Journal of Project Management 4 (2019) 217–228

Contents lists available at GrowingScience

Journal of Project Management

homepage: www.GrowingScience.com

Mapping optimization techniques in project management

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C H R O N I C L E

Article history:
Received: January 3 2019
Received in revised format: January 28 2019
Accepted: March 10 2019
Available online:
March 10 2019

Keywords:
Optimization
Project Management
Operations Research

A B S T R A C T

An important function of the project management is to optimize the project in various phases and at different levels. From sourcing and allocation to scheduling and even dealing with uncertainties, the science of operation research (OR) has played an important role in this area. So far, many papers have been published using the optimization science to make various decisions regarding the project management. This study aims to investigate all papers published on the application of optimization in the project management from 1940 to 2019 and shows: a) how the trend has changed over this 79 years period, b) to what direction the trend has changed, c) determines the interesting topics of the recent years, and d) which subjects are more attractive as future studies as the applications of the optimization techniques in the project management.

1. Introduction

The increased number of industrial and developmental activities in the form of projects has revealed the importance of using the science of the project management wherein the planning and directing are accomplished in terms of time, cost, and other characteristics such as quality through knowledge, skills, tools, and techniques to meet the needs and expectations of the project stakeholders. To successfully achieve the objectives of each project, a wide range of factors should be aligned for the formation of which the project management knowledge seeks to introduce and strengthen the required skills. According to Scott-Young (2008), the project management will succeed if three dimensions shown in Fig. 1 collaborate and can be implemented, effectively.

Optimization is a tool that helps project managers make optimal decisions such as selecting the most appropriate project from the possible options, determining the best time for the project activities and the level of the overtime work, the rate of ordering and the level of storing materials and equipment, etc. Because of the importance and position of optimization in the project management, two points are worth mentioning: 1) many decisions have key impacts on the project success/failure and their consequences can be irreversible and 2) complicated decisions and the need to consider multiple variables and parameters make the intuitive or manual decisions ineffective.

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doi: 10.5267/j.jpm.2019.3.003

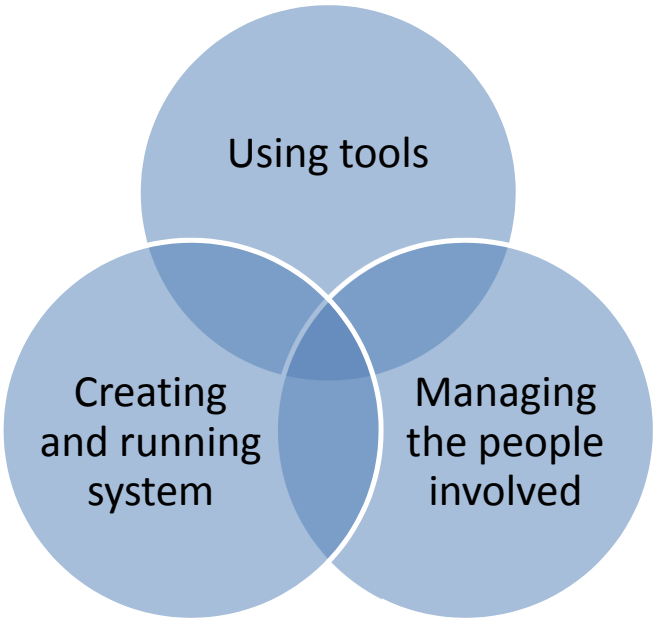

Fig. 1. Dimensions required for the success of the project management (Scott-young, 2008)

2. Position of optimization problems in different project management areas

Regarding the project decision making issues, it can be definitely argued that Brucker et al. (1999) presented a very effective paper wherein they assumed the project planning to be analogous to the single-/multi-product production planning to which limited resources were allocated using the optimization tool. They then developed the idea to propose a comprehensive project planning model through a resource categorization and allocation scheme capable of being used in different sectors of the industries to control projects. Numerous references to this paper reveal that the authors have reached their goal of presenting a comprehensive model used widely in all industries. Presenting a single notation in this regard is another goal they have explicitly set in their paper and have reached it to a large extent. They have also made an effort to examine, present, and explain appropriate, precise, and heuristic solution methods based on the type and properties of each model presented in the paper. Another high-reference related paper belongs to Herroelen (2005) wherein he precisely stated that the main problem is to plan the project activities by considering resource limitations and other constraints. He specified that despite all the efforts made, numerous reports show that many projects have exceeded their planned time and budget, and many planning methods still need to find a practical way to prevent this problem. Aiming at facing the project planning theory and process, he presented a general and hierarchical plan and control framework wherein he considered various planning situations and discussed important research opportunities for the exploration of which can narrow the theory-practice gap. In a paper published by Tavares (2002), the role of optimization models in the project management was studied through reviewing and grouping the important papers published until then. This grouping is limited and involves the following:

1- Modeling the network of the project activities (scheduling and sequencing)

2- Resource allocation methods

3- Project evaluation methods

A review of the paper publication trend in each of these three areas provides interesting information on their attractiveness for researchers and their research needs. Fig. 2 reviews the related papers published during 2000-2019 and shows that the scheduling and sequencing of activities is far more interesting than the other two areas; in the year 2000, the number of papers in this area has been more than 110 among which more than 75 are published in 2018.

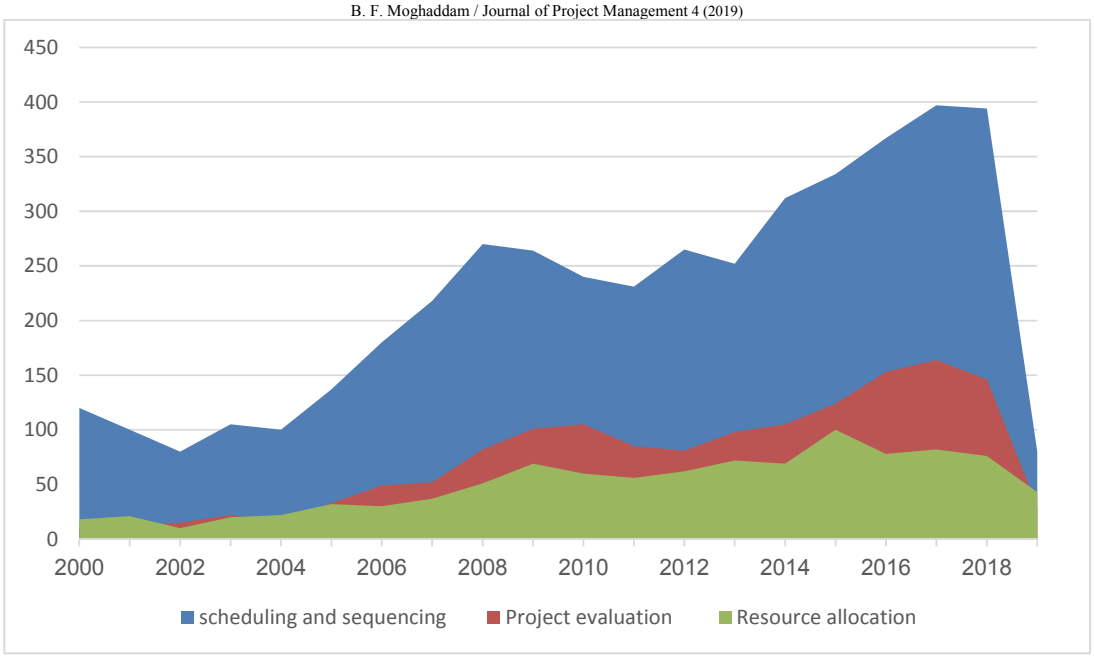

Fig. 2. Related papers published during 2000-2019

Another point concluded from Fig. 2 is the similar rising and falling trend in the number of the papers in the three areas; 2008 shows a considerable growth while 2009 shows an almost identical decline. This means that, regardless of the grouping of different project management areas, the number of the published papers has had an appropriate growth and shows a clear horizon in this area. Table 1 shows the most cited paper in each field. If different users of the project control issue are to be studied from a specialized point of view, it would suffice to check the related papers' publication sources. Fig. 3 shows the number of papers published by major journals in this area. Rankings 2, 3, 9, 11, and 14 of these journals belong to the construction specialized area and other rankings belong to specialized journals of the industrial engineering, especially OR. This means that the optimization look in the project management science has found its acceptable place in other specialized fields as well.

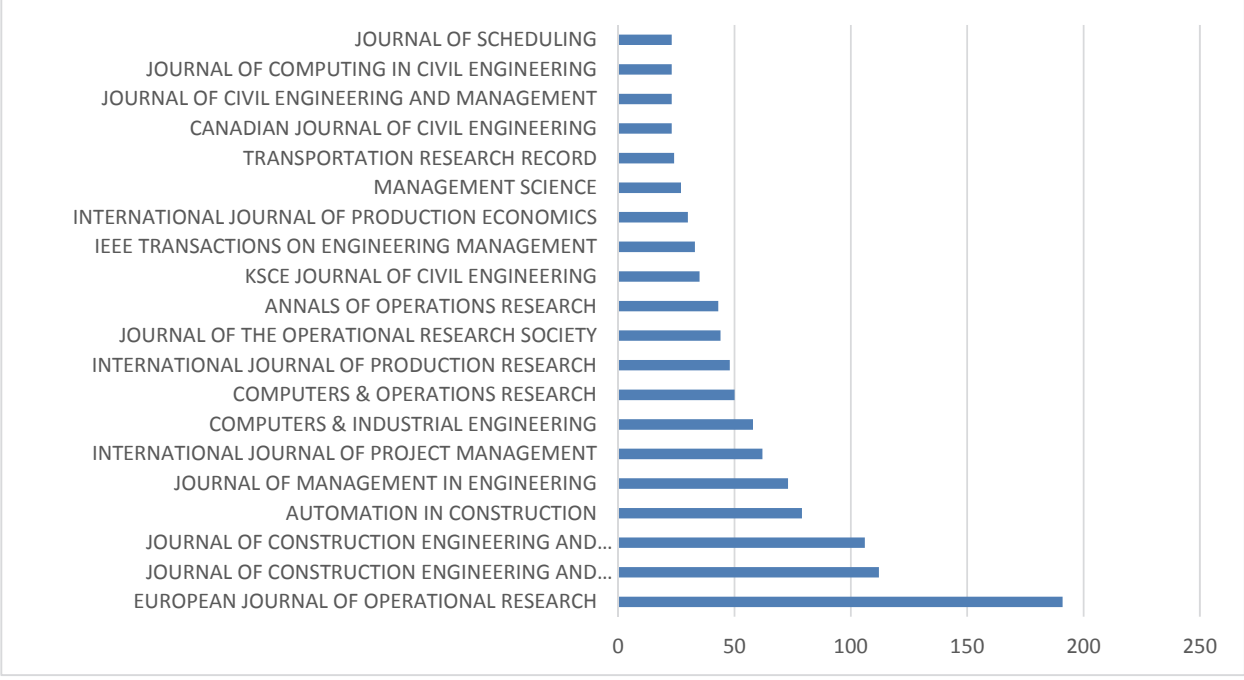

Fig. 3. Most relevent sources

Table 1
Total citation of each feild

No.	Articles	Total Citation	Scheduling and sequencing	Resource allocation	Performance measurement	No.	Articles	Total Citation	Scheduling and sequencing	Resource allocation	Performance measurement
1	(BRUCKER P, 1999)	734	√			67	(SCOTT-YOUNG C, 2008)	67	√		
2	(HERROELEN W, 2005)	409	√	√		68	(WANG M, 2003)	67	√		
3	(KOLISCH R, 2006)	356	√			69	(GHASEMZADEH F, 1999)	66	√		
4	(HARTMANN S, 2010)	329		√	√	70	(KLEIN R, 1999)	66		√	
5	(MERKLE D, 2002)	329		√		71	(HERROELEN W, 2004)	65			√
6	(KELLER RT, 2001)	293		√		72	(WANG W, 2014)	64	√		
7	(HARTMANN S, 2000)	263	√			73	(KONE O, 2011)	64		√	
8	(BOULEIMEN K, 2003)	261	√			74	(BROWNING TR, 2010)	64	√		
9	(HOEGL M, 2004)	233	√			75	(VALLS V, 2009)	64	√		
10	(CHUA DKH, 2003)	228	√			76	(ZHANG H, 2006)	63		√	
11	(HUCHZERMEIER A, 2001)	225		√		77	(GUTJAHR WJ, 2000)	63	√		
12	(KOLISCH R, 2001)	209	√			78	(COELHO J, 2011)	62			√
13	(KELLER RT, 2006)	205		√	√	79	(HEIMERL C, 2010)	62		√	
14	(PULLEY JM, 2012)	189	√		√	80	(KIM KW, 2005)	62			√
15	(CONIGRAVE KM, 2002)	187	√	√		81	(HEGAZY T, 2001)	62	√		
16	(KEIL M, 2000)	176	√			82	(GHODDOUSI P, 2013)	61			√
17	(CHO SH, 2005)	173	√		√	83	(ZIARATI K, 2011)	61		√	
18	(BONNER JM, 2002)	173	√			84	(LAMBRECHTS O, 2011)	61			√
19	(DEBELS D, 2006)	169		√		85	(VANHOUCKE M, 2001)	60		√	
20	(LOVE PED, 2002)	164			√	86	(BENDOLY E, 2007)	60	√		
21	(DREZET LE, 2008)	162		√		87	(LOVE PED, 2012)	60	√		√
22	(JARBOUI B, 2008)	158		√		88	(AGARWAL A, 2011)	59	√		
23	(GALLOWAY PD, 2006)	150	√			89	(GUTJAHR WJ, 2008)	59	√	√	√
24	(HARTMANN S, 2002)	143		√	√	90	(ZHU G, 2005)	59	√	√	
25	(ROPPONEN J, 2000)	140	√			91	(PENA-MORA F, 2001)	59	√	√	
26	(HARTMANN S, 2001)	139	√			92	(DORNDORF U, 2000)	59		√	
27	(ALCARAZ J, 2001)	134		√		93	(PARK M, 2003)	58	√		
28	(LINBERG KR, 1999)	131			√	94	(VIANA A, 2000)	57			√
29	(HERROELEN W, 2004)	126		√		95	(NEUMANN K, 1999)	57		√	
30	(JERGEAS G, 2001)	126		√		96	(HOEGL M, 2003)	56	√		
31	(WEGLARZ J, 2011)	122		√		97	(SCHWINDT C, 2006)	56		√	
32	(KALIBA C, 2009)	122		√		98	(LOVE PED, 2015)	55	√		
33	(GONCALVES JF, 2008)	119	√			99	(LUU VT, 2009)	55			√
34	(ALBA E, 2007)	118		√		100	(LOVE PED, 2008)	55		√	
35	(MENDES JJM, 2009)	117	√			101	(BARRAZA GA, 2004)	55		√	
36	(ALCARAZ J, 2003)	117	√		√	102	(ELLOUMI S, 2010)	54			√
37	(HOEGL M, 2005)	116			√	103	(LIU SS, 2008)	54	√		√
38	(ZHANG S, 2015)	112		√		104	(ELAZOUNI AM, 2007)	54		√	
39	(VALLS V, 2008)	109	√	√		105	(SMITH HJ, 2003)	54	√		
40	(AL-FAWZAN MA, 2005)	109		√	√	106	(KUO SF, 2000)	54		√	
41	(LEE E, 2009)	107			√	107	(NITITHAMYONG P, 2006)	53		√	
42	(MCKOY JM, 2007)	107		√		108	(HYARI K, 2006)	53		√	
43	(ARTIGUES C, 2003)	106			√	109	(KE H, 2005)	53	√		
44	(Yamashita D, 2006)	104	√			110	(ABDEL-HAMID TK, 1999)	53		√	
45	(CESTA A, 2002)	102		√		111	(CHANG CK, 2008)	52	√		
46	(YANG LR, 2012)	101	√			112	(LIBERATORE MJ, 2001)	52		√	
47	(HOEGL M, 2007)	99		√	√	113	(KLEIN R, 2000)	52	√		
48	(LYNEIS JM, 2001)	99		√	√	114	(HWANG BG, 2014)	51	√		
49	(MOHRING RH, 2003)	98		√	√	115	(POPOV V, 2010)	51		√	
50	(MIKA M, 2005)	96		√		116	(VANHOUCKE M, 2007)	51		√	
51	(TORMOS P, 2001)	94	√			117	(CHANG CK, 2001)	51	√		
52	(LIPKE W, 2009)	92		√		118	(KARIM A, 1999)	51	√		
53	(LOVA A, 2001)	89		√		119	(LOVE PED, 2009)	50		√	
54	(VAN DE VONDER S, 2005)	89		√		120	(ULUSOY G, 2001)	50		√	
55	(SENOUCI AB, 2001)	81	√		√	121	(WANG H, 2004)	49		√	
56	(NEUMANN K, 2000)	80	√			122	(CHEN WN, 2010)	49	√	√	√
57	(BACCARINI D, 2004)	79	√	√		123	(CHEN JQ, 2009)	49		√	
58	(IBBS CW, 2001)	75	√			124	(CHOI J, 2004)	49		√	
59	(LEVARDY V, 2009)	72	√			125	(ZHAO √B, 2016)	48		√	
60	(WANG J, 2009)	72		√		126	(GEORGY ME, 2008)	48			√
61	(HERROELEN W, 2005)	71		√		127	(VAN DE VONDER S, 2007)	48		√	
62	(AHSAN K, 2010)	70	√			128	(NA KS, 2007)	48	√		
63	(HEILMANN R, 2003)	70			√	129	(KOULINAS G, 2013)	47	√	√	
64	(CHEN W, 2010)	69	√			130	(KE H, 2010)	46			√
65	(NIGHTINGALE P, 2000)	69	√			131	(SOBEL MJ, 2009)	46			√
66	(CHANG AST, 2002)	68	√			132	(BALLESTIN F, 2007)	46		√	

If the most frequently used words of each project management branch are examined, the word "evaluation" ranks first in the performance evaluation; general terms dominate in other two areas. Table 2 indicates how close the most frequent words in these three areas are.

Table 2
Most frequent words

Scheduling		allocation		performance	
Word	**Occurrence**	**Word**	**Occurrence**	**Word**	**Occurrence**
management	334	management	113	performance	401
model	315	model	100	model	129
genetic algorithm	269	allocation	96	success	121
optimization	254	resource-allocation	68	impact	77
algorithm	246	optimization	66	framework	76
performance	189	performance	57	design	70
heuristics	171	algorithm	51	perspective	66
construction	155	genetic algorithm	44	product development	66
networks	147	selection	36	innovation	62
classification	145	systems	35	systems	59
search	117	product development	33	construction	53
time	114	heuristics	30	organizations	50
system	112	uncertainty	26	knowledge	44
branch	108	construction	25	uncertainty	42
uncertainty	99	framework	24	implementation	41
design	97	information	24	industry	37
scheduling problem	89	classification	23	technology	37

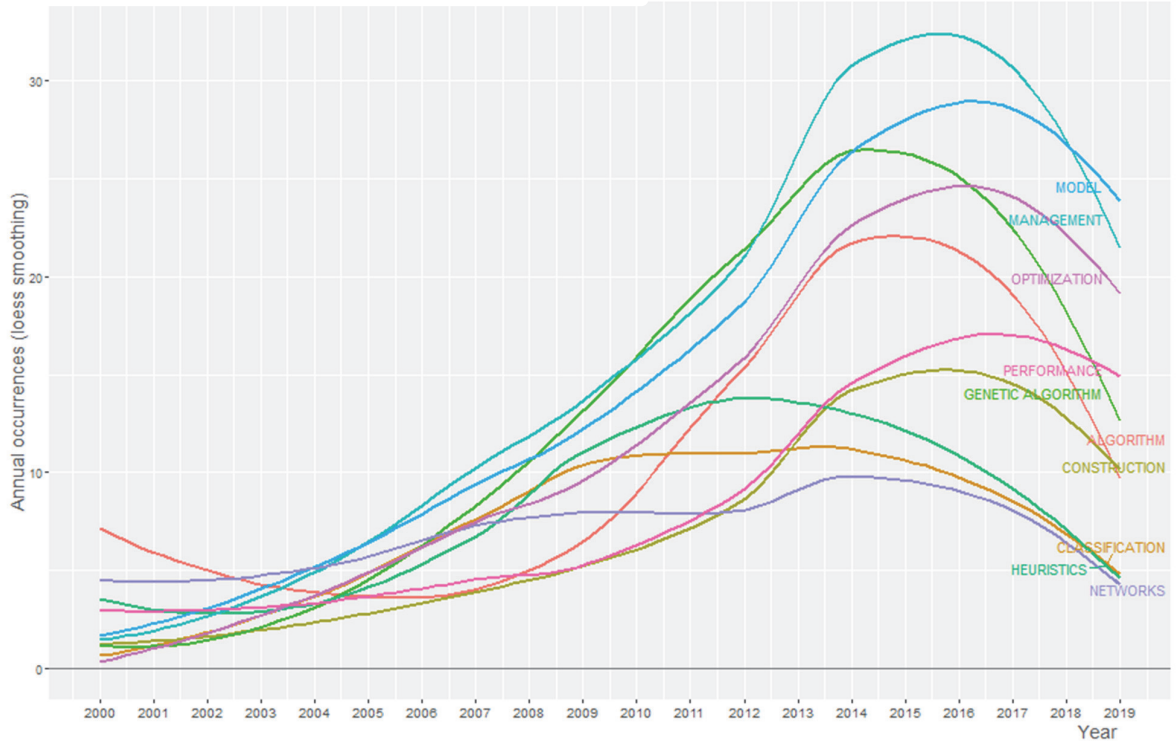

Fig. 4. Word growth

A careful study of the words repeatedly used in papers during the past twenty years shows that the modeling through OR (as a very efficient and effective tool) has found a special place in the project management science. Modeling and optimization in Fig. 4 did not have a specific place in the mentioned science in the late 20th and early 21st centuries; they began their growth in the first decade of the 21st century. This suggests that the project management science has entered a larger scale domain with half a century delay compared with the construction management. Fig. 4 also shows that the concept of evaluation has not yet found its real place and it can be foreseen that there will be a

fast growth in this area in the coming few decades and many researchers will work on it. If the scope of the words used in this science is examined systematically, it will be found that there are significant internal effects among words in the three areas. Fig. 5 shows that the project network has been formed mostly through algorithms and mathematical models and the most specific case considered in the models has been the parametric uncertainty which is a very important factor in the project failure and success; hence, it has attracted more attention. On the other hand, "design" and "modeling" are the keywords that play a role in the evaluation and show the role of optimization in this aspect of the project management.

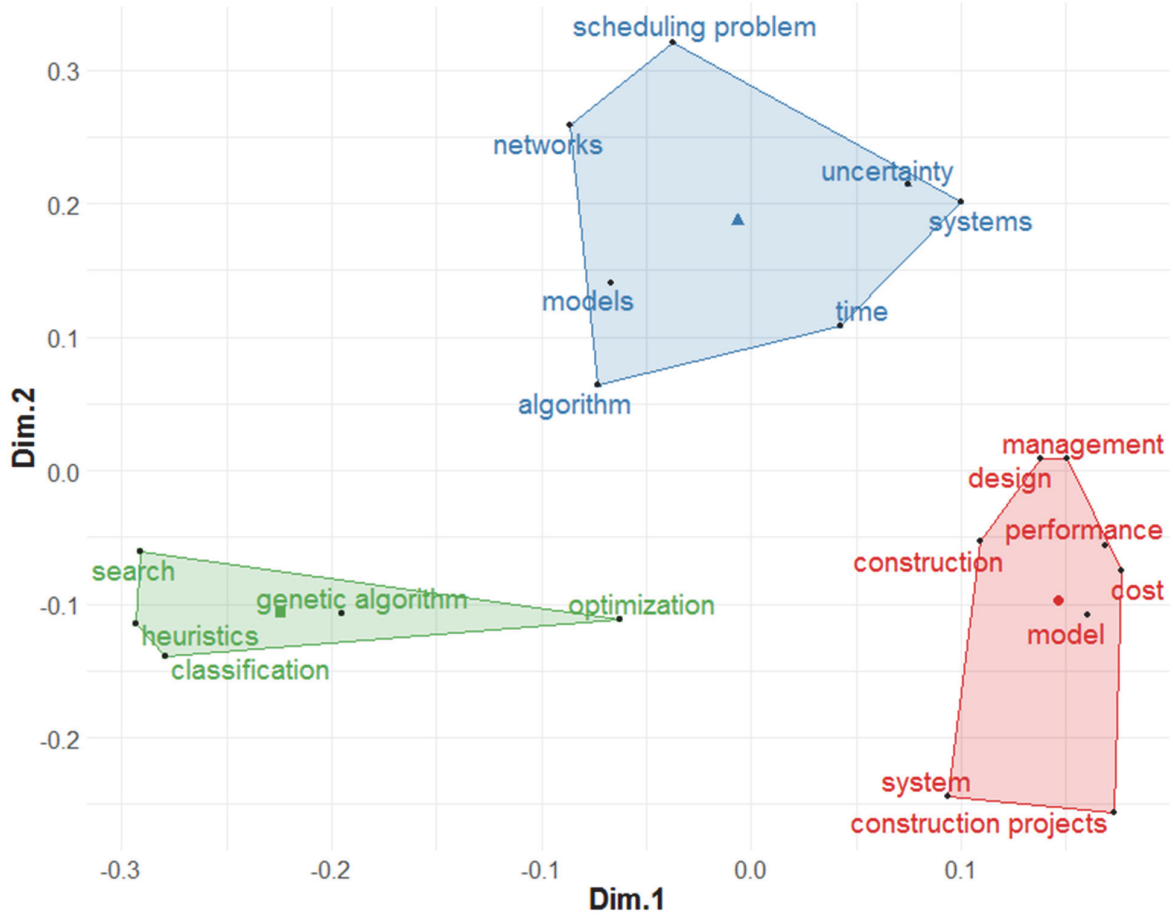

Fig. 5. Conceptual structure map

Conclusions

The effort made in this paper has aimed to study and analyze different phases of the application of optimization in the project management using a scientific approach. Accordingly, all papers published during the period 1940-2019 to answer the project management-related questions with the optimization tool were reviewed and the results have shown that the optimization science has penetrated so deep in this area that other specialized disciplines (not generally familiar with it) should also use it to advance their research objectives. On the other hand, different parts considered more by authors were identified and grouped into three areas of scheduling and sequencing activities, resource allocation, and performance evaluation. Although various issues were raised and investigated in all the three areas, the scheduling and sequencing activities area was known to be more interesting and applicable than the other two. A study of different graphs also shows the emergence of new and growing areas a very important and interesting of which is the use of optimization in the evaluation of the project performance.

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