Operations Research

Operations Research as Multidimensional Complexity Management

Modern Operations Research Underpinning Planning Tasks and Process Optimisation in the COMTESSA Competence Centre

zur deutschen version

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Operations Research (OR) is a young scientific discipline, geared towards solving decision-making problems. It has its origins in situations in which decision makers have to come to a decision in circumstances characterised by precariousness and insecurity, and in which they rely on various OR methods to map and analyse the problem systematically. This analytical aspect is the focus of this text. OR (initially) starts from decision-making problems - frequently exacerbated by insecurity or even risk. The decision maker often has incomplete knowledge of future developments and (despite this) would like to find an optimal solution to the situation. In this, either one optimal solution is presented, if clear goals are set out and the problem is quantifiable, or a number of alternative decisions are advanced. To this end, models are generated (often mathematical ones) to establish a quantitative basis.

Using pertinent data, a (usually simplified) picture of reality is created, to work on the problem or to solve it. The analysis of various possible scenarios to select the best option is also part of OR. Uncertainty is not necessarily part of this process. One example could be the selection of specific production methods to optimise costs.

Characterised by Interdisciplinarity

To this end, research findings of all (!) scientific fields involved must be considered, provided they are conducive to problem solution.[1] For example, the creation of a suitable OR model to analyse a diffusion problem in hybrid vehicles powered by renewable energy, requires a minimum knowledge of the structures of, and the correlations between, technology, economics, sales, psychology and markets. This is why OR is always regarded as interdisciplinary.

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The history of OR is closely connected to military developments. Classic OR was, initially, triggered by the military, before it became part of industrial process management as described above, and then economic research, as well as civilian system analyses. It needs to be mentioned here that OR application and further development have always been characterised by a certain ambivalence, which is also reflected in the ex post assessment of the Vietnam War. This point will be addressed at the end of the article. Apart from the history of OR, which should serve as a motivator in this text, the focus of this article is on current, forward-looking projects. Some of these projects are closely connected with the author; he has always aspired to make this ambivalence a central theme.

The chair of Prof. Dr. Stefan Pickl at the Bundeswehr University Munich, and the COMTESSA Competence Centre instituted by him focus their research activities on the interdisciplinary interaction of such different and complex systems, and its investigation, analysis, and optimisation with regard to certain criteria. In this, special relevance is given to the ambivalence of research and technology in the history of OR.

OR History

With regard to operations research, Wikipedia (German edition) says:

The term operational research was coined by the military. It was used in 1937 for a group of researchers who were tasked with investigating the ideal set-up of a radar system for the British armed forces. In 1940, the British Air Ministry ordered the creation of a group exclusively dedicated to operational research. That year, the British Army and the Royal Navy set up identical groups. Further questions to be investigated by the groups set up during the Second World War in England, the USA (here called operations research), and the Soviet Union, were, inter alia, the ideal number of ships and escorts for shipping convoys or the ideal size of a bomb carpet with regard to precision and scatter. The war over, the researchers turned to the economic field, with the task to achieve a desired goal at the least cost, or the dual task of achieving the best possible result with the means available (economic principle). For operations research, traditionally referred to in Great Britain as operational research, no universally valid German term was found. The terms Unternehmensforschung, Operationsforschung or mathematische Planungsrechnung have been used. In the late 1960s and early 1970s an unsuccessful attempt was made to establish the term Ablauf- und Planungsforschung, which is why the scientific journal Ablauf- und Planungsforschung appeared from 1959 to 1971.[2]

The main features of the present text, starting from this definition, were written for a special publication of the Deutschen Gesellschaft für Wehrtechnik e.V.[3] in which various fields of military decision-making support were presented. It was to elaborate the, then, current understanding of operations research, as well as deal with the new Bundeswehr Office for Defence Planning and its connections to these central, functional areas.

Agencies and offices oftentimes stick to terminology: operations research had its heyday in the 1960s and 1970s; then came decision-making support, followed by modelling & simulation. This has now been replaced by strategic planning in the Office for Defence Planning, and the newly introduced CPM (Customer Product Management). It is the aim of this text to show that OR may not have dominated these trends as a term, but can and should be seen as a connecting link. This points towards the future insofar as OR increasingly comprises quantitative and qualitative approaches. This has not always been the case.

For more details, see Krarup[4]. In a historical context, especially concerning an Austrian perspective, special mention must be made of Abraham Wald,[5] who analysed the damage to bombers. Wald is regarded as one of the founding fathers of OR; his sphere of influence, however, was rather more American than European.

Hard and Soft OR

Until the middle of the 1970s, Operations Research was only understood to mean the application of quantitative methods in the modelling of decision-making situations in order to achieve defined goals within a systematic framework. In the subsequent decades, however, this picture changed as new methods of methodical thinking were developed, which were also regarded as part of OR. Since then, a distinction has been made between Hard OR and Soft OR.[6] Hard OR can be characterised as follows:[7]

The problem is mostly of a technical nature, as far as possible free from human aspects, clearly defined, well-structured, and delineated vis-à-vis its context. The decision maker's goals are known, and their accomplishment can be verified.

- Future possibilities and decisions, as well as their limits, are known.

- The decision maker is in a position to have the solution implemented.

In contrast, Soft OR deals with the interpretation of systems; the problem, as a rule, being rather unstructured and complex. The problem cannot be separated from the various actors and their activities and thus cannot be dealt with by means of mathematical models. Soft OR therefore increasingly asks for the what? rather than the how?. The fundamental characteristics of Soft OR can be summarised as follows:

- It is informed by the necessity of structuring a problem; a specific solution is worked on only subsequently.

- It is imperative to improve the communication between the actors; a concrete decision-making tool is only created subsequently.

Central questions concern the type of topic, appropriate goals, suitable problem definitions, as well as desirable changes to the system.[8]

This point of view implies a special procedural approach, as it is applied in Gabler's[9] online dictionary of economics.

Specific Process Notion as OR's USP

Gabler's respected dictionary of economics lists the process notion as central to an OR-based examination. The process of applying OR to solving problems can be subdivided into the following phases:

(1) formulating the problem;

(2) analysing the relevant context of the problem;

(3) developing a mathematical model isomorphic to the problem;

(4) acquiring and processing data, as well as conceptualising a solution method;

(5) looking for model solutions;

(6) checking results;

(7) translating the solution to the problem.

In this, also Gabler refers to the following analytical methods:

To support specific decision-making processes, a number of different analytical OR methods can be applied, such as the decision tree method, graph-theoretic methods, methods employing mathematical optimisation or simulation, heuristic methods, and methods using game or queuing theory.

Within these methods, the following problem types can be can be classified in a paradigmatic manner:

(1) waiting time problems;

(2) allocation problems: sequence (channels);

(3) transport, production programme;

(4) storage problems;

(5) replacement problems;

(6) competition problems.

Extensive articles by Müller-Mehrbach[10] and Domschke[11] also provide important information on classification. As mentioned above, the possibilities of application are manifold.

In addition, according to Gabler, empirical analyses of industrial enterprises show that in Germany OR was applied most often in in primary industries, in metal processing and chemical industries, as well as in electrical engineering, and utilities. Airlines, trading companies and agricultural businesses are also known to use it. As regards functional areas within companies, the application focused on production, stock-keeping, and sales.

Today, numerous applications can be found in banking and telecommunications. In the past ten years, institutional OR groups in companies have essentially disbanded and have been integrated into IT and related departments. Integration of OR algorithms in standard software packages and decision-support systems is prevalent in these methods.[12] As mentioned before, scenarios and case studies are gaining in importance.

The Importance of Case Studies - Integration into Complex Planning Processes

One method which can be ascribed to Soft OR and which has become increasingly popular involves qualitative case studies and complex planning, which will be addressed in the following. In this, contextual data from limited real phenomena are analysed in order to generate a deeper understanding of existing real phenomena. Numerous studies, however, employ the methodology on the basis of inadequate research design, deficient research into data or wrong analyses of the same.

It is thus not only meaningful, but also self-evident that - within the above-mentioned new planning processes (integrated planning processes IPP) and especially with a view to a new CPM - modern OR expertise be integrated into central planning processes and also into international projects. As a further development of DWT-Info 2013,[13] this text therefore aims to illustrate this modern understanding of operations research in terms of multidimensional complexity management:

COMTESSA

Via international research projects (inter alia with the partner university NPS Monterey, the Tomasek Institute in Singapore, as well as the German Navy's Centre of Excellence) and EU programmes, the Competence Center for Operations Research, Strategic Management, Safety & Security Alliance - COMTESSA is part of complex, first-hand planning projects which meet this academic challenge in the context of concrete applications. In the following, individual projects and examples of research will be presented. They all have this in common:

Modern scenarios, e.g. in the context of CD&E are generated and evaluated by means of OR expertise.

In the following, this perspective is to be illustrated by means of:

1. concrete scenarios in the field of future development analysis

2. data exploration and Big Data

3. agent-based simulation and system dynamics

4. complex networks

5. modern decision-support libraries

6. reachback processes

7. selected examples and integration

8. consolidation of the approaches within innovative course content

Motivation Foresight Analysis: Quantitative Methods in Future Development Analysis

For example, as part of the current project "The evolution of future development analysis methods" a demonstrator is being developed, with the aim of contributing to the Bundeswehr's security research analysis of the future. The focus is put on generating up-to-date scenarios and developing a crisis map:

Modern future development analysis is becoming more important and requires the support of convenient software solutions. Many systems focus on qualitative methods and thus neglect important quantitative techniques. In a current study, an interdisciplinary team at UniBw Munich analyses quantitative methods and attempts to develop an innovative software prototype. The beginnings of modern academic research in the field of future development analysis can be traced to the Second World War. Since that time, qualitative and quantitative methods have been established to be better prepared for developments. Early identification of trends, especially in the field of security policy, plays an ever greater role in our globalised, networked world. The study, supported by the Bundeswehr Office for Defence Planning supports the Bundeswehr's security research analysis of the future.

In this, the cooperation between two chairs at the UniBw Munich - that of International Relations (Professor Dr Carlo Masala)[14] and that of Operations Research (Professor Dr Stefan Pickl) - has not only made it possibly to take an interdisciplinary view of this vital and exciting branch of science, but also amalgamates many years' experience in the field of strategic studies, future development analysis, as well as simulation, and complex systems analysis.[15]

Exploration of Data - Big Data

This study makes clear the current potential of OR today:

The focus of the study on the evolution of future development analysis methods is on the exploration and development of quantitative methods regarding future development analysis and the creation of a software prototype to support risk assessment and horizon scanning. Up to now, many tools which support the foresight analysis process mainly provide qualitative methods and neglect the great potential of quantitative methods.

The research carried out on quantitative methods of future development analysis shows the wide scope of techniques applied. Apart from methods of traditional timeline analysis, computer-based simulations are applied with the help of system dynamics and agent-based simulation.

The research results even found entry into the Quantitative Future Methods Catalogue, in which these techniques' advantages and disadvantages are illustrated. To provide user support, this Catalogue is integrated into the software prototype of a web-based cooperation system for risk assessment and horizon scanning. Based on the German Defence Ministry's Military Scientific Research Annual Report 2013 (Wehrwissenschaftliche Forschung 2013), the following is a brief introduction to the software prototypes developed.

The software prototype combines two components: indicator-based prognosis (IBP) for early country recognition, and topic monitoring (TPM) for internet-based keyword searches and trend analysis. IBP early warning has been implemented as a web service, and its modular setup offers great flexibility and simple scaling possibilities. It serves to visualise the progress and extrapolation of country-based, macro-structural indicators, so as to be able to detect critical developments early. To this end, a selection of various forecast methods was implemented, as well as an automated selection of the best methodology provided, in order to increase the system's user friendliness. TPM monitoring made language and country-specific keyword search possible, as well as visualisation and analysis of the development of activity-related parameters. There is an intensive and forward-looking cooperation of the Chairs for International Relations and for Operations Research with leading international institutes in the field of future development analysis, such as the RAHS Programme in Singapore, which ensures the RAHS prototype's integration into the community. The developments of the past decades - with such diverse events as 9/11, the Arab Spring, the international financial crisis - have illustrated the increasing importance of future development analysis. In this, computer-based support and analysis systems, which combine qualitative and quantitative methods, can make an important contribution (cf. MoD: Military Scientific Research Annual Report 2013).

This motivational first example illustrates the potential and possibilities which OR offers today and which possibilities of cooperation should be developed.

Space does not permit a separate discussion of a complex topic connected with big data, namely machine learning. This deals with data-based production of classification and decision-making methods.

OR is not only to be thought of in connection with transport and logistics management, but can also be defined via its cooperation with the strategic planning and international policy fields. It has already been mentioned that, as part of this project, system dynamics and agent-based modelling take on an important central role. This will be developed in the following.

System Dynamics and Agent-Based Modelling as constituents of Operations Research – IT-based and Service-Oriented Decision-Making Support in Cybernetic Systems

The object to be analysed is characterised by a high degree of complexity and uncertainty - not only in the field of security research analysing the future.

A special focus can be put on an assessment and applicability review of system dynamics-models and agent-based modelling for security-political future development analyses. This Chair for Operations Research has developed this expertise, inter alia, through international cooperation, and also puts it to successful use in other fields of application:

As part of current EU research programmes and the ICT2020 (Information and Communication Technologies) initiative Sustainability in a Connected World, IT-based and service-oriented decision-making support within cybernetic systems designed to explore rational behaviour is being developed. By means of special system-dynamics models and algorithmic optimisation methods the systems are topologically analysed with regard to the following points:

- increasing energy efficiency,

- ensuring security of supply (selected aspects)

- liability to terrorism, and

- resilience of networked infrastructure.

Up to now, research has been carried out as part of a project supported by the German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung) at EU level.

These networks look for the best possible behaviour strategies (inclusion of human factor aspects) as well as stable regions characteristic of such cybernetic systems. Quite often, these regions can only be determined and characterised by means of elaborate algorithmic methods. As part of this working group, a number of researchers therefore work on swarming and computational intelligence, as well as on computational networks (high-dimensional network investigations).

Whereas in the 1960s and 1970s the so-called local view was in the foreground, i.e. the best possible way, the most stable node, the greatest possible flux, the last 10-15 years (stimulated by the concomitant development of the internet) have been characterised by special network structures.

OR Methods Make Complex Networks and High-Dimensional Systems Manageable

Modern Decision-Support Library - KISS

It has already been shown to what extent qualitative and quantitative analyses are based on OR approaches, so one question suggests itself: do the methods have to be continuously re-developed, or is there a possibility to draw on previous experience and to develop special decision-making libraries?

How can a large organisation's knowledge be kept available and interlinked? The Knowledge and Information Sharing System (KISS) presented in the Military Scientific Research Annual Report 2011 provides an innovative possibility, tailored to knowledge storage and transfer, communication, and cooperation in the context of OR projects, and thus answers the question posed above. KISS was implemented there prototypically in the field of military OR.

In our complex world, information and knowledge are gaining in importance as the basis of learning processes. An organisation must be able to store different kinds of information securely and to make them available to authorised personnel. This seems especially important as regards critical projects, such as, for example, military OR, disaster relief, or humanitarian logistics. Successful implementation requires extensive experience on the part of those responsible.

But how can this wealth of experience be made available to others? This process is supported by the Knowledge and Information Sharing System (KISS), developed by the COMTESSA Competence Centre at the UniBw in Munich.

KISS relies on a web-based open-source content management system and thus enables total control of functionality and adaptability to specific requirements, without being dependent on any single company. One application of KISS is the Operational Analysis Toolbox (OAT), designed for the support of OA projects in the military field and prototypically implemented. It has been designed to store project information, interlink it, and provide easy access to it.

The final version is not limited to the field mentioned above but widely applicable. For data storage it stipulates categories derived from the application context. Information is subdivided so that it can be kept available for procedures independent of projects. Using one procedure in numerous projects avoids redundant information provision and diverging displays. As information is separated from individual projects, the connection has to be explicitly re-established during data input.

Dividing information into categories also makes it possible to interlink information beyond the scope of a certain project. This helps in information retrieval. This means that, for example, methods can be linked beyond a shared class of problems, so that an OAT user can find alternative methods more easily. As these methods are connected with projects to which they are applied, the user is also informed as to whether and how they were applied successfully.

In the OAT, access to information and entering data is browser-based by means of filling in customised knowledge templates for the individual categories. Thus, the system is easy to operate. A knowledge library can only yield its full beneficial effect if kept up-to-date by human beings. This paragraph is based on the MoD's Military Scientific Research Annual Report 2011.

COMTESSA uses a further implementation, inter alia, for research projects in the fields of strategic planning, data mining, humanitarian logistics, disaster relief, computational red teaming, and critical infrastructures.

There are plans to integrate further social media technologies, so as to promote communication as well as cooperation among the users and thus create additional system benefit. In this field, there are numerous international contacts in place already.

AIM: integration of decision-support libraries into reachback processes.

Reachback Strategies and the OR Cell

It is now the aim to fuse these results with the development of suitable, concrete solution and reachback strategies for the protection and efficient operation of such networks.

This is tested on the basis of concrete examples (OR cell), together with the Bundeswehr Transformation Centre/Office for Defence Planning, the Centre for Excellence: Confined and Shallow Waters of the German Navy, as well as the Navy Task Force Energy, as coordinated by the Naval Postgraduate School Monterey. The research group is also a member of the smart planet initiative of a global IT corporation, focusing on the simulation and optimisation of complex systems.

A course on energy security at the NATO School in Oberammergau is planned for 2015, which will deal with the aspects described here. The aim is to establish the fundamentals of IT-based decision support and to further develop them in the field of energy security.

IT-Based Decision Support Systems in the Field of Crisis and Disaster Management/Generation of Best Possible Pictures of the Situation

Modern OR-based methods and IT-supported decision making support systems constitute a major contribution to preventative planning and to crisis and disaster management. The unpredictability of such events and the pressing nature of emergency measures mean that emergency and aid services are faced with the difficult task of having to make time-sensitive decisions in an often uncertain overall situation. This aspect was already stressed at the beginning of this article. Analyses based on models and simulations allow far-sighted and comprehensive emergency planning already in the pre-disaster phase, and, at the same time, they support the emergency services in handling an acute emergency or crisis.

This is described in detail in the section on operations research models for efficient humanitarian logistics as regards the field of humanitarian logistics.[16]

Risk Analyses – IT-Based Early Warning Systems/Cyber Threats/OSINT Analyses

Especially by employing methods of so-called computational intelligence and agent-based simulation (as mentioned above), a detailed system and risk analysis can be carried out within operations research, which can show up critical situations already during the planning phase as well as suggest alternative courses of action. In this context, evacuation plans (crowd dynamics) and fire simulations for airports, railway stations, stadia, and office buildings can be mentioned, which can make a substantial contribution to the security of public institutions. These systems also make it possible to carry out a vulnerability assessment of critical infrastructure and logistics systems, especially with a view to power outages and the potential of cascading effects in complex, networked systems. The risk and cost of terrorist threats to infrastructure and public transport, as well as that of cyber threats, can be gauged by employing attacker defender models and net-based OSINT analyses respectively.

A further area of application of modern operations research investigations is the development of IT-based early warning systems.

(Complex) Supply Chains – CIMIC Supply Chains

Operations Research provides highly efficient algorithms which, in spite of limited resources and means, allow emergency services to plan their staff scheduling, the ideal location of distribution centres and camps (facility location problem), and the creation of an ideal (humanitarian) supply chain. In the context of the application scenarios described, access to experts, who are not always in geographical proximity to events, is of utmost importance. This is where so-called reach-back organisations are employed, which link the on-site analysts with a geographically dispersed network of experts who can help with problem solving and decision making.

In this, the focus is on the expedient use of different information systems in the framework of an optimised reach-back architecture. Especially with a view to strategic planning before, during, and after crisis situations, the so-called soft or judgment-based OR procedures have become an established part of modern Operations Research (see the beginning of the article). In complex decision-making situations, it is often difficult to quantify the relevant decision parameters; this is the point where the soft OR procedures can help to integrate human decision-making factors, which are often marked my subjective impressions, into the decision-making process in a sensible, structured, and beneficial manner.

High-Performance Computing, Multi-Agent Systems and Simulation-Supported Experiment Planning/Data Farming, what if? Questions

Using parallel simulation models, what-if? questions can be investigated in greater detail and thus new insights gained concerning the actual system. At this point, the Chair for Operations Research represents two linked research directions: the coupling of simulation models with suitable optimisation procedures to determine the system's ideal and robust properties. In this, especially so-called natural computing procedures are employed, which rely on examples provided by evolution and flocking behaviour. These procedures require fewer prerequisites than classic optimisation procedures and therefore boast a wider field of application. So-called data farming can be regarded as the continuation of the original, simulation-based analysis.

The field of data farming uses simulation systems to produce a multitude of new data, which then can be scrutinised by means of statistical analysis, e.g. to determine critical points. Also in this context, evolutionary algorithms and flock-based procedures can be used profitably at various points of the process. These range from their use in experiment planning, via the automated identification of critical or ideal parameters, to behaviour creation for agents, e.g. using the framework of Computational Red Teaming to check strategies or algorithms for weaknesses (i.e. the optimisation of behaviour by taking the opposing standpoint). In this way, for example, conflict scenarios between aircraft can be dealt with. [17]

Modern Game Theory: red teaming

If conflict scenarios between aircraft can be identified, which either lead to conflict warning procedures sounding false alarms, or failing to identify the conflict, an automated approach offers numerous advantages:

The manual generation of various possible scenarios is carried out by human domain experts. These also determine the red team's course of action. In order to determine good strategies of the red units, experts first have to identify weak points in the system. This requires time and effort and carries the risk that not all weak points are identified.

Here, an automated system is less restricted. As a rule, only a very limited number of different scenarios can be created and scrutinised - a limitation which does not affect an automated approach to such an extent. Such procedures can help analyse and characterise the vulnerability of complex infrastructure networks and to stabilise them by means of computations (computational networks). Apart from the computational networks, which will be dealt with in greater detail in the following, also great efforts are being made in this context to further develop the theory of cellular machines.

Vulnerability of Complex Infrastructure Networks - Computational Networks

Power cuts, e.g., after the 2005 snow chaos in Münsterland and in the wake of the November 2006 outage in the European grid, which hit large parts of Europe, with effects even reaching Morocco, show the high degree of interdependence and the concomitant vulnerability of complex infrastructure networks. Public infrastructure, such as cross-border energy systems, Europe-wide natural gas systems and the public water supply, but also globally networked IT structures as well as large-scale traffic systems are similarly affected by such problems.

The vital importance of these systems for the provision of core services to the population requires the development of new and innovative methods to facilitate a profound understanding of how they work. *Increasingly, the aim is to comprehend the overall system in its operational capability*.

Operational Capability of the Overall System – Process Optimisation and Integrative Risk Management

Modern methods of OR and of IT-based decision-making support contribute decisively to the planning, operation, and maintenance of large-scale, often capital-intensive, infrastructure. At the same time, they ensure the operational capability of the whole system in the event of localised disruption or damage. Integrative risk management, as well as special algorithmic methods of analysis allow the early identification of possible threats of cascading effects, and make efficient protection of critical infrastructure possible. The development of novel mathematical methods and innovative IT-based approaches is therefore of exceptional importance for the future development of large-scale infrastructure systems and can contribute decisively to the sustainable and secure supply of the public.

This is not the place to deal with concrete OR projects in detail. At the moment, COMTESSA heads the three-year, civilian joint project RiKoV. This joint project Risks and costs of the terrorist threat to rail and public transport (Risiken und Kosten der terroristischen Bedrohungen des schienengebundenen ÖPV) constitutes the attempt to provide better protection for critical infrastructure of rail and public transport from terrorist attacks. For this purpose, the universities involved (UniBW, Cologne University of Applied Sciences, Karlsruhe Institute of Technology) will, in eight work assignments, together with the industrial partner Airbus Defence & Space, use qualitative as well as quantitative methods to identify and assess risks, and to determine their consequences.

The project not only aims to analyse risks, but also to develop a final countermeasures realisation plan, to convert research results into a competitive product so that private enterprises can benefit as much as public players. There is, therefore, also a connection in content with Red Teaming. RiKoV's embedded holistic and systemic approach is, up to now, unique. And only this approach ensures that an innovative security concept is generated, which encompasses and comprehensively assesses all possible scenarios, in order to make an important contribution to enhancing security.

Back to Logistics: Warner Logistics Center - an OR Success Story

Attention should also be directed at the impressive example of the Warner Robins Air Logistics Center (USA). The maintenance work on the C-5 Galaxy was analysed and integrated into Critical Chain Project Management. Up to then, maintenance work amounted to 40,000-50,000 man hours, which resulted in a 240 day waiting period. The employment of modern OR procedures and comprehensive process management reduced this waiting time by 33% to 160 days and resulted in economies in the amount of USD 75 million.

Similar examples can be found on the OR Champions website: http://www.orchampions.org/prove/success_stories/wralcrgtptwtirt.html

It is indisputable that the general use of resources in the military can be improved. No serious OR expert, however, will state that s/he can optimise everything. Nor is this the intention of this text. Rather, the aim is to show that OR is more relevant than ever and that OR may well be referred to as “the science of making better…”. This is also the guiding principle of the following summary.

Summary: “Effective Use of Resources – OR … The Science of Making Better“

In England, Operational Research (as it used to be called) has been employed in the military sphere since the 1930s. One of the most important uses of OR during WWII was, without doubt, the land-based use of RAF aircraft to detect and attack German U-boats. In this, too, the goal was the effective use of the resources aircraft, crew, and munitions through the application of quantifying methods. Only after the War was the method further developed by the USA and England, and Operations Research (OR) increasingly found its way into industry, public administration and the economy.

In spite of all modernisation trends, all ups and downs in OR, and in spite, or maybe because of dwindling financial means, effective use of resources has acquired special importance. Process management, business intelligence, etc. are all important aspects and disciplines, but … OR is essential, and often there is more OR in play in many fields than would at first be expected…

A general definition of OR (therefore) still remains difficult, as there are, depending on the respective field of application, different national and international conceptions, especially as regards the demarcation vis-à-vis other scientific fields. Looked at internationally, the Anglo-Saxon OR field still plays a leading role. Great Britain, for example, only recently allocated USD 24 million to selected universities for OR research for the period between 2008 and 2013. Although Operations Research/Management Science are used in one breath (which is not called Operations Research, Modelling & Simulation), the simple term Analytics is used more and more.

OR as the Central Method for the Analysis of Complex Processes

The German Bundeswehr has developed and used OR since the 1960s, and thus boasts a well-established tradition; it also uses it in the Afghanistan operation. In principle, the Bundeswehr defines OR as the application of scientific methods to support decision makers and their staffs.

Apart from the various optimisation procedures, queueing theory, decision theory, and statistical procedures, it is simulation that has been among the most important methods, as it allows for the analysis of highly complex correlations in the employment of modern armed forces, not only in a detailed manner up to system process, but also in an aggregated manner and an overall context. In this, military OR also is closely connected to the simulation support of training and exercises, of research in the field of concept development and experimentation (CD&E) as well as of technology and armament development.

Bundeswehr Logistics and Planning Processes: Characterised by a High Degree of Complexity

Reasons for this are, inter alia, the complexity of global military operations per se, the multifaceted nature of logistics services with a concomitant complex allocation of responsibilities and competences. Conditions for materials management during operations are often very difficult, not least because of the risks generated by enemies and terrorism. These correlations were described in detail above. In this sense, a résumé can now be given, which was already illustrated in DWT-Info 2013 in an abbreviated form:

1. In the foreseeable future, OR methods will (in the German Bundeswehr) improve the command performance of military commanders and their staffs in situation centres and on command posts.

2. OR support during operations will bolster the preparation, execution, and post-processing of operations and, to this end, provide either independent decision support systems or OR-models/OR-functionalities to the C2 systems.

3. Scientific planning support must be asked-for and embraced. It requires time, energy, and means. OR must, however, also be executed by people who, in modern consulting terms, have a conscientious understanding of the problems faced by the decision makers to be supported, and can work out credible recommendations in a short time with limited means.

Quo Vadis? Visualising Decision Making Options - Management Cockpits and Illuminating Path

The aim of the present text was to stress and elaborate on the topicality of Operations Research. To this end, classifications, successful examples, and innovative approaches to architecture have been listed. OR will continue to evolve. The author identifies one decisive branch of this evolution in the integration of modern management cockpits for decision making support with the aim of visualising complex processes (e.g. in the context of big data); this is also referred to as visual analytics. Visual analytics is an interdisciplinary approach which links the advantages of differing fields of research. Its specific aim is to derive results from extremely large and complex sets of data.

This specific approach combines the strengths of automatic data analysis with the capability of human beings, i.e. quickly to identify patterns and trends visually. By means of suitable interaction mechanisms, data can be visually explored and results generated. This approach was introduced in 2004, and described in Illuminating the Path one year later.[18] The Wikipedia pages on visual analytics regard disaster relief, bioinformatics, as well as business intelligence as the main future applications. However, also the transformation process of the armed forces towards the soldier of the future is characterised by the exposure to large amounts of data. Hence, the integration of visual analytics in OR procedures is of central importance.

Consolidation through an Innovative Training Curriculum - Ludwig Bölkow Campus

It has become evident that OR is characterised by its wide field of application and its interdisciplinarity. This is why various disciplines, e.g. mathematics, economics, management, business administration, electrical engineering, construction, chemical engineering, et al, have fully integrated Operations Research into their curricula.[19]

These courses normally deal with OR basics, consisting of problem definition, mathematical modelling, data collection, theoretical methods employed in problem solving, validation, and simulation.[20] Imparting this knowledge by means of traditional teaching formats, such as, for example, teacher-centred approaches, does not seem to produce desirable results. Inefficient training methods can actually serve to make students insecure and thus dissuade them from using OR at a later stage. This is why Moazeni[21], on the basis of an analysis of publications, recommends the use of five methods in order to teach OR to non-mathematicians.

These methods are: active learning (group discussions, individual work, short exercises, etc.), working on examples from real life (interesting questions taken from real life, or virtual examples from sports, which produce especially good results), use of technologies and multimedia (videos to clarify explanations, screenshots to explain software, animations to illustrate complex processes, etc.), the use of quizzes and games [22] as well as of guest speakers, who report on their practical experience with OR.[23] The methods listed should be suitably combined for the course content in question to boost learning outcome.

In the past years, these were the guiding ideas in the development of a new, innovative course concept, established in Munich with the teams of Prof. Dr. Axel Lehmann and Prof. Dr. Markus Siegle, and reflected in the ITIS courses Kombilehrgang Operations Research/Modellbildung und Simulation der Bundeswehr (Combined Course Operations Research/Modelling and Simulation of the Bundeswehr) as well as the accompanying concepts OR/OA Orientation Course Curriculum for NATO Nations and Motivate Senior Leaders for Operations Reseach.

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There are also plans to use the RiKoV and NITIM projects to establish a forward-looking, civilian course on the Ludwig Bölkow Campus, Complexity Management and IT-based Decision Making Support within the framework of an innovative Research Decision Lab for Decision Makers (Senior Leaders). Security-political circumstances and operational frameworks have led to NATO operations becoming much more complex and requiring better decision-making support, not just since NATO adopted the Comprehensive Approach concept at the 2010 Lisbon Summit. NATO, many NATO-PfP nations, and partners across the globe (e.g. Australia) achieve this by applying OR/OA. There have been a number of success stories, as shown, for example, in the final report of the SAS-089 study OA to Support NATO Operations.

Transformation Process of the International Armed Forces – OR's Special Role

This ongoing transformation process of international armed forces, with parallel use of old and new processes/procedures/materials as well as the concomitant introduction of new IT support (SAP etc), does not yet, however, decisively simplify the processes. Acute crisis and disaster situations require fast and cross-organisational coordination of recovery and emergency measures. Modern Operations Research, as shown in this text, promotes these measures in many ways. In the German Bundeswehr, there is currently an intensive discussion concerning CPM and IPT (integrated project teams). CPM also demands efficient use of resources. As first mentioned in DWT-Info 2013, Operations Research methods are to be developed and used to an even greater extent. Within the framework of the new CPW within the new IPTs, OR analysis and process optimisation can be realised.

The armed forces often try to keep OR at arm's length. As a general, tasked with logistics, told the author at the beginning of their meeting: "I don't have time for OR". Connotations such as old-fashioned or only research/academic often lead to rejection, even before the potential and topicality of OR have been identified. The present article, which does not claim to be exhaustive, attempts to raise (some) awareness:

May the final quote by Albert Szent-Gyorgyi, "Research is to see what everybody else has seen, and to think what nobody else has thought." contribute to this motivational awareness. There is another quote on the current INFORMS websites https://www.informs.org/ (The Institute for Operations Research and the Management Sciences): "Operations research is the application of advanced (!) analytical methods to help (!) make better (!) decisions."

Final Words

OR is not (just) about optimisation. Apart from modelling, simulation, and analysis, optimisation is a branch of Operations Research; it is about decision making support in the sense of modern complexity management.

This is not the place to deal with the ethical dimension of OR use in a military context. This question will also increase in importance, not only because of the discussions concerning drones. Their use is of little practical value without modern algorithms and analyses. This again leads to the special role played by OR in the current socio-technological question. OR is a permanent fixture in industry; however, as a noted Chair in OR once said: "The reason why we get a lot of money is because we help save resources and cut jobs". This is the flipside of OR, with a powerful socio-technological dimension. In the military field, the highest goal should be to guarantee security, not simply and blindly maximise one's position and minimise the others. This ambivalence is not just expressed in duality theory.

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[2] Der Begriff Operational Research stammt ursprünglich aus dem Militärwesen. Er wurde 1937 für eine Gruppe von Wissenschaftlern verwendet, die den optimalen Aufbau eines Radarüberwachungssystems für die britischen Streitkräfte erforschen sollte. 1940 verfügte das britische Luftfahrtministerium über eine eigene Gruppe für Operational Research. Die britische Armee und Royal Navy gründeten im gleichen Jahr entsprechende Gruppen. Weitere Fragestellungen der im Zweiten Weltkrieg in England, den USA, hier Operations Research genannt, und der Sowjetunion gegründeten Arbeitsgruppen waren unter anderem die optimale Menge von Schiffen und Begleitschutz für Schiffskonvois oder eine optimale Breite von Bombenteppichen in Bezug auf Genauigkeit und Streubreite. Nach dem Krieg wendeten sich die Mitarbeiter ökonomischen Bereichen zu, mit der Aufgabenstellung, ein gewünschtes Ergebnis mit geringsten Kosten zu erreichen, bzw. der dualen Aufgabenstellung, mit gegebenen Mitteln das bestmögliche Ergebnis zu erzielen (ökonomisches Prinzip). Für Operations Research, in Großbritannien traditionell Operational Research genannt, konnte sich allgemeingültig kein deutscher Begriff durchsetzen. Verwendet wurden und werden, neben Operations Research, die Begriffe Unternehmensforschung, Operationsforschung oder mathematische Planungsrechnung. In den späten 1960ern und frühen 1970ern wurde erfolglos versucht, den Begriff Ablauf- und Planungsforschung in der deutschen Sprache zu etablieren, so erschien von 1959 bis 1971 die wissenschaftliche Zeitschrift Ablauf- und Planungsforschung.

https://de.wikipedia.org/wiki/Operations_Research (downloaded: 10 JUN 2016)

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