Multivariate Optimization of PMBOK, Version 6 Project Process Relevance

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Abstract: This article examines the use of multivariate optimization, as a method, to improve the success of project management tasks. The optimization approach is founded on 8 selected continuous project processes of the execution phase of the PMBOK project management framework. Using a custom-developed, online portal, 103 data sets were collected from project management practitioners, indicating their individual distribution of effort and focus on the selected project processes, as well as, the current health status of their project. Based on this dataset, stepwise regression combined with optimization applying a sequential quadratic programming method was used to define the distribution of project process relevance thereby maximizing the project health.

Keywords: Process Optimization; Multivariate Optimization; Project Management; PMBOK

1 Introduction

Managing a project involves a versatile approach and related skillsets. Although every project is said to be different and unique, project management frameworks like the project management body of knowledge (PMBOK) [1], ICB4 of the International Project Management Association [2], or PRINCE2 framework of Axelos [3] push towards a standardized project management approach by providing certifications and guidelines on how to act as a successful project manager. The basic question underlying this research article is the field of tension between a rigid standardized guideline and framework of how to manage a project and the uniqueness of projects and the individuality of project managers.

Project management frameworks provide different guidelines on how to successfully manage a project. They do not indicate the scope of the different tasks. This situation provides freedom for experienced project managers, but at the same time it can make decisions harder for unexperienced project managers [4], particularly in agile managed IT projects [5]. The fact that decisions are challenging for project managers is also highlighted by the Chaos Report [6] detailing that IT projects only have success rates between 11% in case of waterfall development and 39% in case of agile development.

2 Definitions based on Literature Review

This research uses mathematical methods of multivariate regression and optimization as an attempt to define the most successful way of managing different kinds of projects. In contrast to a dynamic modeling and optimization of project processes based on ER methodologies as described by Kukushkin and Zykov [7], the optimization relies on collected data of project management practitioners. However, before describing in detail how these methods are used, several definitions and terms need to be explained:

Project Process

PMBOK as a project management framework defines in its sixth version 49 project processes. These processes are tasks and activities a project manager has to perform and cover in his or her daily work, such as doing a risk analysis with sophisticated approaches like fuzzy [8] or PRISM [9] based decision-making methods, controlling the budget or keeping the stakeholders engaged. In other words, project processes can be seen as a toolbox of activities a project manager can choose from.

Project Process Relevance

The hypothesis underlying the present research claims, that project managers may decide individually how much focus and time they devote to certain project processes. The amount of focus and time a project manager puts into a certain project process is defined as "project process relevance" is in this research. Using such an approach, business process management (BPM) practices [10] can be applied. The project manager then also covers the role of a process analyst [11] being responsible for monitoring, measuring and optimizing his or her own way of working [12].

Project Process Relevance Distribution

Project process relevance distributions are the input of the multivariate optimization. In the survey, project managers are asked to distribute their individual project process relevance in a specific project of their choosing. As a project is structured in phases, starting at the initiation phase and ending at the closing phase, not all 49 project processes defined in the PMBOK are relevant at the same time. This research shall only act as a proof of concept and therefore, only uses continuous project processes of the execution phase. The advantage of this restriction is a drastic reduction of complexity in the optimization.

Project Health Factors

Project Health Factors are used as the output side of the optimization, measuring the current "health" of a project. The term "success" of a project is not used, because a lot of the datasets are related to ongoing projects, which have not achieved success yet. However, project managers can often provide an indication of the current status regarding budget, scope, schedule and people [13] or more specific, customer satisfaction. Combing these four project health factors to one single output value provides the necessary output side of the optimization. The approach of converting multiple responses to a single response is based on the idea described by Khuri and Conlon [14]. However, a complex vector-distance based model did not seem necessary for the simple goal of combining result variables. Consequently, a amalgamation approach, as in signal noise ratio research [15], was selected. Constrained optimization, defining one single output factor as leading and the others as constraints [16] is not used, because all project health factors are considered equally important for overall project success.

3 Methodology

3.1 Definition of Optimization Focus

To prove that multivariate optimization can be used to optimize the way project managers work, a project management framework was chosen. PMBOK by PMI organization is, with over 500,000 members [17] and its focus on clear tasks, documentation and processes [18], the chosen framework for this research rather than soft skill-related activities that are hard to evaluate.

As many of the survey participants are currently working in a specific project, a project phase was selected. Although planning as a phase is mentioned as a critical success factor [19], the execution phase, which can have quite a long duration comprising the bulk of the project work [20], was selected for this research. The execution phase contains 10 processes, 8 of which are continuous processes, and the scope of the optimization approach.

Below a brief description of continuous processes and their ID of the selected execution phase can be seen [1]:

- **P1 = Direct and Manage Project Work** - the process of leading and performing the work defined in the project management plan and implementing approved changes to achieve the project objectives.

- **P2 = Manage Project Knowledge** - the process of using existing knowledge and creating new knowledge to achieve the project objectives and contribute to organizational learning.
- **P3 = Manage Quality** - the process of translating the quality management plan into executable quality activities that incorporate the organization's quality policies into the project.
- **P4 = Develop Team** - the process of improving competencies, team member interaction, and overall team environment to enhance project performance.
- **P5 = Manage Team** - the process of tracking team member performance, providing feedback, resolving issues, and managing team changes to optimize project performance.
- **P6 = Manage Communications** - the process of ensuring timely and appropriate collection, creation, distribution, storage, retrieval, management, monitoring, and the ultimate disposition of project information.
- **P7 = Implement Risk Responses** - the process of implementing agreed-upon risk response plans.
- **P8 = Manage Stakeholder Engagement -** the process of communicating and working with stakeholders to meet their needs and expectations, address issues, and foster appropriate stakeholder involvement.

Four project health factors have been selected as the optimization output. The classical project success triangle of budget, scope and schedule [21] has been enriched based on the concept of van Wyngaard et al. [22] with an additional factor of customer satisfaction, since especially in IT projects high customer satisfaction and resulting project success are possible even without keeping the initially defined scope, budget or schedule.

3.2 Sampling Procedures

Sample selection was performed by disseminating the invitation for participation of project management practitioners on social networks like LinkedIn or Facebook, sending emails to a network of former Technical Management students at the UAS "FH Campus Wien" in Vienna and addressing suitable participants directly in networking events and conferences. All persons previously or currently involved in project management in different roles were able to participate. An estimated number of 600 invitiations sent over a period of 18 months, led to 103 actual and valid, survey completions.

Additionally, current students at the involved universities (Vienna/Budapest) with previous work experience in those fields were invited to participate even if they did not work in management; basic knowledge of project work and PMI project processes was sufficient. This ensured that participants with various levels of experience were included in the study, thus allowing candidates with different perceptions of project management to contribute to ensure a wide variety of insights.

3.3 Questionaire Design

The actual data collection was implemented using a custom-programmed data collection cloud-based web portal [23], since out of the box survey software solutions did not provide the specific capability of distributing relevance factors.

Link: https://agile-projects-survey.herokuapp.com/home

Besides distributing project process relevance distributions as the input parameter and project health factors as the output parameter, the survey participants also entered characteristics of their background and projects. These additional characteristics are not interpreted in the research results as such, other than in the following chapter summarizing the respondents' characteristics.

3.4 Respondents

Of the 103 people who answered the survey, 73% are male, 27% are female. 45% of the participants are aged between 20 and 30 years, 33% between 30 and 40 years and the remaining participants are of older age. A majority of 86 people has completed university education, and half of the participants (51%) are experienced as project managers or project sponsors. Most participants (51%) work in Management and Business, IT and Financial related industries.

52% of the participants work with agile [24] or at least hybrid [25] project management frameworks.

3.5 Initial Statistical Analysis

A basic statistical analysis of the input and output factors resulted in below average and standard deviation results:

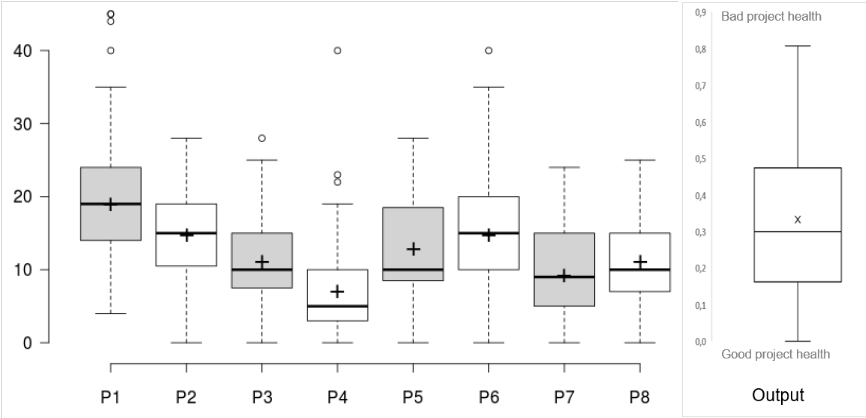

Figure 1
Box Plot Statistics

Source: self-edited

Table 1
Box Plot Statistics

	P1	P2	P3	P4	P5	P6	P7	P8	Output
Upper whisker	35.00	28.00	25.00	19.00	28.00	35.00	24.00	25.00	9.00
3rd quartile	24.00	19.00	15.00	10.00	18.50	20.00	15.00	15.00	6.00
Median	19.00	15.00	10.00	5.00	10.00	15.00	9.00	10.00	4.00
1st quartile	4.00	10.50	7.50	3.00	8.50	10.00	5.00	7.00	3.00
Lower whisker	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
N	103	103	103	103	103	103	103	103	103

Source: self-edited

3.6 Selection of Suitable Multivariate Regression Methods and Optimization Approaches

The next step, after the successful collection of data, is to select the most suitable multivariate regression and optimization approach for the data and its conditions.

Optimization consists of two steps, the first being regression of data points on the input side. The second step is the actual optimization. Depending on the nature of the data and the underlying conditions, different regression approaches need to be evaluated for applicability. Nine different regression methods were selected for evaluation. The table below outlines the methods, a brief introduction and reason for selection or dismissal of the method.

Table 2
Regression Method Selection

Regression Method	Description	Applicability for data set
Least Square	One of the oldest and most used regression methods. Can be used when there is a linear relationship between the dependent and independent variables.[26].	**Dismissed**. Scatterplot analysis indicates a nonlinear nature of the data.
Partial Least Square	This method uses the same approach as normal least square method; it does not address the original data, but uncorrelated variables instead. The main advantage of this method lies in the possibility to address multiple output variables if necessary [27].	**Dismissed**. Multiple output variables are not needed.
Polynomial Regression	This method creates a polynomial function with the following structure [28]: $p(x)=p_1x^n+p_2x^{n-1}+\cdots+p_nx+p_{n+1}$	**Dismissed.** Scatterplot analysis indicates a nonlinear behavior.
Logistic Regression	This method can be used if a categorical output is available and to make the output categories comparable with each other. This is especially helpful if future predictions are needed about how the input will be assigned to a specific output category [29] .	**Dismissed**. The output variable is a single value of the combined sum of project health factors. It is not a categorical output (like yes or no)
Kernel Smoothing	This non-parametric method determines a density function to forecast the probability at which input variables reside in a certain area. The advantage of this method is the capability to identify nonlinear relations between input and out variables [30].	**Dismissed**. The goal of the regression step is to create an actual regression function suitable for optimization. Probabilities of input variable locations is not in focus.
Stepwise Regression	This method uses an iterative approach where variables can be added or deleted in each iteration [26]. In each iteration, the variable with the highest correlation to the output variable is identified using the p-values of the variables.	**Used**. A second-degree polynomial regression function generates a satisfying result.
Lasso Regression	Lasso stands for least absolute shrinkage and selection operator. This iterative method minimizes variables which are not relevant until they are zero [31].	**Dismissed.** Increased complexity in this regression approach is not necessary as a suitable regression with

		acceptable p-values result can be obtained with stepwise regression.
Ridge Regression	Lasso Regression, it is. a selection-based regression method. In contrast to Lasso, ridge regression never sets the value of coefficients to absolute zero [32].	**Dismissed.** Not all coefficients are necessary.

Source: self-edited

After evaluating the different regression methods and selecting step-wise regression as the most applicable, a nonlinear optimization approach including additional constraints was chosen to identify a suitable maximum of combined project health factors in relation to the best distribution of project process relevance factors.

The Matlab solver *fmincon*, finds the minimum of a problem, with these constraints:

$$\min_x f(x) \text{ such that } \begin{cases} c(x) \leq 0 \\ ceq(x) = 0 \\ A \cdot x \leq b \\ Aeq \cdot x = beq \\ lb \leq x \leq ub \end{cases} \tag{1}$$

b and *beq* are vectors, *A* and *Aeq* are matrices, *c(x)* and *ceq(x)* are functions that return vectors, and *f(x)* is a function that returns a scalar. *f(x), c(x),* and *ceq(x)* can be nonlinear functions [33].

For the optimization approach the following constraints were defined:

- The initial starting point for the iterative optimization method was defined as the average values of project process relevance's, ensuring that the result stays close to a common distribution defined by the survey participants.
- The sum of all project process relevance's needed to be 100%.
- Upper and lower bounds of project process relevance's were defined with +/-10% of the average values. This ensures that the optimization avoids extreme results, for example maximizing one project process to 100% and minimizing all other project process relevance's to 0%.
- No linear inequality constraints were defined.

It has to be noted that the solver can only optimize through minimizing, so the reciprocal values of the output variable is used.

3.7 Regression including Fine Tuning

After defining how to optimize the actual optimization in MATLAB, R2018a was performed including data cleaning. Based on the input data, an initial import to MS Excel was used, converting the textual structure of the raw data into table form suitable for MATLAB import. The result of this import can be seen as an example below in form of a table for the first 8 data sets.

It needs to be noted that the four project health factors were added up to a single output value, divided by 400 and then inverted and the reciprocal value taken to utilize the minimization solver of MATLAB for the maximization of project health.

Table 3
Example of 8 Data Sets after Data Cleaning in MS Excel

P1	P2	P3	P4	P5	P6	P7	P8	Budget	Scope	Schedule	Customer	Output
14	20	18	14	28	1	3	2	19	21	14	23	0,8
19	9	6	4	8	35	7	12	92	100	87	100	0,1
14	20	18	14	28	1	3	2	19	21	14	23	0,8
20	13	17	0	15	13	4	18	53	100	30	100	0,3
45	10	10	10	10	5	5	5	100	80	80	90	0,1
15	5	10	5	20	15	10	20	85	70	70	70	0,3
24	15	12	11	20	11	0	7	88	52	61	77	0,3
5	20	20	5	5	25	5	15	100	60	85	85	0,2

Source: self-edited

After import of the cleaned data into MATLAB, the nonlinear stepwise regression approach second order was used to determine a suitable regression function:

>> mdl=stepwiselm(*Input*,*Output*,'poly22222222') (2)

Where:

Input = the input matrix of process 1 to 8

Output = the single column output matrix

As a result of this regression, MATLAB estimates these coefficients and statistical values for the regress function:

The p-values of the sixth process x6 and the combined factor x2*x8 are too high based on the 5% proposed p-value cutoff [34] with values of 13% and 8%. This indicates that there might be a critical collinearity of the sixth process in relation to the output. Therefore, an additional correlation matrix was developed to ensure that all the processes are within acceptable correlation boundaries regarding correlation.

```
Linear regression model:
    y ~ [Linear formula with 19 terms in 7 predictors]

Estimated Coefficients:
                    Estimate         SE         tStat       pValue
                   __________    __________    _______    __________

    (Intercept)        2.5665       0.36019     7.1252    3.3076e-10
    x2              -0.093719      0.018019    -5.2012    1.3745e-06
    x3              -0.032841     0.0065094    -5.0451    2.5826e-06
    x4              -0.068186      0.013673    -4.9869    3.2601e-06
    x5               -0.13995      0.024853     -5.631    2.3202e-07
    x6               0.011896     0.0077462     1.5357       0.12837
    x7              -0.012796     0.0061187    -2.0913      0.039521
    x8              -0.047325       0.01442    -3.2819      0.001503
    x2^2            0.0014954    0.00042943     3.4823    0.00079162
    x2:x4            0.001958    0.00052507     3.7291      0.000348
    x2:x5           0.0022529    0.00051424      4.381    3.3908e-05
    x3:x5           0.0022308    0.00048064     4.6414    1.2633e-05
    x4:x5           0.0018265    0.00050092     3.6462    0.00046034
    x5^2             0.001424    0.00040481     3.5177    0.00070503
    x6^2          -0.00066448     0.0002251    -2.9519     0.0040932
    x5:x7           0.0015826    0.00040548      3.903    0.00019101
    x2:x8           0.0010058    0.00057961     1.7352      0.086365
    x4:x8           0.0014672    0.00044572     3.2917     0.0014578
    x5:x8           0.0016849    0.00054847      3.072      0.002866


Number of observations: 103, Error degrees of freedom: 84
Root Mean Squared Error: 0.149
R-squared: 0.606,  Adjusted R-Squared: 0.522
F-statistic vs. constant model: 7.18, p-value = 1.12e-10
```

Figure 2

Project Regression Result

Source: self-edited

As highlighted with red boxes in figure 3, the process 6, Manage Communications, indicates a high p-value with 0.128, above 0.05 non-significance. Consequently, the influence of the P6 process on the overall model needs to be investigated in detail.

The correlation matrix in table 4 shows that the absolute value of Pearson correlation coefficient is with a maximum of 0.36 less than 0.8, so multi-collinearity is less likely to exist [35].

Table 4

Correlation Matrix with all Variables

		P1	P2	P3	P4	P5	P6	P7	P8
P2	Correlation	-0.128							
	Significance	0.240							
	N	86							
P3	Correlation	0.020	0.005						
	Significance	0.858	0.967						
	N	86	86						
P4	Correlation	-0.356**	-0.003	0.057					
	Significance	0.001	0.979	0.605					
	N	86	86	86					
P5	Correlation	-0.322**	-0.211	-0.083	0.291**				
	Significance	0.002	0.051	0.449	0.007				
	N	86	86	86	86				
P6	Correlation	-0.043	-0.309**	-0.288**	**-0.360****	-0.298**			
	Significance	0.696	0.004	0.007	0.001	0.005			
	N	86	86	86	86	86			
P7	Correlation	-0.243*	0.019	-0.270*	-0.123	-0.159	-0.136		
	Significance	0.024	0.861	0.012	0.261	0.144	0.212		
	N	86	86	86	86	86	86		
P8	Correlation	-0.254*	-0.114	-0.284**	-0.340**	-0.202	0.136	0.127	
	Significance	0.018	0.298	0.008	0.001	0.062	0.212	0.244	
	N	86	86	86	86	86	86	86	
Output	Correlation	0.022	-0.291**	0.111	-0.112	-0.208	0.357**	-0.125	0.137
	Significance	0.837	0.007	0.308	0.303	0.055	0.001	0.252	0.207
	N	86	86	86	86	86	86	86	86
** p < 0.01 (two-tailed)									
* p < 0.05 (two-tailed)									

Source: self-edited

Keeping the critical process P6 static, the partial correlation matrix in table 5 also indicates no critical collinearity between the other input variables and the output variable.

Table 5

Partial Correlation with P6 as Control Variable

			P1	P2	P3	P4	P5	P7	P8
P6	P2	Correlation	-0.149						
		Significance	0.174						
		Degrees of freedom	83						
	P3	Correlation	0.008	-0.093					
		Significance	0.945	0.398					
		Degrees of	83	83					

		freedom							
	P4	Correlation	-0.399**	-0.129	-0.053				
		Significance	0.000	0.241	0.632				
		Degrees of freedom	83	83	83				
	P5	Correlation	-0.351**	-0.334**	-0.185	0.207			
		Significance	0.001	0.002	0.091	0.058			
		Degrees of freedom	83	83	83	83			
	P7	Correlation	-0.252*	-0.024	-0.326**	-0.186	-0.211		
		Significance	0.020	0.826	0.002	0.089	0.053		
		Degrees of freedom	83	83	83	83	83		
	P8	Correlation	-0.250*	-0.076	-0.258*	-0.315**	-0.171	0.148	
		Significance	0.021	0.490	0.017	0.003	0.118	0.176	
		Degrees of freedom	83	83	83	83	83	83	
	Out put	Correlation	0.040	-0.203	0.239*	0.018	-0.114	-0.082	0.096
		Significance	0.714	0.062	0.028	0.868	0.299	0.453	0.382
		Degrees of freedom	83	83	83	83	83	83	83
** p < 0.01 (two-tailed)									
* p < 0.05 (two-tailed)									

Source: self-edited

It can be concluded, that the high p-values may not be critical in regards to the validity of the regression model. In the case combining x2 and x8 factors, the significance level is with 0.086 not as critical as the previously proven uncritical P6 process. For further analysis, the model is accepted as the basis for optimization even at this significance level.

3.8 Optimization of Process Relevance Factors

As a last step, the polynomial regression function is maximized under certain boundaries and conditions to propose an optimum distribution of project process relevance factors.

Using the developed regression coefficients, the following regression function is defined as:

fun=@(x)+2.5665-0.093719*x(2)-0.032841*x(3)-0.068186*x(4)-0.13995*x(5)+0.011896*x(6)-0.012796*x(7)-0.047325*x(8)+0.0014954*x(2)^2+0.001958*x(2)*x(4)+0.0022529*x(2)*x(5)+0.0022308*x(3)*x(5)+0.0018265*x(4)*x(5)+0.001424*x(5)^2-0.00066448*x(6)^2+0.0015826*x(5)*x(7)+0.0010058*x(2)*x(8)+0.0014672*x(4)*x(8)+0.0016849*x(5)*x(8) (3)

As initial starting point for the optimization, the average project process relevance factors are used:

$$x0=[18.9;14.7;11.1;7.1;12.9;14.7;9.3;11.2] \tag{4}$$

The constraint effecting that all input variables add up to 100 is defined as such:

$$Aeq=[1\ 1\ 1\ 1\ 1\ 1\ 1\ 1]$$
$$beq=[100] \tag{5}$$

The constraint defining the upper and lower bounds of the process relevance factors with +/- 10% of the average value is defined as such:

$$ub=[28.9\ 24.7\ 21.1\ 17.1\ 22.9\ 24.7\ 19.3\ 21.2]$$
$$lb=[8.9\ 4.7\ 1.1\ 0\ 2.9\ 4.7\ 0\ 1.2] \tag{6}$$

Linear inequality constraints are defined as such:

$$A=[]$$
$$b=[] \tag{7}$$

The optimization solver x=fmincon(fun,x0,A,b,Aeq,beq,lb,ub) uses a sequential quadratic programming method [36] [37] and generates a suitable optimization result.

4 Results and Discussion

As the overall result of the optimization phase, it can be concluded that the best distribution of project process relevance factors for the defined scope and boundaries based on the currently collected data looks as such:

Table 6
Result of Optimization

Project Process	**Optimized Project Process Relevance**
P1: Direct and Manage Project Work	28.3%
P2: Manage Project Knowledge	4.7%
P3: Manage Quality	1.1%
P4: Develop Team	17.1%
P5: Manage Team	22.9%
P6: Manage Communications	24.7%
P7: Implement Risk Responses	0%
P8: Manage Stakeholder Engagement	1.2%

Source: self-edited

Interpreting the results, it is clearly obvious that defining the upper and lower boundaries as constraints has a large influence on the optimization value. All final values, except the Process Direct and Manage Project Work, which is only 0.6% below the upper bounder, are situated either in an upper or lower boundary. This indicates that the optimization step would bring some project processes to zero and continue maximizing other project processes even more. To get a better understanding of these trends, it is helpful to repeat the optimization without upper and lower boundaries.

Table 7 shows that the optimization without boundaries maximizes only two project processes and sets all other project processes to 0%. This approach suggests putting 87.5% of focus or relevance on the process of Manage Communications. Naturally, these values are far from realistic and usable. Yet, however they can visualize the importance of Communication for project success [38].

It is obvious that the selected boundaries of +/-10% of the average value are open for discussion or change. These boundaries can also be seen as a damper protecting the optimization from being too radical and therefore proposing unrealistic values to project managers.

Table 7
Result of Optimization Considering Boundaries

Project Process	**Optimized Project Process Relevance with Upper and Lower Boundaries**	**Optimized Project Process Relevance without Upper and Lower Boundaries**
Direct and Manage Project Work	28.3%	0%
Manage Project Knowledge	4.7%	0%
Manage Quality	1.1%	0%
Develop Team	17.1%	0%
Manage Team	22.9%	12.5%
Manage Communications	24.7%	87.5%
Implement Risk Responses	0%	0%
Manage Stakeholder Engagement	1.2%	0%

Source: self-edited

With regard to the general overview, the following description of the individual processes can be presented:

Direct and Manage Project Work is the process of actually implementing and doing the work defined in the project plan [39]. In the boundary restricted result this process shows the highest relevance with 28.3%, indicating that a lot of successful project managers put much focus and effort in this project process.

Manage Communications has the second highest relevance with 24.7%. Looking at the unconstrained optimization, the relevance even increases to 87.5%. This indicates high relevance of communication for project health in the execution phase of projects. The importance of successful communication as critical factor for project success is also a widespread result in project management research. [40] [41] [42]

Manage Team is the process of tracking and optimizing the project team performance. With 22.9%, this process shows a high relevance in the work of successful project managers.

Developing the team by improving competences and interaction is also of high importance for project success [43]. The value of 17.1% is the defined upper boundary of the optimization. However, without boundaries, the process moves towards zero due to increasing importance of the project process Manage Communications.

To sum up the project processes **Manage Project Knowledge, Manage Quality, Implement Risk Responses** and **Manage Stakeholder Engagement** it can be said that they show low relevance in the optimized relevance distribution. Explaining this behavior is not within the scope of this research yet. As a hypothesis, it can be suggested that a healthy project needs less of the troubleshooting-oriented project processes, like managing quality, risks, engagement and knowledge about the project. One could argue that a project manager can move towards a positive circle within the project. So, if he or she is not busy implementing risk responses for example, more time for communication, managing the team and the project work can keep the project healthy and successful.

Conclusions

The goal of this research was to show that multivariate optimization methods can be applied, for proposing optimized work flow processes, for project managers. This approach can reduce the tendency of the project management profession of being subjective, individualistic and hard to capture. Each and every project is unique, and it is a highly important competence, for project managers, to adapt and react in a flexible way, with the different challenges, that occur in the daily work of project management. It has to be noted, that this research does not suggest following the optimized relevance factors exactly. Knowing about an optimized distribution, based on data and not on subjective interpretations and recommendations, could help to highlight how successful project managers do their work and therefore, act as guides for all other project management practitioners. The result of this research is a proof of concept, showing the potential of an optimization approach and the challenges involved in using constraints, to adapt unrealistic results, if needed.

Several limitations need to be mentioned in order to prevent potential misinterpretation. The most important factor is the relatively small set of heterogenic survey participants and the resulting data. For more reliable results, the additional project and personal characteristics should be used to filter and preselect data sets for optimization. In order to create a reliable result, for example, only small, agile developed projects, in the financial industry, managed by less-experienced project managers, might be selected. With such specific selection of categories, many additional aspects and insights could emerge from the data, after optimization.

Another limitation that should be mentioned is the fact that many survey participants learned about this research and gave their input during the flow of their projects. There was no phase of introduction about this research from the beginning of their project onwards. Knowing in advance that project process relevance is in focus and measured by a survey application, could lead to less subjective values, increasing the overall quality of the data.

Last but not least, a gap in the nature of input and output variables needs to be mentioned. The project health factors are overall values, which are valid for all project phases from the start. Therefore, positive project health could already be transmitted into other project phases. The survey on the input side completely focusses on the execution phase, not considering results of previous phases. This additional influence on the output factors, which overlap with project phases, reduces the significance of the optimization result.

Perspectives for Future Research

To tackle the mentioned limitation and increase the reliability of the data and the optimization result [13], several improvements are planned for future research.

One approach is the automation of data collection. To reduce the subjective human factor, additional data sources can be used [44], like measured times in certain software programs. For example, the screen time could be measured with MS Project and connected to project plan-related project processes, at least giving survey participants the change to categorize activities on a daily basis. Like not collecting data once per participant, but ongoing, over the whole project. Simply adding the possibility of categorizing meetings in regards to project processes directly in outlook would increase the quality of data drastically.

Another approach, to reduce the subjective nature of the result, is to shorten the research phase in the project. Especially agile frameworks, like SCRUM are perfect candidates for such measures, due to their iterative nature. Thus, a next step could be moving away from PMBOK project processes, towards activities and tasks during sprints. Using the proof of concept of this research as a guideline, optimizing the work in sprints for the different roles in traditional SCRUM based organizations could be a useful goal for further research activities.

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