Remuneration System for Professionals with Requirements for Efficiency and Sustainable Quality. 2. Application of Priority Distribution Method

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Abstract. Usage of decision support methods allows to solve practical tasks of big importance. The systematic approach of Priority Distribution Method's practical application for healthcare provider organizations is created and described.

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Introduction

Previous publication [1] was devoted for analysis of the *Priority Distribution Method* (PDM). This work is aimed to the usage of PDM for inpatient healthcare providers by means of following methods: decision support, data mining for the determination of performance indicators and subsequent monitoring of the achieved results.

The article illustrates the practical solution how to use the mentioned methods for healthcare provider organizations; how to evaluate the value of each job profile, considering subjective and objective social factors which might affect the salary amount.

1. PDM application in healthcare in-patient facilities

In this section we will create a performance related remuneration model for a hypothetical inpatient healthcare facility. We will use PDM to create a performance related payment model for a hospital's ward physicians and nurses.

Table 1. Qualitative and quantitative indicators for performance evaluation.

Indicators	Quantitative criteria	Qualitative criteria
inpatient facilities	average length of stay; ratio of inpatient day surgery visits to overall inpatient visits (including surgery); mortality rate; frequency of pressure sores in bedridden patients; usage of disinfectant liquids.	patient satisfaction level; participation in internal training programs; practiced hygiene level.
healthcare quality and key performance	postoperative complications rate; rehospitalization rate; medical errors / claims.	
non - domain specific criteria	work hours; shift coefficient; medical qualification coefficient; experience coefficient; number of non-compliance / audit issues; number of claims.	team work orientation; help to colleagues; discipline.

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Table 2. Nurse performance evaluation indicators.

Code	Criteria	Description
k_1	Work hours × shift coefficient × medical qualification coefficient	Composite evaluation of workload, assuming different ratios for weekday and night shifts and formally acquired medical qualifications
k_2	Accumulative number of registered issues and claims per quarter	Number of internal issues or external claims during ongoing quarter
k_3	Teamwork ability (half year/yearly)	Shares information with colleagues. Ready to help colleagues. Demonstrates positive attitude. Problem solving orientation
k_4	Personal discipline (half year/yearly)	Physician or head nurse orders performed in time and in quality. Documentation activities performed according to hospital rules
k_5	Average quarter length of stay to average LOS ratio	Quarterly average patients' LOS compared to the country or region's normative average LOS for the ward's specialty
k_6	Mortality rate to average mortality rate ratio	Half yearly or annual average patients' mortality rate compared with the country or region's normative average mortality rate for the ward's specialty
k_7	Frequency of pressure sore in bedridden patients to average frequency ratio	Half yearly or annual amount of pressure sore patient incidents
k_8	Practiced hygiene level	Quarterly quality metric, according to hospital standard (e.g. usage of disinfectant liquids, hygiene quality checks)
k_9	Patient satisfaction level	Half yearly or annual quality metric defined and digitized thorough patient surveys
k_{10}	Participation in internal training programs	Annual quality metric, defined as a percentage of participation in internal training programmes or individual yearly goals

Table 3. Ward physician performance evaluation indicators.

Code	Criteria	Description
k_1	Work hours' × shift coefficient × medical qualification coefficient	Composite evaluation of workload, assuming different ratios for weekday and night shifts and formally acquired medical qualifications
k_2	Accumulative number of registered issues and claims per quarter	Number of internal issues or external claims during ongoing quarter
k_3	Teamwork ability (half year/yearly)	Shares information with colleagues. Ready to help colleagues. Demonstrates positive attitude. Problem solving orientation
k_4	Personal discipline (half year/yearly)	Orders of superior performance in time and in quality. Documentation of activities performed according to the hospital rules
k_5	Average quarter length of stay to average LOS ratio	Quarterly average patients LOS compared to the country or region's normative average LOS for the ward's specialty
k_6	Mortality rate to average mortality rate ratio	Half yearly or annual average patient's mortality rate compared to the country or region's normative average mortality rate for the ward's specialty
k_7	Postoperative complications rate	Half yearly or annual average patients' postoperative complications rate compared to the country or region's normative average rate for the ward's specialty
k_8	Rehospitalization rate	Half yearly or annual average patients rehospitalization rate compared to the country or region's normative average rate for the ward's specialty
k_9	Patient satisfaction level	Half yearly or annual quality metric defined and digitalized thorough patient surveys
k_{10}	Participation in internal training programmes	Annual quality metric, defined as percentage of participation in internal training programmes or individual year goals

As was stated previously, the initial step of PDM is to define indicators which will be used to evaluate the overall outcome of the job. For our use case example, we will use HPOs' performance indicators as approved by the MOH of the Republic of Lithuania in 2012 [2], which aim to raise overall treatment quality and become a strong complementary evaluation to the quantitative metrics of provided medical services. Some of them can be aggregated and successfully projected to the personal employee job evaluation indicators. To restrict different types of healthcare providers and their operation modes, we will use indicators applicable to the general profile hospitals.

The following quantitative and qualitative indicators from the inpatient facilities indicators list [2] were selected as presented in Table 1. Additionally the following healthcare quality and key performance indicators and non-domain specific criteria will be added.

Let us define the criteria sets for ward physicians and ward nurses combining both criteria lists. The ward nurse job profile criteria can be defined as presented in Table 2. The ward physician job profile criteria can be defined as presented in Table 3.

To rank and weigh the identified criteria, we use pair wise comparison as defined in PDM. Below, we provide exempla-

ry calculations, which should be recalculated for each healthcare institution, aiming to apply this method. As explained before, the nature of financing model used in each particular facility will strongly affect individual personnel motivation. Therefore, the ranking and weight of the criteria defined will differ from one healthcare organization to the other.

As a second PDM step, all defined criteria are compared in pairs by the expert panel. The resulting tables for physicians and nurses criteria are provided - Table 4 and Table 5, respectivelly. Using the results of pair wise comparison, the priority matrixes with justifiable a_{ij} are derived - see Table 6 and Table 7.

After the series of priority matrix perturbations described in PDM, K_r estimation error is minimized. Thus when $K_r^f \neq K_r$, z value is adjusted by multiplying it by correction coefficient α iteratively. After the series of initial matrix transformations, the priority matrixes are calculated, see Table 8 and Table 9.

The normalized weight $P_i^{'}$ of each criterion is derived in the resulting matrixes. When the criteria weights are defined, the next step is to evaluate each employee of the same position, i.e. nurse or physician, by assigning measured values for each criterion. This can be done in a number of ways. For quantitative indicators it is a mathematically trivial operation. However, for the qualitative criteria different approaches exist. The formal evaluation is typically easier for hospitals where routine HR processes are established and all employees undergo regularly scheduled performance appraisal meetings. In other cases, we suggest to use PDM to derive possibly more neutrally scored values of employees' qualitative features.

The overall employee performance related value (PRV) calculation is based on derived criteria weights (see Table 10) and measured or evaluated by individual employee's indicator values. Mentioned table was used for ward nurses and physicians PRV calculation.

The overall i-th employee value for j-th criterion equals to product G:

$$G_{i,j} = P_j^{'} \times p_i^{'} \tag{1}$$

The employee's performance related value equals the sum of overall employee's criterion values:

$$PRV_i = \sum_{k=1}^{j} p_{ik}^{'} \times P_k^{'} \tag{2}$$

where i-th - employee and j - number of criteria.

Applying the calculated employee performance related value, the variable salary part is calculated as follows:

$$Salary_{var,i} = Salary_{fix,i} \times K \times PVR \tag{3}$$

where $Salary_{var,i}$ represents the i-th employee variable salary part (performance related pay); $Salary_{fix,i}$ represents the i-th employee fixed salary part.

Table 4. Ward nurses pairwise criteria comparison.
C - Criteria, AV - Average value

C	AV	C	AV	C	AV
w_1 vs w_2	>	w_2 vs w_9	<	w_5 vs w_6	<
w_1 vs w_3	>	w_2 vs w_{10}	>	w_5 vs w_7	<
w_1 vs w_4	>	w_3 vs w_4	<	w_5 vs w_8	<
w_1 vs w_5	>	w_3 vs w_5	<	w_5 vs w_9	<
w_1 vs w_6	>	w_3 vs w_6	<	w_5 vs w_{10}	<
w_1 vs w_7	>	w_3 vs w_7	>	w_6 vs w_7	<
w_1 vs w_8	>	w_3 vs w_8	<	w_6 vs w_8	>
w_1 vs w_9	>	w_3 vs w_9	<	w_6 vs w_9	>
w_1 vs w_{10}	>	w_3 vs w_{10}	>	w_6 vs w_{10}	<
w_2 vs w_3	>	w_4 vs w_5	>	w_7 vs w_8	>
w_2 vs w_4	<	w_4 vs w_6	>	w_7 vs w_9	<
w_2 vs w_5	>	w_4 vs w_7	>	w_7 vs w_{10}	<
w_2 vs w_6	<	w_4 vs w_8	>	w_8 vs w_9	>
w_2 vs w_7	<	w_4 vs w_9	<	w_8 vs w_{10}	>
w_2 vs w_8	<	w_4 vs w_{10}	>	w_9 vs w_{10}	>

Table 5. Ward physician performance evaluation indicators.
C - Criteria, AV - Average value.

C	AV	C	AV	C	AV
w_1 vs w_2	>	w_2 vs w_9	<	w_5 vs w_6	<
w_1 vs w_3	>	w_2 vs w_{10}	>	w_5 vs w_7	<
w_1 vs w_4	>	w_3 vs w_4	<	w_5 vs w_8	<
w_1 vs w_5	>	w_3 vs w_5	<	w_5 vs w_9	<
w_1 vs w_6	>	w_3 vs w_6	<	w_5 vs w_{10}	<
w_1 vs w_7	>	w_3 vs w_7	<	w_6 vs w_7	>
w_1 vs w_8	>	w_3 vs w_8	<	w_6 vs w_8	>
w_1 vs w_9	>	w_3 vs w_9	<	w_6 vs w_9	>
w_1 vs w_{10}	>	w_3 vs w_{10}	>	w_6 vs w_{10}	<
w_2 vs w_3	>	w_4 vs w_5	>	w_7 vs w_8	<
w_2 vs w_4	<	w_4 vs w_6	>	w_7 vs w_9	<
w_2 vs w_5	>	w_4 vs w_7	<	w_7 vs w_{10}	>
w_2 vs w_6	<	w_4 vs w_8	<	w_8 vs w_9	<
w_2 vs w_7	<	w_4 vs w_9	<	w_8 vs w_{10}	>
w_2 vs w_8	<	w_4 vs w_{10}	>	w_9 vs w_{10}	>

Table 6. Initial priority matrix for a ward nurses criteria weight evaluation

i j	w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8	w_9	w_{10}	$\Sigma a_{i,j}$=b_i	P_i	$P_i^{'}$
w_1	1	1,404	1,404	1,404	1,404	1,404	1,404	1,404	1,404	1,404	13,6	135,59	0,1401
w_2	0,596	1	1,404	0,596	1,404	0,596	0,596	0,596	0,596	1,404	8,8	82,25	0,0850
w_3	0,596	0,429	1	0,596	0,596	0,596	1,404	0,596	0,596	1,404	7,8	76,31	0,0788
w_4	0,596	1,571	1,404	1	1,404	1,404	1,404	1,404	0,596	1,404	12,2	117,16	0,1210
w_5	0,596	0,429	1,571	0,429	1	0,596	0,596	0,596	0,596	0,596	7,0	66,85	0,0691
w_6	0,596	1,571	1,571	0,429	1,571	1	0,596	1,404	1,404	0,596	10,7	103,08	0,1065
w_7	0,596	1,571	0,429	0,429	1,571	1,571	1	1,404	0,596	0,596	9,8	94,77	0,0979
w_8	0,596	1,571	1,571	0,429	1,571	0,429	0,429	1	1,404	1,404	10,4	97,96	0,1012
w_9	0,596	1,571	1,571	1,571	1,571	0,429	1,571	0,429	1	1,404	11,7	112,34	0,1161
w_{10}	0,596	0,429	0,429	0,429	1,571	1,571	1,571	0,429	0,429	1	8,5	81,64	0,0843
Sum												967,96	1,0000

Table 7. Initial priority matrix for a ward physician physician's criteria weight evaluation

i j	w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8	w_9	w_{10}	$\Sigma a_{i,j}$=b_i	P_i	$P_i^{'}$
w_1	1	1,571	1,571	1,571	1,571	1,571	1,571	1,571	1,571	1,571	15,1	147,74	0,1643
w_2	0,429	1	1,571	0,429	1,571	0,429	0,429	0,429	0,429	1,571	8,3	68,65	0,0764
w_3	0,429	0,329	1	0,429	0,429	0,429	0,429	0,429	0,429	1,571	5,9	52,98	0,0589
w_4	0,429	1,671	1,571	1	1,571	1,571	0,429	0,429	0,429	1,571	10,7	93,90	0,1044
w_5	0,429	0,329	1,671	0,329	1	0,429	0,429	0,429	0,429	0,429	5,9	51,55	0,0573
w_6	0,429	1,671	1,671	0,329	1,671	1	1,571	1,571	1,571	0,429	11,9	113,36	0,1261
w_7	0,429	1,671	1,671	1,671	1,671	0,329	1	0,429	0,429	1,571	10,9	93,65	0,1042
w_8	0,429	1,671	1,671	1,671	1,671	0,329	1,671	1	0,429	1,571	12,1	107,85	0,1200
w_9	0,429	1,671	1,671	1,671	1,671	0,329	1,671	0,329	1	1,571	12,0	106,59	0,1186
w_{10}	0,429	0,329	0,329	0,329	1,671	1,671	0,329	0,329	0,329	1	6,7	62,72	0,0698
Sum												898,99	1,0000

Table 8. Resulting priority matrix for a ward nurses nurse's criteria weight evaluation

i j	w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8	w_9	w_{10}	$\Sigma a_{i,j}$=b_i	P_i	$P_i^{'}$
w_1	1	0,682	0,682	0,682	0,682	0,682	0,682	0,682	0,682	0,682	7,1	39,1	0,1389
w_2	0,289	1	0,682	0,289	0,682	0,289	0,289	0,289	0,289	0,682	4,8	24,1	0,0856
w_3	0,289	0,209	1	0,289	0,289	0,289	0,682	0,289	0,289	0,682	4,3	22,2	0,0788
w_4	0,289	0,763	0,682	1	0,682	0,682	0,682	0,682	0,289	0,682	6,4	34,0	0,1209
w_5	0,289	0,209	0,763	0,209	1	0,289	0,289	0,289	0,289	0,289	3,9	19,5	0,0695
w_6	0,289	0,763	0,763	0,209	0,763	1	0,289	0,682	0,682	0,289	5,7	29,9	0,1065
w_7	0,289	0,763	0,209	0,209	0,763	0,763	1	0,682	0,289	0,289	5,3	27,5	0,0978
w_8	0,289	0,763	0,763	0,209	0,763	0,209	0,209	1	0,682	0,682	5,6	28,6	0,1016
w_9	0,289	0,763	0,763	0,763	0,763	0,209	0,763	0,209	1	0,682	6,2	32,6	0,1160
w_{10}	0,289	0,209	0,209	0,209	0,763	0,763	0,763	0,209	0,209	1	4,6	23,7	0,0844
Sum												281,21	1,0000

Table 9. Resulting priority matrix for a ward nurses nurse's criteria weight evaluation

i j	w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8	w_9	w_{10}	$\Sigma a_{i,j}$=b_i	P_i	$P_i^{'}$
w_1	1	5,590	5,590	5,590	5,590	5,590	5,590	5,590	5,590	5,590	51,3	1601,9	0,1662
w_2	1,528	1	5,590	1,528	5,590	1,528	1,528	1,528	1,528	5,590	26,9	725,0	0,0752
w_3	1,528	1,172	1	1,528	1,528	1,528	1,528	1,528	1,528	5,590	18,5	570,0	0,0591
w_4	1,528	5,946	5,590	1	5,590	5,590	1,528	1,528	1,528	5,590	35,4	1001,4	0,1039
w_5	1,528	1,172	5,946	1,172	1	1,528	1,528	1,528	1,528	1,528	18,5	551,8	0,0573
w_6	1,528	5,946	5,946	1,172	5,946	1	5,590	5,590	5,590	1,528	39,8	1225,3	0,1271
w_7	1,528	5,946	5,946	5,946	5,946	1,172	1	1,528	1,528	5,590	36,1	994,6	0,1032
w_8	1,528	5,946	5,946	5,946	5,946	1,172	5,946	1	1,528	5,590	40,5	1151,9	0,1195
w_9	1,528	5,946	5,946	5,946	5,946	1,172	5,946	1,172	1	5,590	40,2	1137,6	0,1180
w_{10}	1,528	1,172	1,172	1,172	5,946	5,946	1,172	1,172	1,172	1	21,5	678,0	0,0704
Sum												9637,67	1,0000

Table 10. Performance related value matrix for ward nurses and physicians

Criterion weight value	Criteria rank weights and employee performance values									
Employee's personal label	$P_1^{'}$	$P_2^{'}$	$P_3^{'}$	$P_4^{'}$	$P_5^{'}$	$P_6^{'}$	$P_7^{'}$	$P_8^{'}$	$P_9^{'}$	$P_{10}^{'}$
$P_j^{'}$ for nurses	0,14	0,09	0,08	0,12	0,07	0,11	0,10	0,10	0,12	0,08
$P_j^{'}$ for physicians	0,17	0,08	0,06	0,10	0,06	0,13	0,10	0,12	0,12	0,07

2. Methods and toolsets for monitoring PDM efficiency

The described method for calculating performance related payment of medical personnel is theoretical and needs practical approbation. Therefore, it is essential to provide method and tools for evaluation of the PDM implementation's outcomes. The change of financial personnel incentives may lead to a wide spectrum of implications which, in turn, may influence organization activities not covered by the metrics of the selected PDM indicators. Hence, we propose methodology for monitoring and timely identification of PDM usage effects on HPO's operation. The application of statistical analysis, pattern recognition, dimension reduction and other data mining methods allows us to acquire more detailed information at early stages. Data mining can help determine if new patterns or associations come into force and the way they evolve after the introduction of the new employee remuneration scheme.

We propose the following systematic organization performance monitoring and evaluation approach:

Activity 1: Collect and analyze the change of each criterion K over time (time series analyses)

Activity 2: Calculate correlation coefficient to determine the influence of criterion weight to the measured values of PDM indicators.

Activity 3: Perform direct association rules analyses, i.e. generate rules on acquired PDM indicator values and analyze the interdependent rules.

Activity 4: Perform comprehensive association rules analyses, i.e. generate rules on all available indicators collected from an HPO's medical information systems, e.g. HIS, EMR.

The 1st activity is a basic one and shows direct results of PDM application. Different visualization methods shall be applied for periodic analyses of change in indicators. Following our case example, two visualizations of the values of criteria set's $w_n[w_1; w_{10}]$ changes over a period of 6 months, are provided below. Fig. 1 illustrates normalized measured criteria values. The normalization was performed by rescaling values to [0;1] scale and applying weight calculated by PDM. The minimized values were adjusted to its maximizing values.

Fig. 2 represents the same trend applying dimension reduction. In this example elementary reductions to criteria value sum and mean values were performed.

The next recommended step is to formally calculate correlation R_n (2nd activity) of criterion K_n weight and averaged measured indicator value. Linear regression calculation may be used, which provides statistically well-defined evaluation criteria. Higher correlations coupled with higher variance of measured indicator values will show higher effect of the indicator weight in the applied PDM model.

Finally, deeper analyses for hidden effects may be applied by using association rules learning or inductive logic programming methods. Identified rules with higher confidence and smaller support values will identify non-obvious rules with higher correctness of the rule. Different existing algorithms can be applied for association rules discovery. Depending on the quality of the existing data (missing data and noisy data), appropriate algorithms shall be applied.

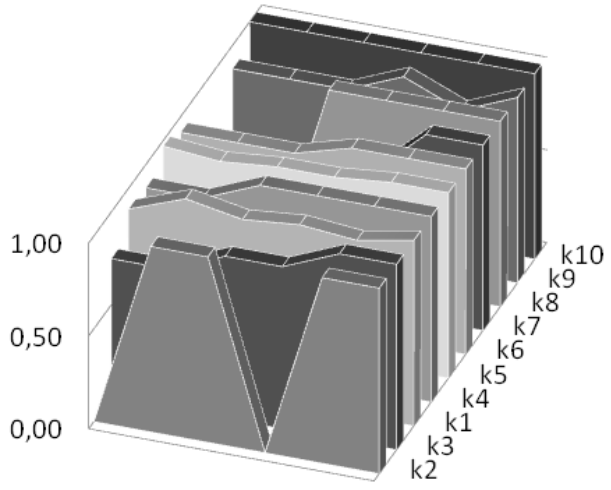

Fig. 1. The trend of measured PDM criteria values over 6 months.

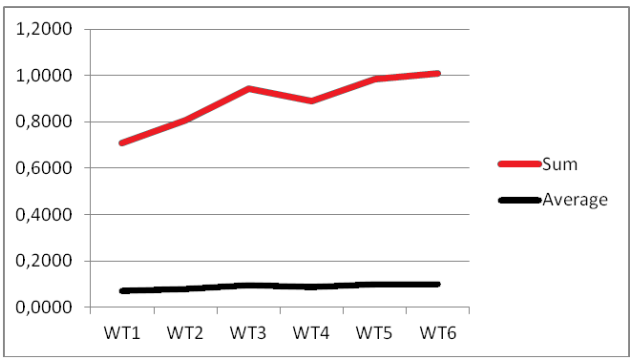

Fig. 2. The trend of descaled PDM criteria values over 6 months.

According to multiple researches the best results are achieved by performing data preprocessing, proper parametrization and applying a set of different DM algorithms [3,4].

From a system engineering perspective, each organization is a complex system interfacing with other external systems. Therefore, the information gained in activities 2-4 should be considered with care, by involving domain experts and analyzing critically the causes of each change.

Conclusions

For the understanding of the applied PDM outcomes the routine monitoring and recurring evaluation of individual and overall HPO performance will be performed. The change of financial personnel incentives may also lead to unpredictable implications, which could influence the provider's activities not covered by the indicators selected for PDM. Therefore, four activities allowing direct and indirect evaluation of enterprise operation were proposed. Data visualization and dimension reduction techniques are useful for regular monitoring of criteria used in PDM. Criteria weight and measured criteria values change correlation analyses may be used for more formal evaluation of the resulting criterion weighed rank performance. Finally, data mining methods, i.e. association rules mining, and inductive logic programming may be used for the discovery of hidden patterns.

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