a total of 9 rules $m \in \bar{M}_1$. These are, for example:

Rule $m \in \bar{M}_1$	$\widetilde{DQ}$	$\widetilde{ILL}$	$\widetilde{PR}_m^1$
1	low	low	medium
2	medium	low	medium
3	high	low	high
4	low	medium	medium
5	medium	medium	medium
6	high	medium	high
7	low	high	medium
8	medium	high	medium
9	high	high	low

Table 3: Rule block 1

We model the membership functions for the linguistic terms l for criterion $d \in \{DQ, ILL\}$ as follows:

$$\mu_d^{low}(x_d) = \begin{cases} 1 & for\ 0 \leq x_d \leq 0.25 \\ \frac{0.4 - x_d}{0.15} & for\ 0.25 < x_d \leq 0.4 \\ 0 & otherwise \end{cases} \tag{44}$$

$$\mu_d^{medium}(x_d) = \begin{cases} \frac{x_d - 0.25}{0.25} & for\ 0.25 \le x_d \le 0.5 \\ \frac{0.75 - x_d}{0.25} & for\ 0.5 < x_d \le 0.75 \\ 0 & otherwise \end{cases} \tag{45}$$

$$\mu_d^{high}(x_d) = \begin{cases} \frac{x_d - 0.6}{0.15} & for\ 0.6 \le x_d \le 0.75 \\ 1 & for\ 0.75 < x_d \le 1 \\ 0 & otherwise \end{cases} \tag{46}$$

For example, if $x_{DQ} = 0.7$ and $x_{ILL} = 0.3$, inserting in (44), (45) as well as (46) or from the graphs of the membership functions $\mu_{\widetilde{DQ}}^{l}$ and $\mu_{\widetilde{ILL}}^{l}$, it follows that rules 2, 3, 5 and 6 are active ($DOF > 0$) and the others are inactive ($DOF = 0$) (see figure 11).

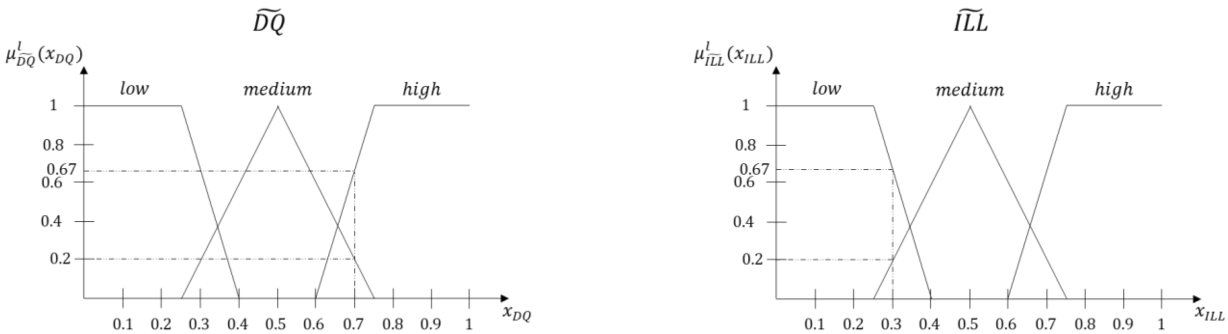

Figure 11: Membership function of $\widetilde{DQ}$ and $\widetilde{ILL}$ of decision rule block $k = 1$

After processing all (seven) rule blocks, the total output and the membership function of the total participation rate can be derived. In the example of Siegling et al. (2023), the fuzzy output set is given by (see figure 12):

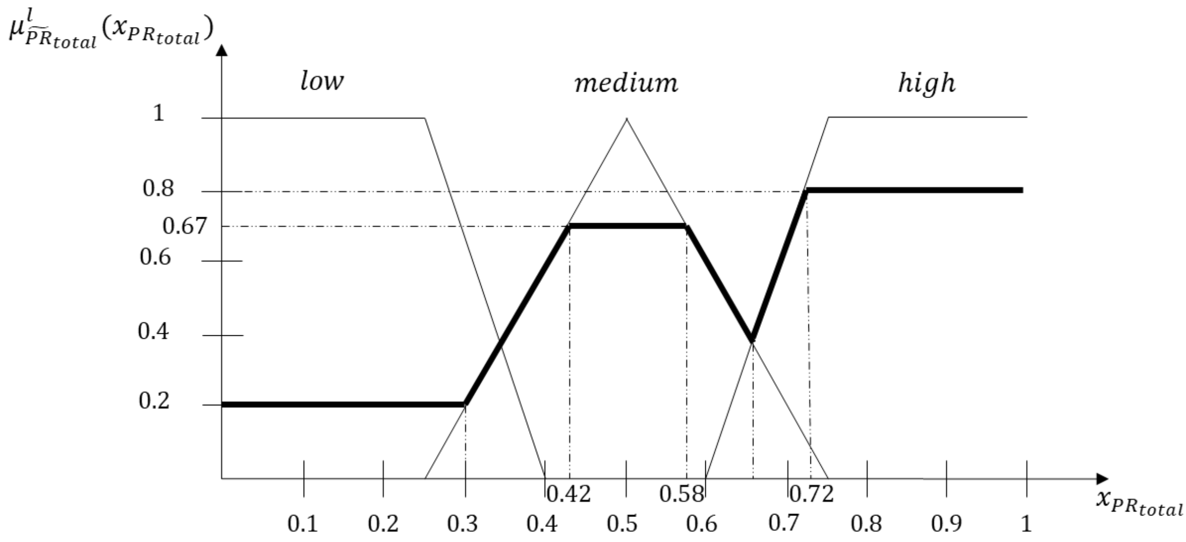

Figure 12: Membership function of $\mu^{l}_{PR_{total}}(x_{PR_{total}})$

To obtain a precise conclusion, it may be useful to defuzzify the fuzzy total participation rate $\widetilde{PR}_{total}$. For this purpose – if one follows the Time Investment Model (Vroom/Yetton 1973) – various maximum methods can be considered (Piegat 2001, Spengler/Herzog 2023). If the first-of-maxima-method (respectively last-of-maxima-method) is chosen, for example, $x_{PR_{total}} = 0.72$ (respectively 1) see figure 12. On the other hand, if one follows the Time Efficient Model (Vroom/Yetton 1973), one would choose a minimum method: With the first-of-minimum method, $x_{PR_{total}}$ would be 0 in the above example and 0.3 with last-of-minimum-method.

However, in fuzzy control, the center-of-gravity-method is also frequently used. The center of gravity (*COG*) of an area can be understood as its center point. The *COG* of a membership function is the center of mass of the membership values. In order to compute centroids, one must determine first of all the contents of the area. As is well known, integral calculus is used for this purpose, especially for (at least partially) curved function graphs. For the exact procedure in detail, see e.g. Spengler/Herzog (2023). The *COG* of the cited example is shown in figure 13:

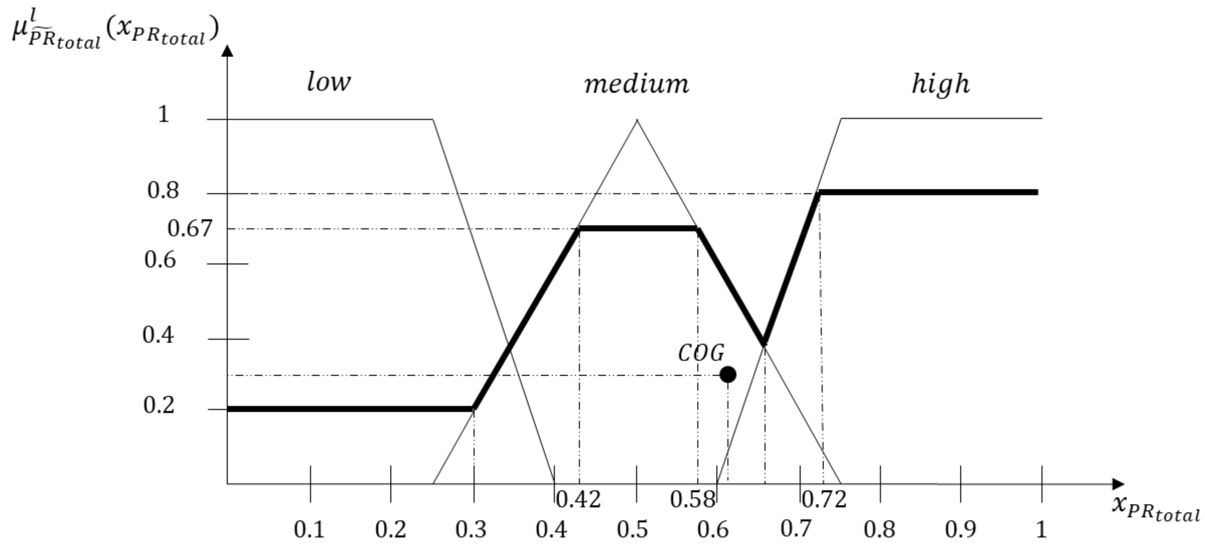

Figure 13: Representation of the fuzzy output set and corresponding center of gravity

$x_{cog} = 0.62$ can then be interpreted as the mean participation rate in the example.

4 Conclusion

This overview article introduces basic models and approaches to personnel planning and leadership. In the second chapter, we deal with availability problems and the associated methods of personnel planning. To this end, we first explain general and formal principles. Subsequently, we formulate various models for optimizing personnel and personnel assignment in crisp situations. We pay special attention to hierarchical planning. We then construct hierarchical planning models for the fuzzy case.

Chapter 3 is devoted to leadership and therefore deals with functionality problems. Again, we first deal with conceptual and systematic foundations, including effective, efficient and optimal leadership. Subsequently, selected concepts of leadership are considered. These include various models for selecting leadership styles and so-called management by ... concepts. At the end of the third chapter, we outline a new fuzzy rule system for selecting leadership styles. Both the field of personnel planning and leadership are much more extensive than presented here. Continuous model extensions and complex interdependencies are the reason why it is hardly possible to address and conclusively discuss all relevant contents of personnel planning and leadership in one paper. In the area of personnel planning, there are relevant models in addition to the approaches presented here, which are based on the implicit and explicit approach and contain corresponding extensions. In this respect, personnel planning models can be differentiated with regard to the following criteria: time reference (short-, medium- and long-term planning), purpose reference (diagnostic, prognosis, decision and simulation models), target space (single- and multi-objective models), solution quality (heuristic and optimizing approaches), flexibility (rigid and flexible planning approaches), degrees of freedom (strategic, tactical and operational planning), contingency (deterministic, stochastic and fuzzy approaches) and planning areas (isolated, integrated, successive and simultaneous personnel planning). In this article, only selected model types are discussed for the solution of various availability problems. For a more comprehensive analysis of corresponding approaches, further studies based on this basic article would be recommended.

In the area of leadership, we have presented basic management by ... concepts, as well as the managerial grid by Blake & Mouton (1964), the situational leadership theory by Hersey & Blanchard (1969), the 3D-Model by Reddin (1970) and the normative decision model by Vroom & Yetton (1973), each in its original form. We also briefly discussed model extensions and corrections that have already been made and that have meanwhile gained relevance in research. The underlying motivation theory and social psychological aspects are essential in the context of leadership (Heckhausen/Heckhausen 2018), but are mentioned at most in this overview article for reasons of complexity. For example, we explain that, among other things, the degree of motivation determines the task-relevant maturity of an employee. However, which motivational aspects in the background are responsible for the corresponding expression (individual interest in the activity, desire for autonomous work, significance of the task, possibility of self-realization and others (Hackman/Oldham 1976) and how this construct can be operationalized in order to be able to make an adequate assignment to the applicable leadership style as a supervisor remains open at this point. While this article provides an overview of relevant models for solving the problem of functionality, it is no substitute for an in-depth and interdisciplinary analysis of situationally effective and efficient leadership style selection.

This overview article is a suitable paper for newcomers who want to enter the fields of personnel planning and leadership. Beyond selected relevant basics of personnel planning and leadership, this article introduces hierarchical planning and the conception of fuzzy rule systems for the selection of appropriate leadership styles. Corresponding considerations represent a new and innovative starting point for further research work.

Appendix

Example 1:

We consider 3 activities ($q = 1,2,3$) and 7 categories of workers ($r = 1,2,\ldots,7$). Table 4 shows the given demand for workers $\left(PD_q\right)$and the wage costs (w_r) as well as the possibilities of each category of workers to perform the different activities [signed by crosses]:

	$r = 1$	$r = 2$	$r = 3$	$r = 4$	$r = 5$	$r = 6$	$r = 7$	PD_q
$q = 1$	×			×	×		×	75
$q = 2$		×		×		×	×	110
$q = 3$			×		×	×	×	62
w_r	8	8	8	9	9	9	10	

Table 4: Deployment possibilities and use possibilities

Model I is shaped as follows:

$8\,P_1 + 8\,P_2 + 8\,P_3 + 9\,P_4 + 9\,P_5 + 9\,P_6 + 10\,P_7 \rightarrow$ min!

subject to:

$75 \leq P_1 + P_4 + P_5 + P_7$

$110 \leq P_2 + P_4 + P_6 + P_7$

$62 \leq P_3 + P_5 + P_6 + P_7$

$185 \leq P_1 + P_2 + P_4 + P_5 + P_6 + P_7$

$137 \leq P_1 + P_3 + P_4 + P_5 + P_6 + P_7$

$172 \leq P_2 + P_3 + P_4 + P_5 + P_6 + P_7$

$247 \leq P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_7$

$P_1, \ldots, P_7 \geq 0$

Optimal solution:

Objective function value: 1976.0000

Variable	Value
P_1	75.000000
P_2	110.000000
P_3	62.000000
P_4	0.000000
P_5	0.000000
P_6	0.000000
P_7	0.000000

Model II is shaped as follows:

$8\ P_1 + 8\ P_2 + 8\ P_3 + 9\ P_4 + 9\ P_5 + 9\ P_6 + 10\ P_7 \rightarrow$ min!

subject to:

$75 = AP_{11} + AP_{41} + AP_{51} + AP_{71}$

$110 = AP_{22} + AP_{42} + AP_{62} + AP_{72}$

$62 = AP_{33} + AP_{53} + AP_{63} + AP_{73}$

$AP_{11} \leq P_1$

$AP_{22} \leq P_2$

$AP_{33} \leq P_3$

$AP_{41} + AP_{42} \leq P_4$

$AP_{51} + AP_{53} \leq P_5$

$AP_{62} + AP_{63} \leq P_6$

$AP_{71} + AP_{72} + AP_{73} \leq P_7$

$AP_{11}, AP_{41}, AP_{51}, AP_{71}, AP_{22}, AP_{42}, AP_{62}, AP_{72}, AP_{33}, AP_{53}, AP_{63}, AP_{73},\ P_1, \ldots,\ P_7 \geq 0$

Optimal solution:

Objective function value: 1976.0000

Variable	Value	Variable	Value	Variable	Value
P_1	75.000000	AP_{11}	75.000000	AP_{72}	0.000000
P_2	110.000000	AP_{41}	0.000000	AP_{33}	62.000000
P_3	62.000000	AP_{51}	0.000000	AP_{53}	0.000000
P_4	0.000000	AP_{71}	0.000000	AP_{63}	0.000000
P_5	0.000000	AP_{22}	110.000000	AP_{73}	0.000000
P_6	0.000000	AP_{42}	0.000000		
P_7	0.000000	AP_{62}	0.000000		

<u>Example 2:</u>

We take into account the data given in example 1, but we additionally consider the following productivity factors:

	$r = 1$	$r = 2$	$r = 3$	$r = 4$	$r = 5$	$r = 6$	$r = 7$
α_r	0.91	0.96	0.85	0.95	0.93	0.97	0.9

Table 5: Productivity factors

Model IV is shaped as follows:

$8\ P_1 + 8\ P_2 + 8\ P_3 + 9\ P_4 + 9\ P_5 + 9\ P_6 + 10\ P_7 \rightarrow$ min!

subject to:

$75 \leq 0.91\ P_1 + 0.95\ \ P_4 + 0.93\ P_5 + 0.9\ P_7$

$110 \leq 0.96\ P_2 + 0.95\ P_4 + 0.97\ P_6 + 0.9\ P_7$

$62 \leq 0.85\ P_3 + 0.93\ P_5 + 0.97\ P_6 + 0.9\ P_7$

$185 \leq 0.91\ P_1 + 0.96\ P_2 + 0.95\ P_4 + 0.93\ P_5 + 0.97\ P_6 + 0.9\ P_7$

$137 \leq 0.91\ P_1 + 0.85\ P_3 + 0.95\ P_4 + 0.93\ P_5 + 0.97\ P_6 + 0.9\ P_7$

$172 \leq 0.96\ P_2 + 0.85\ P_3 + 0.95\ P_4 + 0.93\ P_5 + 0.97\ P_6 + 0.9\ P_7$

$247 \leq 0.91\ P_1 + 0.96\ P_2 + 0.85\ P_3 + 0.95\ P_4 + 0.93\ P_5 + 0.97\ P_6 + 0.9\ P_7$

$P_1, \ldots, P_7 \geq 0$

Optimal solution:

Objective function value: 2151.2650

Variable	Value
P_1	82.417580
P_2	114.583300
P_3	0.000000
P_4	0.000000
P_5	0.000000
P_6	63.917520
P_7	0.000000

Model V, which obviously is trivial in the case being under consideration, is shaped as follows:

$8\ AP_{11} + 9\ AP_{41} + 9\ AP_{51} + 10\ AP_{71} + 8\ AP_{22} + 9\ AP_{42} + 9\ AP_{62} + 10\ AP_{72} + 8\ AP_{33} +$

$+9\ AP_{53} + 9\ AP_{63} + 10\ AP_{73} \rightarrow$ min!

subject to:

$0.91\ AP_{11} + 0.95\ AP_{41} + 0.93\ AP_{51} + 0.9\ AP_{71} = 75$

$0.96\ AP_{22} + 0.95\ AP_{42} + 0.97\ AP_{62} + 0.9\ AP_{72} = 110$

$0.85\ AP_{33} + 0.93\ AP_{53} + 0.97\ AP_{63} + 0.9\ AP_{73} = 62$

$AP_{11} \leq 82.417580$

$AP_{22} \leq 114.583300$

$AP_{33} \leq 0$

$AP_{41} + AP_{42} \leq 0$

$AP_{51} + AP_{53} \leq 0$

$AP_{62} + AP_{63} \leq 63.917520$

$AP_{71} + AP_{72} + AP_{73} \leq 0$

$AP_{11}, AP_{41}, AP_{51}, AP_{71}, AP_{22}, AP_{42}, AP_{62}, AP_{72}, AP_{33}, AP_{53}, AP_{63}, AP_{73} \geq 0$

Optimal solution:

Objective function value: 2151.2650

Variable	Value	Variable	Value
AP_{11}	82.417580	AP_{62}	0.000000
AP_{41}	0.000000	AP_{72}	0.000000
AP_{51}	0.000000	AP_{33}	0.000000
AP_{71}	0.000000	AP_{53}	0.000000
AP_{22}	114.583300	AP_{63}	63.917520
AP_{42}	0.000000	AP_{73}	0.000000

<u>Example 3:</u>

We consider the same wage costs, activities and categories of workers as in example 1. Table 6 shows the given fuzzy personnel demands and table 7 shows the given fuzzy productivity factors:

	$\widetilde{PD}_q$
$q = 1$	$(72{,}80{,}18{,}20)$
$q = 2$	$(108{,}116{,}27{,}19)$
$q = 3$	$(60{,}64{,}15{,}16)$

Table 6: Fuzzy personnel demands

	$\tilde{\alpha}_r$
$r = 1$	(0.9,0.93,0.3,0.2)
$r = 2$	(0.95,0.98,0.25,0.1)
$r = 3$	(0.8,0.9,0.3,0.3)
$r = 4$	(0.93,0.96,0.3,0.4)
$r = 5$	(0.9,0.95,0.2,0.05)
$r = 6$	(0.95,1.0,0.1,0.1)
$r = 7$	(0.85,0.95,0.05,0.1)

Table 7: Fuzzy productivity factors

Model XII is shaped as follows:

$8\ AP_{11} + 9\ AP_{41} + 9\ AP_{51} + 10\ AP_{71} + 8\ AP_{22} + 9\ AP_{42} + 9\ AP_{62} + 10\ AP_{72} + 8\ AP_{33} +$

$+9\ AP_{53} + 9\ AP_{63} + 10\ AP_{73} \rightarrow$ min!

subject to:

$0.6\ AP_{11} + 0.63\ \ AP_{41} + 0.7\ AP_{51} + 0.8\ AP_{71} \geq 54$

$1.13\ AP_{11} + 1.36\ \ AP_{41} + \ AP_{51} + 1.05\ AP_{71} \leq 100$

$0.7\ AP_{22} + 0.63\ AP_{42} + 0.85\ AP_{62} + 0.8\ AP_{72} \geq 81$

$1.08\ AP_{22} + 1.36\ AP_{42} + 1.1\ AP_{62} + 1.05\ AP_{72} \leq 135$

$0.5\ AP_{33} + 0.7\ AP_{53} + 0.85\ AP_{63} + 0.8\ AP_{73} \geq 45$

$1.2\ AP_{33} + \ AP_{53} + 1.1\ AP_{63} + 1.05\ AP_{73} \leq 80$

$AP_{11} \leq \ P_1$

$AP_{22} \leq \ P_2$

$AP_{33} \leq \ P_3$

$AP_{41} + \ AP_{42} \leq \ P_4$

$AP_{51} + \ AP_{53} \leq \ P_5$

$AP_{62} + \ AP_{63} \leq \ P_6$

$AP_{71} + \ AP_{72} + \ AP_{73} \leq \ P_7$

$AP_{11}, AP_{41}, AP_{51}, AP_{71}, AP_{22}, AP_{42}, AP_{62}, AP_{72}, AP_{33}, AP_{53}, AP_{63}, AP_{73},\ P_1, \dots,\ P_7 \geq 0$

Optimal solution:

Objective function value: 2009.1180

Variable	Value
P_1	0.000000
P_2	0.000000
P_3	0.000000
P_4	0.000000
P_5	0.000000
P_6	148.235300
P_7	67.500000

Variable	Value	Variable	Value
AP_{11}	0.000000	AP_{62}	95.294110
AP_{41}	0.000000	AP_{72}	0.000000
AP_{51}	0.000000	AP_{33}	0.000000
AP_{71}	67.500000	AP_{53}	0.000000
AP_{22}	0.000000	AP_{63}	52.941170
AP_{42}	0.000000	AP_{73}	0.000000

Model XIII is shaped as follows:

$8\ AP_{11} + 9\ AP_{41} + 9\ AP_{51} + 10\ AP_{71} + 8\ AP_{22} + 9\ AP_{42} + 9\ AP_{62} + 10\ AP_{72} + 8\ AP_{33} +$

$+9\ AP_{53} + 9\ AP_{63} + 10\ AP_{73} \rightarrow$ min!

subject to:

$0.6\ AP_{11} + 0.63\ AP_{41} + 0.7\ AP_{51} + 0.8\ AP_{71} \geq 54$

$1.13\ AP_{11} + 1.36\ AP_{41} + AP_{51} + 1.05\ AP_{71} \leq 100$

$0.7\ AP_{22} + 0.63\ AP_{42} + 0.85\ AP_{62} + 0.8\ AP_{72} \geq 81$

$1.08\ AP_{22} + 1.36\ AP_{42} + 1.1\ AP_{62} + 1.05\ AP_{72} \leq 135$

$0.5\ AP_{33} + 0.7\ AP_{53} + 0.85\ AP_{63} + 0.8\ AP_{73} \geq 45$

$1.2\ AP_{33} + AP_{53} + 1.1\ AP_{63} + 1.05\ AP_{73} \leq 80$

$AP_{11} \leq P_1$

$AP_{22} \leq P_2$

$AP_{33} \leq P_3$

$AP_{41} + AP_{42} \leq P_4$

$AP_{51} + AP_{53} \leq P_5$

$AP_{62} + AP_{63} \leq P_6$

$AP_{71} + AP_{72} + AP_{73} \leq P_7$

$0.9\ AP_{11} + 0.93\ AP_{41} + 0.9\ AP_{51} + 0.85\ AP_{71} \geq 72$

$0.93\ AP_{11} + 0.96\ AP_{41} + 0.95\ AP_{51} + 0.95\ AP_{71} \leq 80$

$0.95\ AP_{22} + 0.93\ AP_{42} + 0.95\ AP_{62} + 0.85\ AP_{72} \geq 108$

$0.98\ AP_{22} + 0.96\ AP_{42} + \ AP_{62} + 0.95\ AP_{72} \leq 116$

$0.8\ AP_{33} + 0.9\ AP_{53} + 0.95\ AP_{63} + 0.85\ AP_{73} \geq 60$

$0.9\ AP_{33} + 0.95\ AP_{53} + \ AP_{63} + 0.95\ AP_{73} \leq 64$

$AP_{11}, AP_{41}, AP_{51}, AP_{71}, AP_{22}, AP_{42}, AP_{62}, AP_{72}, AP_{33}, AP_{53}, AP_{63}, AP_{73},\ P_1, \dots,\ P_7 \geq 0$

Optimal solution:

Objective function value: 2187.3680

Variable	Value
P_1	20.000010
P_2	104.210500
P_3	0.000000
P_4	0.000000
P_5	59.999990
P_6	72.631580
P_7	0.000000

Variable	Value	Variable	Value
AP_{11}	20.000010	AP_{62}	9.473584
AP_{41}	0.000000	AP_{72}	0.000000
AP_{51}	59.999990	AP_{33}	0.000000
AP_{71}	0.000000	AP_{53}	0.000000
AP_{22}	104.210500	AP_{63}	63.157890
AP_{42}	0.000000	AP_{73}	0.000000

Model XIV is shaped as follows:

$\lambda \rightarrow$ max!

subject to:

$0.6\ AP_{11} + 0.63\ \ AP_{41} + 0.7\ AP_{51} + 0.8\ AP_{71} \geq 54$

$1.13\ AP_{11} + 1.36\ \ AP_{41} + \ AP_{51} + 1.05\ AP_{71} \leq 100$

$0.7\ AP_{22} + 0.63\ AP_{42} + 0.85\ AP_{62} + 0.8\ AP_{72} \geq 81$

$1.08\ AP_{22} + 1.36\ AP_{42} + 1.1\ AP_{62} + 1.05\ AP_{72} \leq 135$

$0.5\ AP_{33} + 0.7\ AP_{53} + 0.85\ AP_{63} + 0.8\ AP_{73} \geq 45$

$1.2\ AP_{33} + \ AP_{53} + 1.1\ AP_{63} + 1.05\ AP_{73} \leq 80$

$AP_{11} \leq \ P_1$

$AP_{22} \leq \ P_2$

$AP_{33} \leq \ P_3$

$AP_{41} + \ AP_{42} \leq \ P_4$

$AP_{51} + \ AP_{53} \leq \ P_5$

$AP_{62} + \ AP_{63} \leq \ P_6$

$AP_{71} + \ AP_{72} + \ AP_{73} \leq \ P_7$

$18\ \lambda - 0.9\ AP_{11} - 0.93\ \ AP_{41} - 0.9\ AP_{51} - 0.85\ AP_{71} \leq -54$

$20\ \lambda + 0.93\ AP_{11} + 0.96\ \ AP_{41} + 0.95\ AP_{51} + 0.95\ AP_{71} \leq 100$

$27\ \lambda - 0.95\ AP_{22} - 0.93\ AP_{42} - 0.95\ AP_{62} - 0.85\ AP_{72} \leq -81$

$19\ \lambda + 0.98\ AP_{22} + 0.96\ AP_{42} + \ AP_{62} + 0.95\ AP_{72} \leq 135$

$15\ \lambda - 0.8\ AP_{33} - 0.9\ AP_{53} - 0.95\ AP_{63} - 0.85\ AP_{73} \leq -45$

$16\ \lambda + 0.9\ AP_{33} + 0.95\ AP_{53} + \ AP_{63} + 0.95\ AP_{73} \leq 80$

$178.25\ \lambda + 8\ AP_{11} + 9\ AP_{41} + 9\ AP_{51} + 10\ AP_{71} + 8\ AP_{22} + 9\ AP_{42} + 9\ AP_{62} +$

$+10\ AP_{72} + 8\ AP_{33} + 9\ AP_{53} + 9\ AP_{63} + 10\ AP_{73} \leq 2187.368$

$AP_{11}, AP_{41}, AP_{51}, AP_{71}, AP_{22}, AP_{42}, AP_{62}, AP_{72}, AP_{33}, AP_{53}, AP_{63}, AP_{73},\ P_1, \ldots,\ P_7, \lambda \geq 0$

Optimal solution:

Objective function value: 0.60204180

Variable	Value
λ	0.602042
P_1	0.000000
P_2	40.118320
P_3	0.000000
P_4	0.000000
P_5	47.755210
P_6	119.129800
P_7	25.714190

Variable	Value	Variable	Value
AP_{11}	0.000000	AP_{62}	62.255500
AP_{41}	0.000000	AP_{72}	0.000000
AP_{51}	47.755210	AP_{33}	0.000000
AP_{71}	25.714190	AP_{53}	0.000000
AP_{22}	40.118320	AP_{63}	56.874340
AP_{42}	0.000000	AP_{73}	0.000000

References

Adams, J.S. (1965): Inequity in social exchange, in: Advances in experimental social psychology, Berkowitz, L. (Ed.), Vol. 2, pp. 267–299, Academic Press: New York.

Akerlof, G.A. (1970): The Market for 'Lemons': Quality Uncertainty and the Market Mechanism, in: The Quarterly Journal of Economics, Vol. 84, No. 3, pp. 488–500.

Anderson, E.G./Joglekar, N.R. (2005): A Hierarchical Product Planning Development Planning Framework, in: Production and Operations Management, Vol. 14, No. 7, pp. 344-361.

Auer-Rizzi, W./Reber, G. (2013): Leadership styles: Inertia and changes in the Czech Republic, in: Journal for East European Management Studies, Vol. 18, No. 1, pp. 9-35.

Baldwin, J.F./Xie, D. (2005): Simple fuzzy logic rules based on fuzzy decision tree for classification and prediction problem, in: International Conference on Intelligent Information Processing (IIP2004), October 21–23, 2004, pp. 175-184, Springer US: China.

Bellmann R.E./Zadeh, L.A. (1970): Decision-Making in a Fuzzy Environment, in: Management Science, Vol. 17, No. 4, pp. 141-164.

Blake, R.R./Mouton, J.S. (1964): The managerial grid, Gulf Publishing: Houston.

Blake, R.R./Mouton, J.S. (1985): The managerial grid III, 3rd edition, Gulf Publishing: Houston.

Blake, R.R./Mouton, J.S./Bidwell, A.C. (1962): Managerial grid, in: Advanced Management-Office Executive, Vol. 1, No. 9, pp. 12-15.

Bouchon-Meunier, B. (1991): Inferences With Imprecisions and Uncertainities in Expert Systems, in: Kandel, A. (Ed.): Fuzzy Expert Systems, pp. 43-54, CRC Press: London et al.

Buckley, J.J./Eslami, E. (2002): An Introduction to Fuzzy Logic and Fuzzy Sets, Springer: Heidelberg/New York.

Cintra, M.E./Monard, M.C./Camargo, H.A. (2012): FuzzyDT - a fuzzy decision tree algorithm based on C 4.5, in: Proceedings of the Brazilian Congress on Fuzzy Systems, June 10-15, pp. 199-211, IEEE: Australia.

Coase, R.H. (1937): The nature of the firm, Winter, SG: Willianson.

Demsetz, H. (1967): Toward a Theory of property Rights, in: American Economic Review, Vol. 57, pp. 347-359.

Driankov, D./Hellendoorn, H./Reinfrank, M. (Eds.) (1993): An Introduction to Fuzzy Control, Springer: Berlin et al.

Drucker, P.F. (1954): The practice of Management, Harper & Row: New York.

Dubois, D./Ostasiewicz, W./Prade, H. (2000): Fuzzy Sets: History and Basic Notions, in: Dubois, D./Prade, H. (Ed.): Fundamentals of Fuzzy Sets, pp. 21-124., Springer: Boston et al.

Dubois, D./Prade, H. (1978): Operations on Fuzzy Numbers, in: International Journal of Systems and Science, Vol. 9, No. 6, pp. 613-626.

Dubois, D./Prade, H. (1980a): Fuzzy Sets and Systems: Theory and Applications, Academic Press: New York et al.

Dubois, D./Prade, H. (1980b): New results about properties and semantics of fuzzy set-theoretic operators, in: Wang, P.P./Chang, S.K. (Eds.): Fuzzy Sets, pp. 59-75, Springer: Boston.

Dubois, D./Prade, H. (1991): Fuzzy sets in approximate reasoning, Part 1: Inference with possibility distributions, in: Fuzzy Sets and Systems, Vol. 40, pp. 143-202.

Duncan, W.J./LaFrance, K.G./Ginter, P.M. (2003): Leadership and decision making: A retrospective application and assessment, in: Journal of Leadership & Organizational Studies, Vol. 9, No. 4, pp. 1-20.

Erffmeyer, E.S. (1983): The Vroom-Yetton Model of Decision Making: an Empirical Evaluation in Applied Settings, LSU Digital Commons: Louisiana (Doctoral dissertation, University of Louisiana).

Field, R.G. (1979): A critique of the Vroom-Yetton contingency model of leadership behavior, in: Academy of Management Review, Vol. 4, No. 2, pp. 249-257.

Field, R.G. (1982): A test of the Vroom-Yetton normative model of leadership, in: Journal of Applied Psychology, Vol. 67, No. 5, pp. 523-532.

Field, R.H./Andrews, J.P. (1998): Testing the incremental validity of the Vroom–Jago versus Vroom–Yetton models of participation in decision making, in: Journal of Behavioral Decision Making, Vol. 11, No. 4, pp. 251-261.

Field, R.H./House, R.J. (1990): A test of the Vroom-Yetton model using manager and subordinate reports, in: Journal of applied psychology, Vol. 75, No. 3, pp. 362-366.

Fleishman, E.A. (1960): Manual for leadership opinion questionnaire, Science Research Association: Chicago.

Fodor, J./Yager, R.R. (2000): Fuzzy-Set-Theoretic Operators and Quantifiers, in: Dubois, D./Prade, H. (Eds.): Fundamentals of Fuzzy Sets, pp. 125-193, Springer: Boston et al.

French, J.R.P./ Raven, B. (1959): The Bases of Social Power, in: Cartwright, D. (Ed.): Studies in Social Power, Institute for Social Itcsearch: Ann Arbor, pp. 259-269.

Garcia-Aguado, C./Verdegay, J.L. (1993): On the sensitivity of membership functions for fuzzy linear programming problems, in: Fuzzy Sets and Systems, Vol. 56, No. 1, pp. 47-49.

Gomolka, E.G./Mackin, J.L. (1984): Individual vs. Group Grade: An Exercise in Decision Making, in: Developments in Business Simulation and Experiential Learning, Proceedings of the Annual ABSEL conference, Hawaii, Vol. 11, pp. 128-132.

Gottwald, S. (1993): Fuzzy Sets and Fuzzy Logic. Foundations of Application from a Mathematical Point of View, Springer: Wiesbaden.

Hackman, J.R./Oldham, G.R. (1976): Motivation through the design of work: Test of a Theory, in: Organizational Behavior and Human Performance, No. 16, pp. 205-279.

Hall, L.O./Kandel, A. (1991): The Evolution From Expert Systems to Fuzzy Expert Systems, in: Kandel, A. (Ed.): Fuzzy Expert Systems, pp. 3-21, CRC Press: London et al.

Hall, L.O./Lande, P. (1998): Generation of Fuzzy Rules from Decision Trees, in: Journal of Advanced Computational Intelligence and Intelligent Informatics, Vol. 2, No. 4, pp. 128-133.

Halpin, A.W. (1957): Manual for the leader behavior description questionnaire, Columbus: Bureau of Business Research, Ohio State University.

Heckhausen, J./Heckhausen, H. (Eds.) (2018): Motivation and action, 3rd edition, Springer International: Cham.

Hersey, P./Blanchard, K.H. (1969): Management of organizational behavior, Eaglewood Cliffs: New York.

Hill, T.E./Schmitt, N. (1977): Individual differences in leadership decision making, in: Organizational Behavior and Human Performance, Vol. 19, No. 2, pp. 353-367.

Horgan, D.D./Simeon, R.J. (1990): Mentoring and participation: An application of the Vroom-Yetton model, in: Journal of Business and Psychology, Vol. 5, No. 1, pp. 63-84.

Humble, J.W. (1973): How to manage by objectives, Amacom: New York.

Jago, A.G./Ettling, J.T./Vroom, V.H. (1985): Validating a Revision to the Vroom/Yetton Model: First Evidence, in: Academy of Management Proceedings, Vol 1985, No. 1, pp. 220-223.

Janikow, C.Z. (1998): Fuzzy decision trees: issues and methods, in: IEEE Transactions on Systems, Man, and Cybernetics - Part B (Cybernetics), Vol. 28, No. 1, pp. 1-14.

Katz, D./Kahn, R.L. (1966): The Social Psychology of Organizations, Wiley: New York.

Klement, E.P./Mesiar, R./Pap, E. (2004): Triangular norms. Position paper I: basic analytical and algebraic properties, in: Fuzzy Sets and Systems, Vol. 143, pp. 5-26.

Koopmans, T.C. (1951): Analysis of production as an efficient combination of activities, in: Koopmans, T.C. (Ed.): Activity analysis of production and Allocation, pp. 33-97, John Wiley & Sons: New York et al.

Lertworaprachaya, Y./Yang, Y./John, R. (2010): Interval-valued fuzzy decision trees, in: International Conference on Fuzzy Systems, July 18-23, pp. 1-7, IEEE: Spain.

Likert, R. (1967): The human organization: its management and values, McGraw-Hill: New York.

Locke, E.A./Shaw, K.N./Saari, L.M./Latham, G.P. (1981): Goal setting and task performance, in: PB 90/1981, pp. 125-152.

Lunenburg, F.C. (2010): Models of decision making, in: Focus on Colleges, Universities, And Schools, Vol. 4, No. 1, pp. 1-9.

Mamdani, E.H. (1981): Advances in the Linguistic Synthesis of Fuzzy Controllers, in: Mamdani, E.H./Gaines, B.R. (Eds.): Fuzzy Reasoning and its Applications, pp. 311-323, Academic Press: London.

Margerison, C./Glube, R. (1979): Leadership decision-making: An empirical test of the vroom and yetton model, in: Journal of Management Studies, Vol. 16, No. 1, pp. 45-55.

Negoita, C.V./Sularia, M. (1976): On fuzzy Mathematical Programming and Tolerances in Planning, in: Economic Computation and Economic Cybernetics Studies and Research, pp. 3-15.

Odiorne, G.S. (1973): MBO II, Fearon Pitman Publishers, Inc: Belmont, Ca., USA.

Olaru, C./Wehenkel, L. (2003): A complete fuzzy decision tree technique, in: Fuzzy sets and systems, Vol. 138, No. 2, pp. 221-254.

Pap, E. (2002): Aggregation Operators in Engineering Design, in: Calvo, T./Mayor, G./Mesiar, R. (Eds.): Aggregation Operators. New Trends and Applications, pp. 195-223, Physica: Heidelberg, New York.

Pate, L.B./Heiman, D.C. (1987): A Test of the Vroom-Yetton Decision Model in Seven Field Settings, in: Personnel Review, Vol. 16, No. 2, pp. 22-26.

Peabody, R.L. (1964): Organizational Authority, Atherton Press: New York.

Pedrycz, W. (1993): Fuzzy Control and Fuzzy System, 2. Edition, Wiley: New York et al.

Piegat, A. (2001): Fuzzy Modeling and Control, Physica: Heidelberg, New York.

Pratt, J.W./Zeckhauser, R.J. (1985): Principals and agents: The structure of business, Harvard Business School Press: Boston.

Presthus, R.V. (1962): Perceptions of Organizational Behavior: A Comparative Analysis, in: Administrative Science Quarterly, Vol. 6, No. 4, pp. 463-482.

Reddin, W.J. (1970): Managerial effectiveness, ERIC Institute of Educational Science: New York.

Rommelfanger, H. (1989a): Inequality relations in fuzzy constraints and its use in linear fuzzy optimization, in: Verdegay, J.L./Delgado, M. (Eds.): The interface between artificial intelligence and operations research in fuzzy environment, TÜV: Rheinland, pp. 195-211.

Rommelfanger, H. (1989b): Interactive decision making in fuzzy linear optimization problems, in: European Journal of Operational Research, Vol 41, pp. 210-217.

Rommelfanger, H. (1990): FULPAL – An interactive method for solving (multiobjective) fuzzy linear programming problems, in: Slowinski, R./Teghem, J. (Eds.): Stochastic versus fuzzy approaches to multiobjective mathematical programming under uncertainty, pp. 279-299, Springer: London et al.

Ross, S.A. (1973): The economic theory of agency: The principal's problem, in: The American economic review, Vol. 63, No. 2, pp. 134-139.

Samosudova, N.V. (2017): Modern leadership and management methods for development organizations, MATEC Web of Conferences, October 28 – November 01, 2016, in: EDP Sciences, Taiwan, pp. 1-10.

Schneeweiß, C. (1998): Hierarchical planning in organizations: Elements of a general theory in: Int. Journal of Production Economics, Vol. 56-57, pp. 547-556.

Schneider, M./Kandel, A. (1991): General Purpose Fuzzy Expert Systems, in: Kandel, A. (Ed.): Fuzzy Expert Systems, pp. 23-41, CRC Press: London et al.

Shartle, C.L. (1979): Early Years of the Ohio State University Leadership Studies, in: Journal of Management, Ohio, Vol. 5, No. 2, pp. 127-134.

Shavell, S. (1979): Risk Sharing and Incentives in the Principal and Agent Relationship, in: Bell Journal of Economics, pp. 55-73.

Siegling, K.M./Spengler, T./Herzog, S. (2023): Rule-based systems for leadership style selection, in: FEMM Working Paper Series, Working Paper No. 07/2023, Magdeburg.

Spengler, T./Herzog, S. (2023): Defuzzification in Scenario Management – A theoretical and practical Guide, in: FEMM Working Paper Series, Working Paper No. 05/2023, Magdeburg.

Stogdill, R.M. (1963): Manual for the LBDQ-form XII, Columbus: Bureau of Business Research, Ohio State University.

Stogdill, R.M./Coons, A.E. (1957): Leader behavior: Its description and measurement, Columbus: Bureau of Business Research, Ohio State University.

Tannenbaum, R./Schmidt, W.H. (1958): How to choose a leadership pattern, in: Harvard Business Review Press, Vol. 51, No. 3, pp. 95-101.

Vignesh, M. (2020): Decision Making using Vroom-Yetton-Jago model with a practical application, in: International Journal for Research in Applied science & Engineering Technology, Vol. 8, No. 1, pp. 330-337.

Vroom, V.H. (1959): Some personality determinants of the effects of participation (Doctoral dissertation, University Göttingen).

Vroom, V.H. (1964): Work and motivation, John Wiley Sons: New York, London and Sydney.

Vroom, V.H. (1967): Leadership, in: Dunnette, M.D. (Ed.): Handbook of Industrial and Organizational Psychology, pp. 1527-1551, Rand McNally College Publishing Company: Chicago.

Vroom, V.H. (2003): Educating managers for decision making and leadership, in: Management decision, Vol. 41, No. 10, pp. 968-978.

Vroom, V.H./Jago, A.G. (1988): Managing participation: A critical dimension of leadership, in: Journal of Management Development, Vol. 7, No. 5, pp. 32-42.

Vroom, V.H./Jago, A.G. (1995): Situation effects and levels of analysis in the study of leader participation, in: The Leadership Quarterly, Vol. 6, No. 2, pp. 169-181.

Vroom, V.H./Jago, A.G. (2007): The role of the situation in leadership, in: American psychologist, Vol. 62, No. 1, pp. 17-24.

Vroom, V.H./Yetton, P.W. (1973): Leadership and decision-making, University of Pittsburgh Press: USA.

Vroom, V./Yetton, P.W./Jago, A. (2015): Normative decision process theory, in: Miner, J.B. (Ed.): Organizational Behavior 1. Essential theories of Motivation and Leadership, pp. 207-232, Routledge: London and New York.

Wang, H.-F./Chang, W.-Y. (2000): Fuzzy Scenario Analysis in Strategic Planning, in: Int. J. General Systems, Vol. 30, No. 2, pp. 193-207.

Weber, M. (1947): The theory of social and economic organization. Oxford University Press: Oxford.

Wedley, W.C./Field, R.H. (1984): A predecision support system, in: Academy of Management Review, Vol. 9, No. 4, pp. 696-703.

Weiner, B. (1985): An attributional theory of achievement-related emotion and motivation, in: Psychological Review, Vol. 29, pp. 548-573.

Williamson, O.E. (1975): Markets and hierarchies: Analysis and antitrust implications, Free Press: New York.

Yager, R.R. (1980): On a General Class of Fuzzy Connectives, in: Fuzzy Sets and Systems, Vol. 3, No. 3, pp. 235-242.

Yager, R.R. (1991): On the Representation of Relational Production Rules in Expert Systems, in: Kandel, A. (Ed.): Fuzzy Expert Systems, pp. 55-67, CRC Press: London et al.

Yuan, Y./Shaw, M.J. (1995): Induction of fuzzy decision trees, in: Fuzzy Sets and systems, Vol. 69, No. 2, pp. 125-139.

Zadeh, L.A. (1965): Fuzzy Sets, in: Information and Control, Vol. 8, pp. 338-353.

Zadeh, L.A. (1975): The Concept of a Linguistic Variable and its Application to Approximate Reasoning – Part I, in: Information Sciences, Vol. 8, pp. 199-249.

Zadeh, L.A. (1983): The role of fuzzy logic in the management of uncertainty in expert systems, in: Fuzzy sets and systems, Vol. 11, No. 1-3, pp. 199-227.

Zadeh, L.A. (1987): The Concept of a Linguistic Variable and its Application to Approximate Reasoning – Part II, in: Yager, R.R./Ovchinnikov, S./Ton, R.M./Nguyen, H.T. (Eds.): Fuzzy Sets and Applications: Selected Papers by L.A. Zadeh, pp. 271-327, Wiley: New York et al.

Zimmer, R.J. (1978): Validating the Vroom-Yetton normative model of leader behavior in field sales force management and measuring the training effect of Telos on the leader behavior of district managers (Doctoral dissertation, Virginia Tech University).

Zimmermann, H.-J. (1987): Fuzzy Sets, Decision Making, and Expert Systems, Kluwer Academic: Boston et al.

Zimmermann, H.-J. (1996): Fuzzy Set Theory – and Its Applications, Third Printing, Kluwer-Nijhoff: Boston et al.

Otto von Guericke University Magdeburg
Faculty of Economics and Management
P.O. Box 4120 | 39016 Magdeburg | Germany

Tel.: +49 (0) 3 91 / 67-1 85 84
Fax: +49 (0) 3 91 / 67-1 21 20

www.fww.ovgu.de/femm

ISSN 1615-4274