**Программа учебной дисциплины «Прикладной системный анализ»**

*(на английском языке)*

Утверждена

Академическим советом ООП

Протокол № от «\_\_\_\_»\_\_\_\_\_\_\_\_\_\_\_20\_\_\_ г.

|  |  |
| --- | --- |
| Автор | Дегтярев К. Ю., к.т.н., доцент |
| Число кредитов | 5 |
| Контактная работа (час.) | 64 |
| Самостоятельная работа (час.) | 126 |
| Курс | 1 (магистратура) |
| Формат изучения дисциплины | без использования он-лайн курса(-ов) |

# Course Information

## Author of the Program: Assoc. Prof., PhD. Konstantin Y. Degtyarev (responsible lecturer)

**Course Title in English:**Applied System Analysis

# 1 Field of Application and Regulations

The course "Applied System Analysis" ("System and Software Engineering" MS Program, 1st year) syllabus lays down minimum requirements for student’s knowledge and skills; it also provides description of both contents and forms of training and assessment in use. The course is offered to students of the Master Program "System and Software Engineering" (area code 09.04.04) in the [Department of Software Engineering](http://se.hse.ru/progr_ob/), Faculty of Computer Science (FCS) of the National Research University Higher School of Economics ([HSE](http://www.hse.ru/en/)). The course is a part of MS curriculum pool of compulsory courses (1st year, Base Clause – *General Scientific disciplines*of the academic year’s curriculum, M.1 – *General Courses of Specialization* (Цикл общих дисциплин направления)), and it is a four-module course (semester A quartile 1 thru semester B quartile 4).

# 2 Course Objectives

The main objective of the course "Applied System Analysis" is to present, examine and discuss with students fundamentals and principles of both *System Analysis* and *Systems Thinking* that emerged in response to (1) steadily growing complexity of managerial type problemsarising in various areas of day-to-day human activity, (2) necessity to present (viz. to develop model(s) whether it is mental or formal one(s)) and to assess emerged situations complemented with a search for acceptable solutions (problem solving).

Despite the fact that System Analysis (SA) and its practical orientation Applied Systems Analysis (ASA) form a fervid point at issue for a long time, there is no common comprehension and general approach to present SA and its practical applicability from interdisciplinary viewpoint within the scope of university courses, text-books (or, manuals). *As an integrate*, the objective of the course can be thought as a combination of the following constituents:

* discussion of historical and methodological preconditions for the rise of system analysis,
* familiarity with peculiarities of both General System Theory and Cybernetics as applied areas related to general description of organization and control within systems,
* understanding of the notion of system and origin of system properties, classification of systems, structural aspects of systems, systems complexity, general-system regularities as well as the framework of system analysis (SA) as the most significant area of applied system studies, specificity of applied systems analysis and systems thinking,
* understanding of the mission (goal-oriented nature / purposefulness) and effectiveness of systems, goals and difficulties with goal-setting, importance of goals analysis, criteria definition, accounting of stakeholder interests, use of heuristic methods in problem solving (viz. informal analysis),
* understanding of the role of models (modeling) in SA, SA base methods, «hard» system methodology, SA tools; discussion of some approaches to (re)solving problem situations, particularities of optimization tasks, multi-criteria problems (arranging key factors for the problem under study in a hierarchic structure / AHP method), decision-making under uncertainty (fuzzy case),
* obtaining skills in utilizing «soft» systems thinking (SST) techniques in problem solving (decision support in real-world complex problems), examination of SSM («soft» system methodology) stages, decision-making based on soft models,role ofsystem approach to problem solving.

From the standpoint of course’s seminar organization, the main aim is to provide detailed knowledge of systems principles, modeling («hard» system analysis tools), systems thinking (ST) and systems thinking tools (e.g. *causal loop diagrams*, *cognitive maps*). The matter is related to shaping competences of systems thinking, because it allows to take a view in a new way of habitual (and frequently recurrent) managerial (organizational) problems and the role of people (participants) in such problems – one of main ST propositions states that *«everything and everybody are linked up into* *indefinitely complex network of systems»*. Seminar examples (case studies) can be done individually or in small groups (two to three students); exercises stipulate thinking over certain problem’s points, substantiation (defense) of answers (theoretical schemes), discussion of Applied SA techniques (study of multistage chain of actions starting from problem statement to decision making and potential improving interference).

# 3 Learning Outcomes

While mastering the course material, the student will

* *understand* historical and methodological preconditions for rise of System Analysis (SA), peculiarities of both general system theory and cybernetics as applied disciplines related to general description of organization and control within various systems,
* *know* what the system is and what systems properties are, the structure (framework) of system analysis as an area of applied systems studies, specificities of both applied system analysis and systems thinking, system-wide regularities and technology of ASA,
* *understand* the role of models (modeling) in system analysis, main aims of system analysis as a methodology of problem solving (as a process of step-by-step establishing priorities of problem’s constituents), particularities of multi-criteria problems, decision-making under uncertainty, *consider* system approach as a methodological base for software design process, *identify* systems and their components, think in «big picture» terms while analyzing the problem,
* *have* a *clear notion* about systems modeling, types (representation forms) of models, so-called «hard» и «soft» system methodologies, *perceive* modeling objectives and its base role in studies and research,
* *obtain* necessary skills to diagnose the problem, *see* both patterns and trends in a problem, *gain insights* about our role in problems we experience, *discover* (systemic) structure behind a pattern of behavior,
* *acquire practical skills* in using «hard» (formal) models, systems thinking tools (e.g. Causal Loop Diagrams (CLD), mind maps), «defend» their own elaborated approaches and solutions while working on problem’s solution individually and/or in small groups (collaborative efforts)

[***option – only if access is provided***] *master practical work* with one of software products aimed at analysis of complex systems functioning (elaboration of scenarios *«what will happen, if…»*),

* *acquire skills* of analyzing and solving weakly structured/unstructured problems, heuristic methods of problem solving, *gain experience* in reading, understanding and presenting in their own words (ad-lib report in a condensed form) the main point of selected scientific papers (in English).

In short, the course contributes to the development of the following professional competencies:

(1) **research activities** (the ability to manage self-paced and/or team work on research projects, read and analyze publications in English and use acquired knowledge in practice),

(2) **project activities** (the ability to handle project work in a systematic way, develop appropriate descriptive model(s), conduct (mainly) qualitative analysis),

(3) **technical activities** (the ability to apply state-of-the-art approaches (technologies) in course of problem solving and software development).

# 4 The Course within the Program’s Framework

Course’ academic control forms include

(1) Course Examination (CE), which implies (option 1) computer-based testing + written test or (option 2) just written test only in the end of 2nd module (December 2017). Date and time are discussed with students and the Manager of the Educational Program / Departmental Office of Studies (Department of Software Engineering); material to be covered by CE is fully determined by both course schedule and topics discussed in the course by corresponding date,

(2) one Homework Assignment (HW) (*course’s Homework* (HW)) to be prepared within the period that starts from the second half of the Module 2 (appr. December 15th ÷ December 23rd) and ends by (appr.) March 25th – March 30th, 2018. All necessary details and exact dates will be discussed in the class. Written reports in the form of IEEE, Elsevier or Springer LNCS publ. papers that follow certain format templates – see <https://www.overleaf.com/gallery/tagged/academic-journal>, have to be prepared and submitted in the electronic form to the instructor through HSE *L*earning *M*anagement *S*ystem (LMS)); HW contains 1 (one) task that is related to field of IT, Computer or Software Engineering,

(3) two classroom (written) quizzes (WQ) covering 2 to 3 questions (free-form answers) are offered in Module 2 (e.g. in November-December) + one optional quiz in Module 3 – their results are taken into account while calculating final standing in the course,

(4) Final Examination (FE) is composed of HW report(s) (papers) oral presentation (.ppt file is a MUST requirement for students!) and questions-answers session arranged after the presentation (April-May 2018; follow the schedule to be announced in March 2018 / Module 3).

**Prerequisites**

It is presupposed that all students enrolled on the course completed corresponding *full-time Bachelor degree training programs* and were selected (based on either portfolio tenders, or other core performance indices) to continue their MS education in the educational program “Software Engineering”. Therefore, no other special requirements, apart from those that are just mentioned, are put forth.

# 5 Course Contents (Main Topics / Sections)

**NOTE**: The lectures and seminars are given to one group of students (i.e. dividing into subgroups is not stipulated). Therefore, the discussion of lecture material and seminar topics can be arranged in more *flexible manner* allowing to alternate lectures and seminars as necessary.

**Section 1.** Introduction and Overview of the Course. Origins of Systems Analysis. Notions of System and Systems Thinking. Definitions of System and Systems Engineering. Classification of Systems; SPE-pyramid (grasping system’s structure), causal schemes, examples,

**Section 2.** Organizations and System approach. Systems and Complexity. Models of Systems (static/dynamic models). Hard and Soft Methodologies in the Analysis of Systems (discussed throughout the course),

**Section 3.** System Methodologies. Mental Models. Properties of Systems. Specific features of Applied System Analysis. SA Base Methods (stages). Stakeholder Analysis,

**Section 4.** SA Base Methods (stages)*.* Use of Structural Analysis (StrA) Methods in Systems Studying. System Analysis Tools. Examples, Case Study (Vendor/Technology selection),

**Section 5.** Problem Situation. Optimization problems (as examples of hard models). Next Release Problem (NRP)/ILP problem. Structural Analysis of Systems (Q-analysis),

**Section 6.** Multi-criteria selection. AHP Method and Its Discussion. Purposefulness of Systems (goals). Heuristic Solutions. Examples and Discussion. Goals Uncertainty. System Approach to Problem Solving. Decision-making under Uncertainty. Examples and Discussion,

**Section 7.** System Engineering. System Analysis (SA) of Goals. Discussion: Problem statement to wide extent[[1]](#footnote-1). What System Analysis Really is?

Selected Topics (*subject for changes*) to discuss at Seminars:

**-** Defining characteristics of systems. Events, templates, structure

**-** What are system’s boundaries? Representation of systems. Information systems

**-** Discussion of paper (related to the material covered – *to be specified*)

**-** Case Study (*to be announced at the lectures*). Preliminary comments and observations

**-** Q-analysis procedure. Formal description of system’s structure. Local and global characteristics of connectivity

**-** Q-analysis: Simplices and simplicial complex, first structural vector of simplicial complex, eccentricities

**-** Q-analysis: Discussion of selected papers (R.Atkin / J.Casti)

**-** Decision-making under uncertainty: fuzzy sets approach; operations on fuzzy sets. Case study – discussion

**-** Optimization tasks. Multi-criteria selection. Discussion of examples

**-** Heuristic approaches

**-** Comments related to [causal loop diagram](http://en.wikipedia.org/wiki/Causal_loop_diagram) ([CLD](http://www.pegasuscom.com/cld.html))

**-** Templates of system’s behavior (explanations, performing exercise. Case Study. Preliminary comments and observations

**-** Templates of system’s behavior (explanations)

**-** Аnalysis of systems behavior – revealing of behavior templates and understanding of reasons that cause such behavior

**-** Understanding of feedback (connections between system’s components, presence of feedback)

**-** Principles of systems thinking 1 («big» picture), measurable and non-metering (non-measurable) data

**-** Understanding of feedback (connections between system’s components, feedback). Case Study

**-** Connections and interdependencies among components of a problem, intangible aspects of a problem, widening view of a problem

**-** Inputs and Outputs. Discussion of the paper “Software Systems Analysis – A Research Area Overview” (comments, ideas)

**-** Uncovering systemic structures: formulating the problem, identifying key variables in the situation (problem) / main actors

**-** (Explanations) identification of main problem in complex situation, graph the behavior of key variables over time

**-** Setting goals and measuring results, short-term and long-term aspects of the work (explanations, exercise(s))

**-** Uncovering systemic structures: building causal loop diagrams (СLD). Relationships between variables (‘s’ and ‘o’ notations)

**-** Feedback loops; hidden troublemakers. Building СLD, discussion of approaches. Multiloop diagrams. Case Study

**-** (Explanations, exercise(s)) Distinguishing reinforcing and balancing processes. Discovering dynamic structure

**-** Discussion of the paper #1: ˝Teaching systems analysis to software engineering students: experience with a structured methodology˝

**-** System analysis and design. Are they really needed?

**-** AHP method, its use in IT/CE and SE fields (following publications by T.L.Saaty and others). Fuzzy AHP. Case Study

**-** Archetypes in CLD. Information links and rate-to-level links in CLD (difference). Formal approaches in CLD analysis

**-** Case Study (works of C.Eden). Pattern of behavior (structure behind a pattern of behavior)

**-** Topological features of CLD (qualitative assessment of strengths / works of B.Kosko and C.Eden)

**-** Homework presentations (schedule to be announced in the middle of March, 2017). Q-A session (discussion).

/ all papers mentioned above can be accessed through electronic resources of HSE library /

# Recommended Books (Publications)

(additional papers will be also recommended to students for self-studying and analysis – see “Applied System Analysis” LMS pages)

*Printed Sources:*

* [ in Russian]Козлов В.Н.Системный анализ, оптимизация и принятие решений (уч. пособие), М.: Проспект, 2010 (**Kozlov V.** Systems Analysis, Optimization and Decision Making (Teaching Aid), Prospect Publ., Moscow, 2010) (available: HSE Library),
* [ in Russian]Волкова В.Н., Денисов А.А. Теория систем и системный анализ : учебник для вузов, М.: ИД Юрайт, 2010 (**Volkova V., Denisov A.** System Theory and Systems Analysis (Textbook), URight Publ. House, 2010) – или более поздние издания (available: HSE Library),
* [ in Russian]Тарасенко Ф.П. Прикладной системный анализ : учеб. пособ., М.: КНОРУС, 2010 (**Tarasenko F.** Applied Systems Analysis (Teaching Aid), KNORUS Publ., Moscow, 2010) (available: HSE Library),
* [ in Russian]Антонов А.В.Системный анализ, М.: Высшая Школа, 2006 (**Antonov A.** Systems Analysis, Higher School ((Visshaya Shkola) Publ., Moscow, 2006) – или более поздние издания (available: HSE Library),
* Schaveling J., Bryan B. Making Better Decisions Using Systems Thinking: How to Stop Firefighting, Deal with Root Causes and Deliver Permanent Solutions, Palgrave Macmillan Publ., 2018 (available: HSE Electronic Resources / Books 24x7),
* Gorod A., et al. Case Studies in System of Systems, Enterprise Systems, and Complex Systems Engineering, CRC Press, 2015 (available: HSE Electronic Resources / Books 24x7),
* Eisner H. Topics in Systems, Mercury Learning, 2013 (available: HSE Electronic Resources / Books 24x7).

*Internet-based Publications (sources):*

* Guide to the Systems Engineering Body of Knowledge (SEBoK) – Foundations of Systems Engineering, Applications of Systems Engineering, etc.; <https://www.sebokwiki.org>
* The Guide to the Software Engineering Body of Knowledge (SWEBOK Guide) – <https://www.computer.org/web/swebok>
* Principia Cybernetica Project (PCP), 2002, <http://pespmc1.vub.ac.be/> (in particular, section on Systems Concepts) - <http://pespmc1.vub.ac.be/SYSCONC.html> )
* Kotelnikov V. Systems Thinking – Focusing on the whole, Not the Parts, of a Complex System, <http://www.1000ventures.com/business_guide/crosscuttings/thinking_systems.html>
* International Society for the Systems Sciences, <http://www.isss.org/world/>

*Other Recommended Sources of Information (under Free Electronic Access):*

* Legrand J. [How Far Can Q-analysis Go Into Social Systems Understanding?](http://www.afscet.asso.fr/resSystemica/Crete02/Legrand.pdf) (Association Française de Science des Systèmes), 5th European Systems Science Congress, 2002,
* Gharajedaqhi J.Systems Thinking: Managing Chaos and Complexity. A Platform for

Designing Business Architecture, 3rd ed., Morgan Kaufman Publ., 2011 (available: HSE Electronic Resources / Books 24x7),

* Crawford L., Pollack J. [Hard and Soft Projects Framework for Analysis](http://www.sciencedirect.com/science/article/pii/S026378630400047X), Int. Journal Project Management, vol. 22, #8, 2004, pp. 645-653 (available: HSE Electronic Resources / ScienceDirect),
* Backlund A. [The Definition of System](http://www.emeraldinsight.com/journals.htm?articleid=875856), Kybernetes, vol. 29, #4, 2000, pp. 444-451 (available: HSE Electronic Resources / Emerald Insight),

**[** VVV **publications related to Q-analysis** VVV **]**

* Casti J.L. [Connectivity, Complexity and Catastrophe in Large-Scale Systems](http://www.iiasa.ac.at/Admin/PUB/Documents/XB-79-107.pdf) (International Series on Applied Systems Analysis), John Wiley & Sons, 1979.
* Casti J.L.[Polyhedral Dynamics: I. The relevance of Algebraic Topology to Human Affairs](http://www.iiasa.ac.at/Admin/PUB/Documents/WP-75-030.pdf), IIASA (International Institute for Applied Systems Analysis) Working Paper WP-75-030, 1975.
* Casti J.L.[Polyhedral Dynamics - II: Geometrical Structure as a Basis for Decision Making in Complex Systems](http://www.iiasa.ac.at/Admin/PUB/Documents/RM-75-034.pdf), IIASA Research Memorandum RM-75-034, 1975.
* Casti J.L., Karlqvist A. [Complexity, Language, and Life: Mathematical Approaches](http://www.iiasa.ac.at/Admin/PUB/Documents/XB-85-406.pdf)*,* Springer-Verlag (Heidelberg), 1985.
* Atkin R., Casti J.L. [Polyhedral Dynamics and the Geometry of Systems](http://www.iiasa.ac.at/Admin/PUB/Documents/RR-77-006.pdf), IIASA Research Report RR-77-006, 1977.

**NOTE**: The list shown above includes only recommended sources of information. A wide variety of both printed and electronic books that cover (from various perspectives and to different extent) aspects of system theory, Systems Analysis, complexity, etc., opens up possibilities to choose those particular books (documents, reports) that seem useful and convenient for perception from the standpoint of material’s presentation and refinement.

# 6 Forms of Control and Assessment

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Type of control | Form of control | 1st year | | | | | Parameters |
| 1 | 2 | 3 | | 4 |
| Progress control  (week) | Written quizzes (WQ) - 2 | - | ◼  weeks 2 - 4  (November-December) | - | | - | Written tests (2 to 3 questions) offered during regular class hours (50 to 70 min. each) |
| Course Examin. (CE) | - | ◼  week 7 or 8  (end of December) | - | | - | Computer-based test **or** written test (70 to 85 min.) |
| Homework (HW) - 1 | - | week 7 (*module 2*) - week 9 or 10 (*module 3*)  (exact time periods will be specified further on) | | - | | written report (paper / IEEE, Elsevier or Springer LNCS publ. template) |
| Resultant | Final Exam (FE) | - | - | - | | ◼  (April - May 2017) | Oral presentation of the work done / extra questions (optional)… |

**Evaluation criteria**

Progress (interim) and resultant grades are made up of the following components:

**** course examination (CE) – end of the 2nd module (Semester A Quartile 2)

implies arrangement of (option 1) computer-based testing + written test or (option 2) written test only for all students enrolled (final decision is taken be the course instructor). Subject area covered by tests embraces those topics of the course that are discussed during both lectures and seminars up to the date announced. The computer-based test () may contain both single-choice and multiple-choice questions; in that case the grade is given out by the test program automatically. As a second option, written test () includes 2 to 3 questions (letter ‘T’ means *«test»*).

If student misses CE because of some *valid reason* (only this particular case is covered by the document!), situation has to be discussed with the representatives (managers) of the Departmental (Program’s) Office of Studies.

The course examination (CE) is assessed on the ten-point scale (usual rounding takes place after weighted sum calculation is completed) – corresponding grade (*Interim Evaluation 1*, *IE1*) is obtained as follows (depends on option is use as mentioned earlier):

(option 1) ,

(option 2) ,

**** homework assignment (HW) – 2nd -3rd modules (Sem. A Quartile 2 – Sem. B Quartile 3)

is prepared by students individually or in groups by two (at most), herewith each student (group) has to prepare electronic (PDF format solely) report, which is of the form of a scientific paper (5 to 7 pages) in IEEE or other well-established formats (*following IEEE*, *Elsevier or Springer LNCS publ. format template*). Students are free to choose a system to consider (under specified topic) based on their own interests and preferences – after approval by the instructor, the work can be started (appr. second part of December 2017).

All reports should be submitted to instructor for consideration *before* the date , which is set (last decade of March 2017 as a rough estimate) and announced in the beginning of Module 3. All reports are checked and graded by the instructor on ten-point scale by the end of the 4th Module as the latest, and **** gives evaluation for the 4th module of the academic year.

[**Important note**] Please, be informed in advance that failure to comply with specified time limit  for submission of the report leads automatically to the reduction of **** by *0.4**points* for each delayed day.

After multiplication, "corrected" grade (homework report evaluation) is rounded.

Finally, the total course grade on ten-point scale is obtained as



(usual rounding takes place after calculations are done), where **** is a"corrected" grade (if correction factor is applied – see Important note above), WQ – a grade for written quizzes (see also page 3 above), and O(FE) is a grade obtained for the presentation done (additional questions related to topics covered by the course and HW report prepared can be asked to students). A grade of 4 or higher means successful completion of the course ("Pass"), while grade of 3 or lower means unsuccessful result ("Fail"). Student has a chance to obtain “automatic” O(Total) grade (final course grade that can be only at the “excellent” level, i.e. 8, 9 or 10) *without* passing through FE (presentation) provided that

(1) classroom test (WT) is marked as “very good”, “almost excellent” or above (7 or above out of 10),

(2) the result of O() is 8 or above and O() is 8 or above (under option 1 – see top of the page), or the result of O() is 8 or above (under option 2 – see top of the page), and

(3) homework assignment (HW report) is graded with 8 (out of 10) or above. However, it is strongly recommended to all students, without exceptions, to make presentations of their works (HW).

Conversion of the concluding rounded grade O(Total) to five-point scale grade is performed in accordance with the following table:

**Summary Table: Correspondence of ten-point (10) to five-point (5) system’s grades**

|  |  |
| --- | --- |
| **Ten-point scale [10]** | **Five-point scale [5]** |
| **1** – unsatisfactory  **2** – very bad  **3** – bad | Unsatisfactory – **2** |
| **4** – satisfactory  **5** – quite satisfactory | Satisfactory – **3** |
| **6** – good  **7** – very good | Good – **4** |
| **8** – almost excellent  **9** – excellent  **10** – brilliantly | Excellent – **5** |

# 7 Educational Methods and Technologies

Class studies in the discipline "Applied System Analysis" (ASA) are organized in the form of lectures and seminars; the initial (appr. 15%) part of the theoretical material is supported by course slides that allow to cover corresponding material faster, without spending much time on writing. The rest of the discussion in the course stipulates active utilization of markers and whiteboard (writing + explanations) and case studies (formulation, discussion, etc.) that highlight vividly core ideas, their meaning, analysis/research approaches in use, regular and unusual situations, and so on.

As stated in [1], case study can be considered as “an ideal methodology when a holistic, in-depth investigation is needed; case studies have been used … increasingly in instruction”. According to Professor Paul Lawrence (Harvard Business School), a good case study is the “vehicle by which a chunk of reality is brought into the classroom to be worked over by the class and instructor”. As a result, the case study approach used in class makes the learning process more interactive and entertaining; it also allows students to feel at real-world situation both in teamwork as well as independent work. In addition, much attention is also paid to encourage students to approach responsibly to the preparation of the homework reports (in the form of papers that follows IEEE, Elsevier or Springer LNCS format template; see

<https://www.overleaf.com/gallery/tagged/academic-journal>) and its presentation in English.

To the extent possible, case studies deal with those topics that are related on the whole to IT, engineering and management fields.

**7.1 Recommendations for Course Instructors**

It should be emphasized that the core problem for the instructor offering this course is the lack of ready-to-use sources of information (e.g. 1 or 2 titles to recommend students to follow straight on, slides that in-depth accomplish book’s contents, detailed description of case studies that can be followed and analyzed in all minute aspects, etc.). This fact must be addressed responsibly while preparing materials.

# 8 Learning Resources (software and supplementary ref. materials)

It is also strongly advised to all students to use **Electronic Resources** of the **HSE library** (<http://library.hse.ru/e-resources/e-resources.htm>) that provide access to information sources related to foreign scientific journals, full-text theses, electronic books, dictionaries and encyclopedias.

Besides, the following software titles (*Free Mind Mapping tools*) can be noted as candidates for use while preparing course homework:

- Edraw MindMap (a vector-based mind mapping software with rich examples and templates) – <http://www.edrawsoft.com/freemind.php>) – *free mind map software*,

- Freeplane (a free and open source software to support thinking, sharing information and getting things done – <http://freeplane.sourceforge.net/wiki/index.php/Main_Page>) – *free mind map software*,

- XMind is a popular mind mapping software - <http://www.xmind.net/>),

- FreeMind (a free mind mapping software –

<http://freemind.sourceforge.net/wiki/index.php/Main_Page>) – *free mind map software*,

Additional information on FreeMind tool can be found at

<http://upgradeway.ru/articles/eshhe-odin-udobnyj-instrument-dlya-sozdaniya-intellekt-kart/>)

- MAPMYself (инструмент для создания интеллект-карт онлайн –

<http://www.mapmyself.com/>) – *free mindmapping software*,

- VUE (The Visual Understanding Environment, Tufts University | is a tool for managing and integrating digital resources in support of teaching, learning and research; visual environment for structuring, presenting, and sharing digital information – <http://vue.tufts.edu/>) – *free tool*,

- TheBrain (a powerful brainstorming and knowledge management tool –

<http://www.thebrain.com/>),

- mindmaps (online service to work with mind maps –

<http://ruseller.com/service.php?rub=22&id=2228>) – *free* *online service (in Russian)*,

- IHMC Cmap Tools (a software that enpowers users to construct, navigate, share knowledge models represented as Concept Maps) – *free access* – <https://cmap.ihmc.us> .

**8.1 Additional reference sources (Mind Mapping tools)**

- Main principles of mind maps processing (in Russian –

<http://www.cfin.ru/management/controlling/mind_map.shtml>),

- What is Mind Map? – <http://en.wikipedia.org/wiki/Mind_map>,

- 7 Ways to Use Mind Maps in Business (ThinkBuzan, 2010 –

<http://www.thinkbuzan.com/uk/articles/view/7-ways-to-use-mind-maps-in-business>,

- The Theory Underlying Concept Maps and How to Construct and Use Them by Novak J.D. and Carias A.J. –

<http://cmap.ihmc.us/Publications/ResearchPapers/TheoryCmaps/TheoryUnderlyingConceptMaps.htm>,

- Introduction to Concept Mapping –

<http://www.inspiration.com/visual-learning/concept-mapping>.

1. Problem understanding – discovering main actors of the problematic situation – obtaining subjective estimates of the reality – adequate model building – goals and criteria – experimental study – model adjustment (update) – formation of alternatives – decision making – improving interference. [↑](#footnote-ref-1)