Application of Linear Programming on Example of Relationship between Two Types of Activity and Optimized Dietary Supplement Intake

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Abstract: Kinesiology, as a science on movement, can use reductive and constructive logic and tools to inspect, analyse and produce phenomena related to human, activity. Deterministic and stochastic nature of kinanthropological phenomena are often analysed by complex statistical methods. Application of linear programming for optimization in producing simple decision and recommendation regarding intake of exact proportion of recovery dietary supplements complexes in two different activities (aerobic and anaerobic) revealed elegance of the method, and revealed prospective practical implication in sport practice, rehabilitation process, and in everyday life.

1 INTRODUCTION

Decision making is mostly rational act, based on good estimates and facts, but in real life it often depends on feelings, intuition, and happiness. It becomes harder to decide when more different conditions have to be fulfilled in order to reach the best possible (optimal) decision. Mathematical modelling and programming can be helpful, to different varying degree, depending on the nature of the observed phenomenon and the complexity of the problem (Špirelja, 2007).

Within general knowledge of multicriteria linear optimizations (Ehrgott, 2005, Neralić, 2003, Steuer, 1986, Špirelja, 2007), analysis of relations and differences between dietary/nutrition regimes (Aird et al., 2018, Denham, 2017, Ferguson et al., 2004, Henson, 1991, Rawson et al., 2018), and influences of different training/exercise regimes (Pasiakos et al., 2015, Patel et al., 2017), specific optimizations by implementation of mathematical tools were feasible and applicable (Asano et al., 2018, Briend et al., 2018, Persson et al., 2018,)

The aim of this paper was, through a cross-section of mathematical methods and two concrete example of linear programming, to provide a practical tool for optimizing simple and everyday needs for sport, but also for everyday life, out of the relationship between two types of activity and optimized input of dietary supplement (DS).

2 METHODS

2.1 Linear Programming with Two Variables

For those problems which have linear nature and require only two variables (e.g. dietary supplements), it is sufficient to know the graphical solution of linear inequalities and the mathematical fact that the optimum solution lies in one of the vertices of a feasible set, defined by the constraints (cross section of linear inequalities).

2.2 Linear Programming with More Variables – A Simplex Method

Finding the vertex of the feasible set by the graphical method in a more-than-two-dimensional space is often demanding and time-consuming. A simpler approach is to apply the Simplex Method, which is an iterative method, i.e. step-by-step method of improvements of the basic feasible solution, until the final step results with optimal feasible solution (if it

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exists). It mostly implies application of Gauss-Jordan transformations of matrices which can be solved manually and by different software tools.

2.3 Experimental Design

Dietary supplements (DS) for recovery after intensive activity have the function of supplying body with calories, proteins, amino acids (BCAA, Glutamine), electrolytes (e.g. magnesium ions), vitamins (B1, B2, B6) etc. The goal of the 'optimization' was to calculate minimum intake of DS as possible within the default features of the training and the limit on the input.

Table 1: An example of a composition of three related DS (mass in one portion of DS1:91g, DS2:75g, DS3:65g).

portion	**DS 1**	**DS 2**	**DS 3**
calories	320	270	235
carbohydrates	60	53	28
proteins	20	13	27
B1	0.008	0.005	0.0033
B2	0.0085	0.004	0.0066
B6	0.008	0	0.0033
Mg	0.250	0.160	0.205
BCAA	4.5	0.98	5.98
Glutamine	6	1.56	0

In addition to regular activity and controlled diets, for the purpose of this example, constraints for intake of a part of the vitamin B complex are:

- B1 less than 7mg
- B2 less than 7mg
- B6 less than 7mg

2.3.1 Anaerobic Training

Consumption in the chosen anaerobic training in the example assumes intake of:

- more than 280kcal
- more than 15g of protein
- more than 200mg of magnesium
- more than 2g of BCAA amino acids
- more than 3g amino acids Glutamine

2.3.2 Aerobic Training

Consumption in the chosen aerobic training in this example assumes intake of:

- more than 320kcal
- more than 55g of carbohydrates
- more than 15g of protein
- more than 200mg of magnesium
- more than 2g of BCAA amino acids
- more than 3g amino acids Glutamine

3 OPTIMIZATION OF INTAKE OF TWO DIETARY SUPPLEMENTS

3.1 Relationship between Anaerobic Activity and Optimized Intake of Two Dietary Supplements

For variables X1 - the mass of portion intake of the DS1, X2 - the mass of portion intake of the DS2, with regard to default constraints and parameters, and Z - objective (goal) function linear optimization problem for *anaerobic training* was set:

MINIMIZE: $Z = 91\,X1 + 75\,X2$ (1)

$$320\,X1 + 270\,X2 \geq 280 \quad (2)$$

$$20\,X1 + 13\,X2 \geq 15 \quad (3)$$

$$0.25\,X1 + 0.16\,X2 \geq 0.2 \quad (4)$$

$$4.5\,X1 + 0.98\,X2 \geq 2 \quad (5)$$

$$6\,X1 + 1.56\,X2 \geq 3 \quad (6)$$

$$0.008\,X1 + 0.005\,X2 \leq 0.007 \quad (7)$$

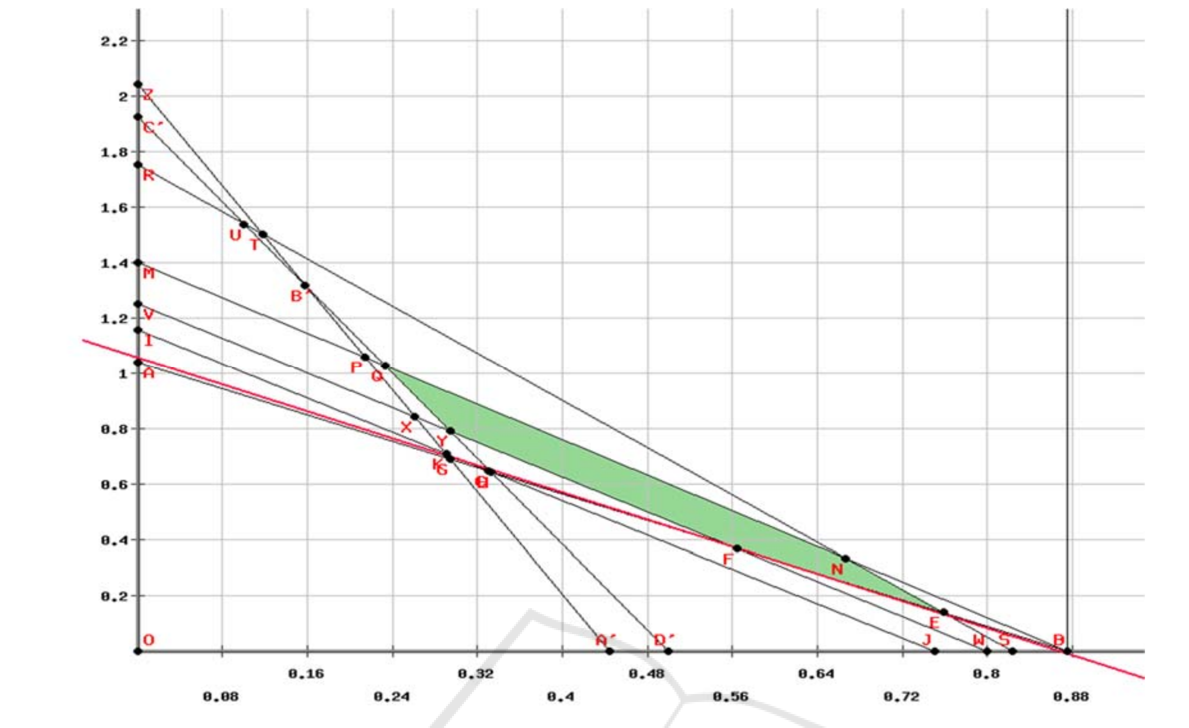
$$0.0085\,X1 + 0.004\,X2 \leq 0.007 \quad (8)$$

$$0.008\,X1 \leq 0.007 \quad (9)$$

$$X1, X2 \geq 0 \quad (10)$$

The feasible set is pentagon (Figure 1), and the candidates for the optimal solution are in vertices of that pentagon. The optimal solution is in the vertex in which the objective function reaches the minimum value.

The solution is in vertex *F (0.56, 0.37),* which would mean that the optimal combination of two preparations is: *DS1 51.36 g and DS2 28.58 g.*



Point	X coordinate (X1)	Y coordinate (X2)	Value of the objective function (Z)
E	0.75862068965517	0.13793103448276	79.379310344828
F	0.56441717791411	0.3680981595092	78.969325153374
N	0.66666666666667	0.33333333333333	85.666666666667
Q	0.23287671232877	1.027397260274	98.246575342466
Y	0.29473684210526	0.78947368421053	86.031578947368

Figure 1: Anaerobic training parameters.

3.2 Relationship between Aerobic Activity and Optimized Intake of Two Dietary Supplements

For variables X1 - the mass of portion intake of the DS1, X2 - the mass of portion intake of the DS2, with regard to default constraints and parameters, and Z - objective (goal) function linear optimization problem for *aerobic training* was set:

MINIMIZE: $Z = 91\ X1 + 75\ X2$ (1)

$320\ X1 + 270\ X2 \geq 320$ (2)

$20\ X1 + 13\ X2 \geq 15$ (3)

$0.25\ X1 + 0.16\ X2 \geq 0.2$ (4)

$4.5\ X1 + 0.98\ X2 \geq 2$ (5)

$6\ X1 + 1.56\ X2 \geq 3$ (6)

$60\ X1 + 53\ X2 \geq 55$ (7)

$0.008\ X1 + 0.005\ X2 \leq 0.007$ (8)

$0.0085\ X1 + 0.004\ X2 \leq 0.007$ (9)

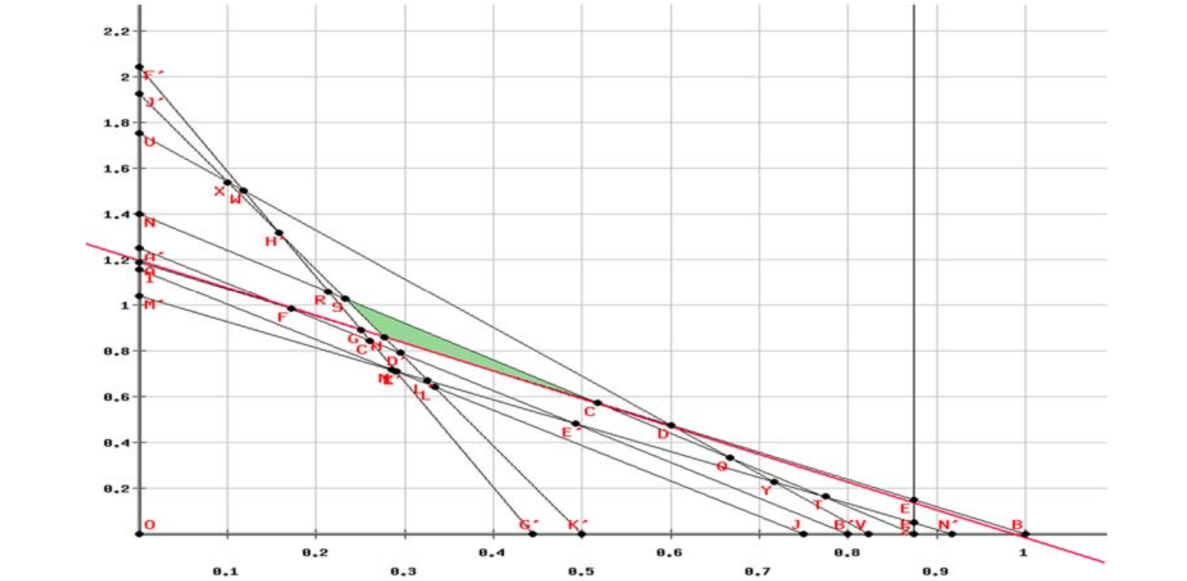
$0.008\ X1 \leq 0.007$ (10)

$X1,\ X2 \geq 0$ (11)

The feasible set is triangle (Figure 2), and the candidates for the optimal solution are vertices of that triangle. The optimal solution is the vertex in which the function of the target reaches the minimum value. The solution is at point *H (0.28, 0.86)* which would mean that the optimal combination of two preparations*: DS1 25.27 g, and DS2 64.24 g.*

4 OPTIMIZATION OF INTAKE OF MORE DIETARY SUPPLEMENTS

In next example three different dietary supplements were included. Graphical method, presented in previous examples, would here require plotting linear inequalities in 3-D and defining feasible region. Simplex method will then be more appropriate.



Point	X coordinate (X1)	Y coordinate (X2)	Value of the objective function (Z)
C	0.51785714285714	0.57142857142857	89.982142857143
H	0.27730192719486	0.85653104925054	89.474304068522
S	0.23287671232877	1.027397260274	98.246575342466

Figure 2: Aerobic training parameters.

4.1 Relationship between Anaerobic Activity and Optimized Intake of Three Dietary Supplements

For variables X1 - the mass of portion intake of the DS1, X2 - the mass of portion intake of the DS2, X3 - the mass of portion intake of the DS3, with regard to default constraints and parameters, and Z - objective (goal) function linear optimization problem for *anaerobic training* was set:

MINIMIZE: $Z = 91\ X1 + 75\ X2 + 65\ X3$ (1)

$320\ X1 + 270\ X2 + 235\ X3 \geq 280$ (2)

$20\ X1 + 13\ X2 + 27\ X3 \geq 15$ (3)

$0{,}25\ X1 + 0{,}16\ X2 + 0{,}205\ X3 \geq 0{,}2$ (4)

$4{,}5\ X1 + 0{,}98\ X2 + 5{,}98\ X3 \geq 2$ (5)

$6\ X1 + 1{,}56\ X2 + 0\ X3 \geq 3$ (6)

$0{,}008\ X1 + 0{,}005\ X2 + 0{,}0033\ X3 \leq 0{,}007$ (7)

$0{,}0085\ X1 + 0{,}004\ X2 + 0{,}0066\ X3 \leq 0{,}007$ (8)

$0{,}008\ X1 + 0\ X2 + 0{,}0033\ X3 \leq 0{,}007$ (9)

$X1,\ X2,\ X3 \geq 0$ (10)

The optimal solution (in table 2) is (0.3864, 0.4368, 0.1634) which would mean that the optimal combination of three preparations is: *DS1 35.16 g, DS2 32.76 g and DS3 10.62 g.*

Table 2: Final solution shown in transformed matrix after six iterations (by using simplex method).

			-91,0000	-75,0000	-65,0000	0	0	0	0	0	0	0	0	0
Base	Cb	P0	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
P2	-75,0000	0,4368	0	1	0	-0,0128	0	14,7160	0	0,0715	0	0	0	0
P7	0,0000	1,1444	0	0	0	0,0380	0	-72,7481	1	0,2537	0	0	0	0
P3	-65,0000	0,1634	0	0	1	0,0059	0	-11,6977	0	0,1701	0	0	0	0
P1	-91,0000	0,3864	1	0	0	0,0033	0	-3,8262	0	-0,1853	0	0	0	0
P5	0,0000	2,8198	0	0	0	0,0605	1	-201,0520	0	1,8176	0	0	0	0
P9	0,0000	0,0012	0	0	0	178533408,4789	0	-0,0044	0	0,0006	1	0	0	0
P10	0,0000	0,0009	0	0	0	-162846765,6084	0	0,0509	0	0,0002	0	1	0	0
P11	0,0000	0,0034	0	0	0	-46333521,1973	0	0,0692	0	0,0009	0	0	1	0
P12	0,0000	0,0000	0	0	0	0,0000	0	0,0000	0	0,0000	0	0	0	1
Z		-78,5482	0	0	0	0,2724	0	4,8281	0	0,4383	0	0	0	0

4.2 Relationship between Aerobic Activity and Optimized Intake of Three Dietary Supplement

For variables X1 - the mass of portion intake of the DS1, X2 - the mass of portion intake of the DS2, X3 - the mass of portion intake of the DS3, with regard to default constraints and parameters, and Z - objective (goal) function linear optimization problem for *aerobic training* was set:

$$\textbf{MINIMIZE: } Z = 91\ X1 + 75\ X2 + 65\ X3 \quad (1)$$

$$320\ X1 + 270\ X2 + 235\ X3 \geq 320 \quad (2)$$

$$20\ X1 + 13\ X2 + 27\ X3 \geq 15 \quad (3)$$

$$0{,}25\ X1 + 0{,}16\ X2 + 0{,}205\ X3 \geq 0{,}2 \quad (4)$$

$$4{,}5\ X1 + 0{,}98\ X2 + 5{,}98\ X3 \geq 2 \quad (5)$$

$$6\ X1 + 1{,}56\ X2 + 0\ X3 \geq 3 \quad (6)$$

$$0{,}008\ X1 + 0{,}005\ X2 + 0{,}0033\ X3 \leq 0{,}007 \quad (7)$$

$$0{,}0085\ X1 + 0{,}004\ X2 + 0{,}0066\ X3 \leq 0{,}007 \quad (8)$$

$$0{,}008\ X1 + 0\ X2 + 0{,}0033\ X3 \leq 0{,}007 \quad (9)$$

$$60\ X1 + 53\ X2 + 28\ X3 \geq 55 \quad (10)$$

$$X1,\ X2,\ X3 \geq 0 \quad (11)$$

The optimal solution (in table 3) is (0.2773, 0.8565, 0) which would mean that the optimal combination of three preparations is*: DS1 25.23 g, DS2 64.24 g and DS3 0 g.*

Table 3: Final solution shown in transformed matrix after eleven iterations (by using simplex method).

			-91,0000	-75,0000	-65,0000	0	0	0	0	0	0	0	0	0
Base	Cb	P0	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
P6	0,0000	0,0064	0	0	-0,0855	-0,0005	0	1	0	-0,0145	0	0	0	0
P2	-75,0000	0,8565	0	1	1,2580	-0,0054	0	0	0	0,2855	0	0	0	0
P7	0,0000	0,0873	0	0	-6,2190	0,0010	0	0	1	-0,8042	0	0	0	0
P10	0,0000	0,0012	0	0	0,0043	95824411,1349	0	0	0	0,0009	0	1	0	0
P12	0,0000	7,0343	0	0	19,0503	-0,2002	0	0	0	0,6781	0	0	0	1
P9	0,0000	0,0005	0	0	-0,0004	156316916,4882	0	0	0	0,0005	1	0	0	0
P1	-91,0000	0,2773	1	0	-0,3271	0,0014	0	0	0	-0,2409	0	0	0	0
P11	0,0000	0,0048	0	0	0,0059	-111349036,4026	0	0	0	0,0019	0	0	1	0
P5	0,0000	1,6809	0	0	-17,1874	-0,0418	1	0	0	-1,1064	0	0	0	0
Z		-89,4743	0	0	0,4127	0,2748	0	0	0	0,5086	0	0	0	0

5 CONCLUSIONS

The problem of choosing a suitable method in sports research, in this case the introduction of recovery preparations and dietary supplements, is a key issue because of the often stochastic nature of the observed variables.

In the latest trends in research in sports and kinesiology, there is the concept of 'vicarianza' (Sibilio, 2017), through which different variables of input are set into the relationship with the rules of the observed activity (e.g. rules of handball, tactics, or verified protocol of therapeutic procedure after operative procedure, etc.), then through decision-making mechanisms, all the way to last and finite, mostly measurable effects of the activity described by input variables. In this context, linear multicriteria optimizations tool was useful for introducing DS3 as appropriate for recovery after anaerobic training, but not necessary for recovery after aerobic training.

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PHPSimplex - online simplex method solver

http://www.zweigmedia.com/RealWorld/simplex.html

http://www.mathstools.com/section/main/simplex_online_calculator#.UdHztJw1nzc.