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Advances in Decision Making

Edited by Fausto Pedro García Márquez

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Preface

Advances in Decision Making synthesizes the analytical principles with the business practice of decision making. Specifically, it provides an interface between the main disciplines of engineering/technology and the organizational, administrative, and planning abilities of decision-making. It is complementary to other sub-disciplines such as economics, finance, marketing, decision and risk analysis, and more. The chapters introduce and demonstrate decision-making theory using practical case studies. Discussions of the theory of decision-making are accompanied by relevant analysis techniques, progressing from simple theory to complex and dynamic decisions with multiple data points. Computational techniques, dynamic analysis, probabilistic methods, and mathematical optimization techniques are expertly blended to support the analysis of multi-criteria decision-making problems with defined constraints and requirements. The algorithms, approaches, and methods presented in each chapter can be applied to problems of all sizes. This book is useful for graduate students, researchers, professionals, engineers, and other interested readers.

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Chapter 1

Introductory Chapter: Introduction to Advances in Decision-Making

Fausto Pedro García Márquez

1. Introduction

The main principles of decision-making applied in business practice by advance analytics are summarized in this book [1]. The book is the compilation of chapters written by authors who are experts in the topic covered. Main disciplines, such as management, engineering/technology, economic, etc., are considered as interface with decision-making, being complementary to others, e.g., administrative, finance, risk analysis, marketing, etc.

Decision-making could be defined as the choosing process from several options. It can be done by simple or advanced analytics, by exact or not procedures, by the opinion of any, etc. [2]. The frequency at which the decision-making is done is also variable, from 1 to any. If the effect of decision is considered in a period, then decision-making is classified as operational (short period: daily, weekly, or monthly), strategic (long period: generally 1 year), and politic (very long period: usually more than 1 year).

Decision-making is gaining more importance because the new market scenario is being more competitive [3–6]. This leads the researchers to focus on this topic, together with new technologies and advanced analytics, generating new software and tools based on the Internet of Things [7, 8].

Triantaphyllou analyzed the best decision-making method according to the best decision-making method [9].

The measurement of the efficiency for decision-making units was done via linear and nonlinear programming methods [10]. The authors also took into account the economic and engineering relationship for decision-making.

Hwang and Masud [4] and White [11] showed a complete review of decision-making methods. New algorithms are appearing, for example, [12–14], where more robust and complex problems are being solved by employing artificial intelligence [15–17] and the most important ones are presented in this book.

The main theories are studied and presented in this book in different case studies. The main results are analyzed and discussed, suggesting new future works to continue working on that. Case studies are going from simple to complex cases, including big data, from static to dynamic problems, and also from offline to online cases, including the Internet of Things. Models, methods, and algorithms based on dynamic analysis, mathematical optimization, and computational techniques are designed and implemented to carry out the data analysis of decision-making, also considering the constraints.

The book has been written to be used by students and professionals of multiple disciplines, e.g., industrial organization, applied microeconomics, business administration, among others, and, of course, decision science applied to simple problems to complex and large problems and for different case studies. The book is also written for academics and researchers on different disciplines.

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Chapter 2

Cognitive Decision-Making in Dynamic Systems: When the Objectivity (of the Processing) Does Not Guarantee the Validity (of the Choice of Action)

Bernard Cadet

Abstract

Since around 1970, academic studies on decision-making have changed in nature. Whereas they used to be laboratory studies of selected situations giving rise to the expression of individual choices, nowadays studies focus on real situations. These situations are processed in their natural contexts at the time they occur. The decisions to be made concern generally social problems (for instance forest fires, maritime pollution or global warming). This mutation in the nature of situations studied requires a paradigm shift, which leads to elaborate decisions in complex, dynamic and evolving systems, even sometimes resilient to human actions implemented to control them. This chapter analyses, at individual and group level (crisis units), cognitive difficulties encountered by decision-makers in handling such situations. These situations consist in treating information by assigning them, from the outset, meanings (sometimes personal). This is done by looking for temporary interactions, while respecting the global nature of the situation, by focusing on knowing the properties of context as well as those of the temporal evolution of the system concerned. This chapter analyses a case study for which urgent and fundamental decisions could not be taken and proposes an interpretation in terms of paradigms. Previous studies noted that the decision in complex systems, could entail paradoxes. This study on the decision-making dynamic shows that seeking objectivity, as defined under its current intangible form, does not produce a significant increase in the validity of choices made.

Keywords: Decision-making, Complexity, Dynamism, Systems, Holism, Paradigm

1. Introduction

Since psychology has set as its main purpose the study of behaviour, decision-making behaviour represents a stimulating subject for studies and research. Not only are there numerous circumstances in which it proves necessary to make a choice, but they are also highly varied. This chapter analyses a quite specific category of decisions: those concerning the action choices in complex and dynamic systems. Highly different from other decisions studied in fixed environments, they lead us to explore the field of epistemology and cognitive psychology and offer the advantage of generating sensitive crossed interrogations in these two disciplines also required for the construction of knowledge.

This chapter will focus on one of these, in other words the relations between the choice of an objective epistemology and the absence, observed in the field, of relevant decisions. The argument has seven facets. The first describes the cognitive and epistemological specificities of decision-making in complex and dynamic systems. The second deals with the assignment of meaning to information, while the third describes a selection of real situations which led to decision-making difficulties. The fourth facet is dedicated to the examination of an investigation tool: the paradigm, and refers to a particular paradigm; the objective experimental paradigm (OEP) which underlies scientific progress in numerous disciplines. The fifth facet focuses on its transferability to decision-making in complex and dynamic systems and any resulting cognitive dilemmas. The sixth facet raises the question of the globality of the situations to be processed (rather than their breakdown into variables) by taking as guideline an attempt made to this effect in psychology. The seventh examines the epistemological position of the decision-makers faced with a paradox which seems to be related to valorisation at all costs of objectivation, at the expense of other characteristics of the decision.

2. Decision-making aimed at cognitive psychology

2.1 A decision-making proto-schema

The most concise characterisation of decision-making facing with uncertainty [1] consists in describing it as an approach prior to choosing one action [Ai] amongst a set of *n* actions [An] considered as being potentially relevant. In this characterisation, decision-making consists in generating what psychologists call a conduct (a behaviour in common language) in order to choose the action [Ai] amongst a set of **n** possible actions. This action is evaluated as being the most relevant to change an existing situation considered to be inappropriate or dangerous. For example: which action(s) should be chosen to stop the persistent financial losses of a company? However, the cognitive approach is not solely interested in the end result (the chosen action); it attempts to explain the characteristics which led to this conclusion. These characteristics must be found in the information present in the situation and with respect to the objective to be reached. The theoretical references used will therefore concern cognitive psychology, whose purpose is to study how to process the information which will lead to a judgement, then to a decision.

2.2 Decision-making as cognitive management of systems and networks

It can be observed that, in this conception, decision-making is not limited to initially selecting outcomes to create the set **n** and to making a limited number of binary comparisons. This type of limitation would exclude from the field of the decision any "surprise" which could arise from the reality of the situation processed. We will then observe that the informational characteristics of the environment and even more its ability to evolve, are largely or totally absent from this approach. While the condition that the set of **n** actions must be exhaustive is initially put forward, it is not always possible to meet this condition. All operational decision-makers are aware of the frequency of unexpected or unforeseen conditions in the initial plan [2]. Mental fixism, which consists in thinking that "everything is under control" and that everything has been planned, is often accepted too readily due to the sole fact that it confirms an earlier mental representation.

This type of difficulty is frequently encountered in situations where behavioural automation is important, for example when piloting an aircraft. While it undoubtedly reduces the mental effort, automation may nevertheless prove to be disconcerting faced with unplanned situations, especially if the level of concentration drops temporarily. Amongst the causes mentioned during "inappropriate decision-making", analysts estimate that "airline pilots do not receive sufficient training on manual piloting".

2.3 Epistemological characteristics of the chosen action

The chosen action [A1], also referred to as the dominant action, is that which, at the end of the decision-making process, is the one most likely to achieve the required effect. This first requirement applies to all decisions to define the objective to be reached but involves specificities in decisions qualified as complex. In such contexts, deciding is much more than choosing a subject or a procedure. Based on the dynamics of the systems concerned, we must consider that the decisions are taken to cause *state changes* in order to set up new operating balances in the systems: the health system, the economic system, the company, the emergency systems, etc.

Except in special cases, to obtain these state changes, the "decision" entity must itself be composite, i.e. must consist of a set of elementary actions (a1, a2, … ak), where each individual action has an impact on the system and where the set of actions taken together forms a global action module. The decision as such is the equivalent of a vector.

Scientific knowledge requires that the epistemological characteristics of the chosen informations must be clearly defined. The most obvious are the validity *(v),* the generality (*g*) and the fidelity (*f*). The sequence of elementary actions must prove that it is composed in such a way that it can act on the system in the required direction (v), do so for all situations of the same type (g), with a stability of effect which is repeated over time (f). These qualities can be used to distinguish the daily information forming know-how from the scientific information which satisfied these requirements, substrate on which the theoretical systems are built.

3. Information, cognition, and assignment of meaning

3.1 Perception and interpretation

In the press and in the media, the discriminating power of the sensory functions is largely overestimated. Taking vision for example, the eye, compared with a camera, which would record events, is supposed to provide a faithful image of the external context sometimes called reality. However, the information that we will use to build an adapted our conduct is necessarily obtained by *interpretation*. It consists of dynamic entities to which meanings are assigned due to the mere fact they have transited via the neural networks of the brain. The retinal image therefore acquires, in the brain, a meaning related to the decision-maker's knowledge networks.

3.2 Two cognition modules (levels)

Decision-making thus appears as a mental task involving two different but complementary types of operation corresponding to two cognition levels, each one representing a homogeneous subset of operations and therefore deserving to be considered as a module.

3.2.1 The information sampling *process (module 1)*

The first cognitive operations consist in collecting information by performing a global inspection of the situation; the subsequent operations, carried out in successive steps, will then reduce the field explored.

All human-decision-makes absorb the situation to be processed using data supplied by their sensory functions. Two important points must nevertheless be specified. Firstly, the term “sensory functions” must be understood in a very broad sense not restricted to the well-known five senses but also including all the receptors involving movement, sensitivity and possibly intuition. The range of information available therefore extends far beyond the data processed in the specific areas traditionally mentioned. Secondly, we must stress, as said previously, that each sensory input is processed and *interpreted* by the brain. Apart from its physiological properties, we must therefore point out its main characteristic: being an element which brings meaning.

3.2.2 The information formatting *processes (module 2)*

The level-2 cognitive processes are referred to as executive functions. They differ from the previous functions by the fact that they regulate the scheduling (planning) of the behavioural construction sometimes as activation (useful information) and sometimes as inhibition (interfering information). The main functions concerned are attention, flexibility of thought, implementation of adaptive feedback loops, global reformulations, etc. They are involved in determining the behaviour at a global activation level. The most illustrative example is that of attention, which does not belong to any specific item of information but which can be applied to each one.

3.3 Complementarity

In line with the systemic outlooks, it is important to consider that these modules represent two entities which, far from being opposed, complement each other in numerous circumstances. It would be worthwhile considering them as inducing each other mutually. Module 1 samples information in situ whereas module 2 handles the formatting and organisation of the set so created. Module 2 is involved in the creation of the cognitive maps which will be described in greater detail in this document.

4. Epistemological characteristics of the situations studied

4.1 Structural data

To complete the data collection, it is necessary to mention a few real decision-making situations in complex systems which occurred since about 1960. The situations studied by the social sciences exhibit four properties:

- complex situations which include a large number of dimensions with non-linear relations, making it difficult to assess how the situations are going to evolve.

- systems organised in subsystems, not around variables. These subsystems represent activation “focal points” which create dynamisms.

- evolving entities which change state over time. Time must therefore be taken into consideration when determining the appropriate action.

- situations which often have a strong societal dimension. In numerous contexts, the action choices are designed to put an end to a damaging situation by controlling its effects and the situation itself (for example, controlling a technological accident such as the Chernobyl disaster). The decisions must be made rapidly, under the pressure of public opinion, in a context where stress is highly present.

4.2 Field data

In natural situations, this type of characterisation applies to events which appear to be quite different from the outside but which are relatively similar as regards their underlying architecture and organisation. The media report these events regularly when they have harmful effects.

The events most frequently encountered are:

- Forest fires, extremely difficult to control, whose recurrence and duration (sometimes lasting several months) are retrospective signs of decisions that are hard to take. Recently in California and Australia, despite major and appropriate firefighting measures, the fires lasted for several weeks, even several months, and caused serious human and material damage.

- Marine pollution due to oil spills from tankers. Coastal areas have been polluted by hydrocarbons from shipwrecks on numerous occasions. Those which received the most media attention, due to the scale of the damage caused, are remembered by the names of the oil tankers themselves. We may mention Amoco Cadiz (1978), Exxon Valdez (1989), Aegean Sea (1992), Erika (1999), Prestige (2002) and Hebei Spirit (2007).

- Global warming represents another complex and dynamic system for which decisions must be taken at large scale. Scientists quickly raised the alert on the need to "manage" the climate. The Swedish chemist Arrhenius (1859–1927) was the first to establish a link between energy production (coal at the time) and global warming. Over the next decades, however, there was such a gap between the perceived reality and the difficulties announced that these predictions were forgotten by the public opinion. More recently, a predominant political factor has been added to the initially scientific treatment given to this issue. Since 1995, the United Nations has organised in a different country every year a conference hosting some 185 nations. Known under the acronym COP (Conference of Parties), these meetings have already been held 25 times. COP 26 to be held in the United Kingdom in 2021 for about ten days has been postponed due to the Covid-19 pandemic but finally will take place, another example as disconcerting as the previous ones regarding the management of a complex system.

- The management of pandemics exhibits all the above-mentioned characteristics of a complex system. The objective to be reached is clearly determined and the means to change it from its current state to the final required state consist in setting up a decision-making sequence. This entity, which includes an evolving time dimension, comprises a series of successive decisions, each one being designed to make the system evolve in the required direction. The decision is built one step at a time, so as to preserve what has been achieved and validated and to duly validate the changes introduced. Examination of the strategies implemented in the countries of the European Community, federated around a common project, reveals, both in terms of time and structure, major differences in the way the situation is processed and the decisions made.

In all these categories (the types of situation which have just been mentioned), the decision-makers encounter major difficulties in managing the active systems not only individually but also as a committee: the collective intelligence so often proposed as the solution is temporarily inoperative. Some forest fires last for weeks, even months, damaged oil tankers continue to spill their cargoes for weeks and sometimes much longer, the issue of global warming proves difficult to manage, like the pandemic which, since the alert was raised in 2019, has not yet been controlled at the time this document was written.

In view of such obvious and recurrent difficulties, we must examine the methods and cognitive strategies involved in the decision-making process when faced with complex systems.

5. Decision-making in dynamic systems: the paradigm tool

5.1 Cognition and complex systems (reminder)

Historically, relations between cognition and complex systems have been difficult to manage. It was around the 1900s with the studies conducted by J.H. Poincaré (1854–1912) that the first evidence relating to a problem observed in astronomy was detected. It was only in the 1970s, however, probably out of despair, that the expression "chaos theory" was introduced. It was to experience a major impact in relation with the quasi-oxymoron characterising it. The project to theorise disorder is in fact the exact opposite of the deterministic conceptions on which scientific theories are built and based. In other words, chaos seemed to be a chance event.

When studying turbulences, Ruelle and Takens [3] indicate quite to the point that, beyond an apparent disorder, chaos is in fact "deterministic", but this observation introduces a new paradigm into the scientific research activity. Today the complexity of the situation and the dynamics that underlie it are no longer considered to be disruptive elements but as structuring characteristics of the situation and can be used to find the appropriate concrete action [4].

5.2 Roles and functions of the paradigm

Very broadly characterised, a paradigm, sometimes defined as a "school of thought" is the combination, within a given set, of theoretical and methodological notions with concrete cases which are compatible together so that there is no rupture in the approach to build a corpus of knowledge. For the last two centuries, the objectivity required to choose the relevant action has been related to the experimental method resulting in the construction of the objective experimental paradigm (OEP) which has witnessed major successes. OEP has led to the development of physical sciences, material sciences, life and health sciences. This paradigm underlies experimental medicine, as well as the progress made in the techniques which have accelerated its development.

5.3 Objective experimental paradigm and psychology

While the formalised sciences (virtually) never raise the question of which paradigm to use since the OEP is the obvious choice, in the human and social sciences, it must be chosen in a preliminary step. This is clearly the case of psychology where the OEP has been used for many years in laboratory studies (Wundt created the first experimental psychology laboratory at Leipzig in 1879. His initial training as a physiologist probably contributed to the transfer of skills and models to psychology). The central theme studied by this laboratory was in fact perception. More recently, from the 1960s, cognitive psychology has made extensive use of this OEP adding new technological tools in order to study the dynamics of the brain processes during information processing operations.

5.4 Characteristics and migrations of the PEO

The well-known OEP has become so dominant that it represents an idealised conception of research built around clearly defined options. The main ones, apart from the public nature of the investigation procedure, include the permanent concern for verification using a device conceived and/or built by the researcher. To meet these epistemological requirements, a workplace and clearly defined working conditions are necessary. The workplace is the laboratory, isolated from the influences of the outside world, to prevent unwanted influences - without really knowing what they are - from disturbing the network of relations between variables. The device used is a reconstruction simplified by means of the "scientific reductionism" of potential relations between certain (potentially causal) independent variables and (resulting) dependent variables. Validation tools, sometimes statistical, are used to check whether or not the links proposed are valid.

In view of the guarantees it offers regarding the objectivity of the conclusions and their applicability in real situations, the OEP has been adopted in numerous human and social science research studies [5], rarely in its canonical form and frequently in forms adapted to the situation being processed. The latter forms may be increasingly remote from the basic schema. From an epistemological point of view, it is interesting to consider these successive shifts. They highlight the existence of a compromise, in other words an attenuation of the generality and rigour of the method by considering the specific characteristics of each situation.

5.5 Epistemological functions of the paradigm

In addition to the intrinsic functions of the paradigm, those of information processing, Kuhn [6] adds a global, trans-situational function. This author points out that the results obtained during its applications to situations of different type but of similar architecture (organisation) are indicators of its validity (the generality requirement g is met). Due to scientific progress, all paradigms are superseded as soon as they are no longer able to provide answers to the questions raised. A new epistemological option and a new paradigm become necessary. Kuhn designated this moment of transition "a scientific revolution". The progress made in scientific knowledge is neither linear nor regular; it is built up discontinuously by a series of leaps separated by periods of stability, of irregular duration, but which shorten according to the degree of progress of science.

6. Cognitive dilemmas

6.1 Opposed characteristics

The most recent paradigmatic leap in the evolution of human sciences is that marking the transition from the objective experimental paradigm to the systemic paradigm. What are the consequences? The study of dynamic and complex situations using the OEP analysis grid is unable to determine the efficient decision which would bring the system to the required state (how to put out the forest fire, for example).

Due to the recurrence of difficulties and failures, a more in-depth epistemological analysis must be conducted. This could be explained, for example, by the fact that the characteristics of the complex and dynamic situation to be analysed (S) and those of the tool (paradigm O) used to do so, clearly appear to be contradictory in many respects. As regards the structuring units considered: dynamic subsystems (S) against variables (O); a problem *reconstructed* to be operationalised in a laboratory isolated from the outside world (O) faced with a *real* problem observed in natural environment (S); non-linear relations (S) translated by linear relations (O); dismissal of the temporal perspective (O) although the time of observation and evolution of the system is a determining factor for the decisional choice (S). This amounts to applying a tool built using properties which are rigorously opposed to the situations to which it is applied.

6.2 An epistemological choice and its consequences

Due to another source of malfunction, the scientific reductionism operation must be re-examined. In this case, the methodological reductionism will be considered differently from its ordinary meaning: we will consider it as a methodological approach aimed at condensing a real situation to reduce it to its most fundamental components. This type of operation, also used for a quite different purpose, has been called "eidetic reduction" by the phenomenologists, to shift, using their terminology, from the "existence" of things to their "essence".

Thus, a natural situation (i.e. outside the laboratory) is an instantiation surrounded by a "clutter" of temporal or circumstantial particularisms, which prove secondary for those wanting to isolate *general* information to be used for theorising and modelling. Moreover, this reduction also takes a material form when it allows researchers to build the device mentioned above in order to select from the flow the information which must be kept and then test the information which seems important, in particular that used to satisfy the objectivity.

6.3 Cognitive map / heuristic map

The cognitive map, sometimes also referred to as the heuristic map, is a mental model or representation that a human individual makes of the arrangement of steps, methods or conditions which he/she considers necessary to decide what to do. In other words, it is an organised representation of knowledge. It indicates the time required to identify a task (about one minute), in forms that are sometimes rather basic, it transmits, when necessary, the information to the long-term memory which stores it for future reuse.

Like numerous cognitive productions, this map is subject to the heuristic approaches identified by Kahneman, Slovic and Tversky [7]. While numerous occurrences exist, they all have the same objective: introduce simplicity into a situation which, due to its complexity, appears to be disconcerting. We may mention again the initial lack of understanding conveyed by the term "chaos theory", direct reflection of a cognitive failure. As confirmed subsequently by the research studies in cognitive psychology on judgement, as part of the basic need of every human being to understand the present world, individuals will perform heuristic reductions of this complexity which will then be used to produce simplified cognitive maps. However, although the mental representation is simplified, the reality of the situation nevertheless remains complex. Applying the simplified mental models to the reality of the situation fosters errors of judgement and therefore inappropriate decisions. (A very similar approach in the field of perception underlies the development of conspiracy "theories".)

7. Management of globality: counterproductive simplifications

7.1 An essential requirement

In the decision-making concerning the complex situations mentioned in 2.2, the decision is more complex than choosing a single action directly. The term "decision-making" means determining a *sequence of actions* meeting the characteristics stated at the start of this study. Each situation chosen must be considered as a reactive systemic globality. Trying to isolate the elements, separate them from the set means simultaneously altering the system and fragmenting the relations between elements. Unlike the device built in the laboratory whose architecture is intangible and where only the intensities vary, the complex system is an evolving and reacting entity: a forest fire does not have the same characteristics when it has just broken out as when it has lasted for several days. The temporal dynamic aspect becomes preponderant.. Assessing the potential of a complex system implies being able to quantify a global index that expresses its evolutionary power. Entropy represents a reference often used although in different forms: quantified when the data allow it [8], cognitive in other cases [9].

7.2 Consider the globality: the example of gestalt psychology

How to conceive the processing of globality? A first option mainly consists in not breaking it down according to the Cartesian and Newtonian analysis methods, which are highly attractive since they have demonstrated their usefulness for the construction of numerous highly attractive disciplinary corpuses. The recommended strategy in this case is not to discard them but to examine, when analysis tools are concerned, the conditions and benefits of preserving the globality.

The Gestalt Psychology initiated by German researchers working in the United States, and pioneered by Lewin (1890–1947), attempted to do so. The Gestalt movement does not refer to the laboratory and adopts the principle based on the analysis of global entities. These terms designate the situation as such (often referred to as the figure) and the informational field in which it is immersed (often referred to as the ground). According to this epistemological movement, trying to distinguish between the elements is pointless since "the whole is more than the sum of its parts". The whole has its own characteristics (we might be tempted to say its own "personality") which is more than the sum of the elements taken individually.

7.3 Dynamisms

Another extremely important property of the Gestalts is their dynamism. This can be easily observed by examining the reversible figures widely published in magazines, designed in such a way that the figure and the ground can be interchanged. It takes a few moments to observe the dynamism of the phenomenon which globally and suddenly modifies the nature of what is perceived.

When attempting to sketch out an epistemology of globality, Lewin, who developed the concept of group techniques, strived to study each situation, each type of behaviour, inserted in its natural context. One well-known example is that of purchasing behaviour. So no isolation and no more or less successful reconstruction. In his book entitled "Principles of Topological Psychology", Lewin [10] studies social behaviour and is the first one to analyse psychological behaviour. His project consists in modelling the analysis approaches used in psychology on those of mathematics but mainly of the physics of his time, in other words in terms of forces and force resultants. Lewin also introduces the concept of psychological life space including space, time and forces as dynamic elements; entities which prepare the way for the distribution of dynamic complex systems in human sciences.

8. Structural differences between the object and the tool

8.1 The decision-maker's locus of control in situation

Psychologists use the term "locus of control" to designate: "*the degree to which people believe that they, as opposed to external forces (beyond their influence), have control over the outcome of events in their lives*."[1] In this case, the control concerns the choice of the action which would bring the system to the required objective.

8.2 Means underlying the locus of control

What means are available to decision-makers to consider that they can control the development of the situation? In actual fact, these decision-makers implicitly or clearly perceive that their resources are limited. They are not in a position to use a previous professional experience or an apprenticeship since, in most cases, the situations to be processed are both complex and infrequent; in human sciences, they have in fact given rise to very few conceptualised approaches. In terms of decision-making, the only "scientific" data regarding the action choices are determined based on case studies and generally to analyse errors or malfunctions. In such a context, few cognitive resources are assigned to the locus of control, based at best on "degrees of belief", i.e. at best on subjective probabilities. The resulting uncertainty experienced has a negative effect on the action choices, especially if the stakes are high.

8.3 A transition

To reduce this uncertainty in order to choose the best actions, the decision-makers will opt for a strategy different from that of collecting ever more information. Although the PEO guarantees objectivity, this is at the cost of reducing the field of study. In addition, being a typical laboratory paradigm, it does not apply to the situations we have qualified as natural. Being unable to determine the action required with a sufficient guarantee of validity, the decision-makers will switch to type 2 information. They will build their decision using the properties of type 2 information, in other words giving priority to structuring a set rather than accumulating information (type 1). This emphasis placed on the tool before processing the informational context reminds us of the "toolbox" of Gigerenzer's concepts ("The mind as an adaptive toolbox") [11].

[1] Wikipedia

8.4 Existence and consequences of a paradox

Not all the difficulties have been resolved, however. In view of the difficulties arising in the field situations, the verdict of reality suggests the potential existence of future obstacles. We will make the assumption, currently only supported by observations, that application of this toolbox depends on a cognitive map and that the map is a simplified representation of the reality of field data, which remain complex.

It is therefore not unreasonable to mention the underlying existence of a paradox for the decision-makers. Since [12] they are all scientists, engineers and high-level technicians experienced in traditional scientific procedures, they will seek to be objective in the decisional choices by applying, naturally one might say, the PEO via the cognitive map to data which are above all complex and dynamic. This paradigmatic tool, imported from the experimental paradigm, too fixist and too simplified and which, finally, provides quality (objectivity) but which in these situations considerably limits the validity. The PEO proves to be poorly adapted to the characteristics of complex systems.

9. Conclusion

What can be concluded from the decisional inabilities identified in this document? We observe firstly the importance of the internal consistency of the paradigm, in particular that required between the characteristics of the information and the tools used to process it. We then note that all subjective references involving the personal knowledge and experience of the decision-makers have been carefully avoided. The Italian statistician de Finetti (1906–1985) proposes abandoning the objective definition of probability without this affecting the quality of the judgements. The method used is that of the odds applied to bets on racecourses. This type of quantification known as "subjective probability" is considered as expressing the "degrees of belief" which are clearly cognitive.

List of acronyms

DMCS	Decision making in complex systems
OEP	Objective experimental paradigm
COP	Conference of parties

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Chapter 3

Single-Period Capacity and Demand Allocation Decision Making under Uncertainty

Sangdo Choi

Abstract

The newsvendor model deals with a single-period capacity allocation problem under uncertainty. The real world examples include perishable products (e.g., fish, vegetable), holiday-related products (e.g., Easter, Christmas, Halloween), seasonal products (e.g., fashion), and promotional products. This section addresses three newsvendor models: traditional newsvendor, inverse newsvendor, and sequential newsvendor models. The main decision under the traditional newsvendor setting is capacity allocation (i.e., how much to order), whereas the main decision under the inverse newsvendor setting is demand allocation (i.e., how many customers to be served) under the fixed capacity. This section demonstrates how to compare profit maximization approach to customer-oriented approach under the traditional newsvendor. The inverse newsvendor applies to revenue management for the hospitality industry. The sequential newsvendor model determines the optimal sequence when the number of customers to be served (determined by the inverse newsvendor model) is given. Normal distribution is considered for analytical solution and numerical studies. In addition, a discrete distribution is considered for numerical studies.

Keywords: Capacity Allocation, Demand Allocation, Newsvendor, Inverse Newsvendor, Sequential Newsvendor

1. Introduction

How can an operations manager make a one-time decision that covers a fixed future period if the manager cannot adjust the decision afterwards? A typical approach to this question is the single-period newsvendor model [1–4]. Suppose the operations manager herein is a newsvendor who would like to maximize profit or to satisfy a probability of not running out of newspaper. The newsvendor must place and receive an order before the start of each day to put on the newspaper stand. All left-over newspapers will be salvaged through paper-collection companies after the day, because nobody is interested in out-dated newspapers. The newsvendor is supposed to know all demand history and is able to forecast demand distribution properly, but not exact demand quantity on certain date. The newsvendor will not be able to match supply with demand exactly, unless the newsvendor is lucky [1], because only one demand scenario is realized during the selling period, i.e., $P(\textit{demand quantity} = \textit{order quantity}) = 0$ for a continuous demand distribution. Similar examples include grocery products (e.g., fish, vegetable), holiday-related products (e.g., Christmas, Easter, Halloween), seasonal products (e.g., fashion), and promotional products (e.g., T-shirts for a championship basketball or football game) [3]. These products also have a single selling period and will be deeply discounted after the selling season. If the newsvendor orders too much, left-over (overage) inventory is salvaged or steeply discounted. Otherwise, the newsvendor will forgo net profit because of lack of inventory (underage). Erlebacher et al. [5, 6] address the multi-item newsvendor model for inventory optimization problem with a capacity constraint. The newsvendor would like to keep balance between overage and underage, depending on the importance of two opposing directions.

The main decision variable for the traditional newsvendor is how many orders to be placed, which is a capacity allocation problem. Inversely, the newsvendor can also make decision on demand size to take full advantage of capacity [7–11]. If the newsvendor allocates too many demand, the resource is over-utilized (overusage). Otherwise, the resource is under-utilized (underusage). The inverse newsvendor would like to keep balance between overusage and underusage. A sequential newsvendor can make sequencing decision, when the demand size is determined by the inverse newsvendor [12]. Each customer is assigned to a slot in a sequence and the expected service start time should be scheduled. The sequential newsvendor would like to keep balance between earliness and lateness.

This chapter is organized as follows. Section 2 explains the traditional newsvendor model. Section 3 addresses the inverse newsvendor model. Section 4 addresses the sequential newsvendor model. Section 5 concludes this chapter.

2. The traditional newsvendor model

The traditional newsvendor is supposed to deal with inventory control. The newsvendor has to decide the order quantity to maximize the expected profit. If the newsvendor orders one less than the desired quantity, the newsvendor will forgo unit net profit owing to the lost sales. If the newsvendor order one more than the desired quantity, the newsvendor will loose unit net loss owing to the left-over inventory. Through the marginal analysis, the critical fractile determines the desired (or optimal) quantity and is regarded as the customer service level (CSL) [1–4].

On the contrary, the newsvendor may be interested in improving CSL than maximizing internal profit. For example, the newsvendor might want to make 90 percent sure of not running out of inventory, even though the critical fractile to maximize the expected profit is 0.7. The newsvendor would expand the market size in the long run while sacrificing the short-term maximum profit.

2.1 Mathematical model and solution approach

Let p be price; c order cost; s salvage, respectively. Demand D has mean of μ and standard deviation σ. Our decision variable is order quantity, q. The objective function is to maximize the expected profit. The profit function $\pi(q)$ is defined as follows:

$$\max_{q} \pi(q) = pE[\min(q, D)] - cq + sE\left[(D-q)^{+}\right], \qquad (1)$$

where $\min(q, D)$ is the realized sales out of demand and $(D-q)^{+}$ is left-over inventory, respectively. The profit maximization problem $\pi(q)$ reduces to the equivalent problem $\tilde{\pi}(q)$ to minimize the expected sum of underage and overage as follows:

$$\min_q \tilde{\pi}(q) = c^o E\left[(q-D)^+\right] + c^u E\left[(D-q)^+\right], \tag{2}$$

where $c^u = p - c$, net profit and $c^o = c - s$, net loss, respectively. The optimal solution to either $\pi(q)$ or $\tilde{\pi}(q), q^*$ can be obtained by first and second necessary conditions or through marginal analysis as follows [1, 2, 4]:

$$F(q^*) = \frac{c^u}{c^u + c^o}, \tag{3}$$

where $F(\cdot)$ is the cumulative distribution function of demand D. In addition, $F(q^*)$ is the probability that you are able to cover all demand up to q^*, CSL for order quantity, q^*.

2.2 Numerical example of discrete demand

The newsvendor is supposed to sell Christmas trees between Halloween and Christmas Eve, this year. Suppose that the newsvendor has such a long sales history to build a reasonable demand forecast. **Table 1** shows the demand forecast based upon the historical data.

The newsvendor has to place and receive an order before Halloween, which is supposed to be the first day of selling season. The newsvendor sets the selling price to $25 per unit and promises to pay $10 per unit to a farmer. A local mulch firm will collect left-over trees for $3 per unit to cut them into small pieces for mulch after Christmas. Note that the underage penalty $c^u = 25 - 10 = 15$ per unit and the overage penalty $c^o = 10 - 3 = 7$ per unit. The newsvendor tends to order more than the average 260, which is close to median, because $c^u > c^o$, i.e., the newsvendor wants to avoid underage rather than overage. The critical fractile is $\frac{15}{15+7} = 0.68$. The optimal order quantity should be 300 because of $F(250) < 0.68 < F(300)$. However, if the newsvendor sets CSL to 90 percent, the order quantity should be 350 because of $F(350) > 0.9$, of which profit is lower than the profit of the optimal order quantity 300.

Table 2 provides the expected profit of three order quantities: 250, 300, and 350. Order quantity of 300 is (at least) a local optimum. Note that the profit function $\pi(q)$ is convex function, i.e., increasing-then-deceasing [1, 2, 4]. If the newsvendor would compute the expected profit for all other order quantities, the newsvendor can recognize that order quantity of 300 is global optimal. If the newsvendor orders too much (e.g., 350), salvages are larger than the optimal

Demand quantity	Probability	Cumulative probability
100	0.03	0.03
150	0.07	0.10
200	0.10	0.20
250	0.25	0.45
300	0.30	0.75
350	0.20	0.95
400	0.05	1.00

Table 1.
Demand forecast with probability and cumulative probability for Christmas tree.

Demand	Probability	Revenue	Cost	Salvage	Profit
Order = 250					Exp. Profit = 3,387
100	0.10	100 × 25	250 × 10	150 × 3	450
150	0.10	150 × 25	250 × 10	100 × 3	1,550
200	0.15	200 × 25	250 × 10	50 × 3	2,650
250	0.15	250 × 25	250 × 10	0 × 3	3,750
300	0.25	250 × 25	250 × 10	0 × 3	3,750
350	0.15	250 × 25	250 × 10	0 × 3	3,750
400	0.10	250 × 25	250 × 10	0 × 3	3,750
Order = 300					Exp. Profit = 3,642
100	0.10	100 × 25	300 × 10	200 × 3	100
150	0.10	150 × 25	300 × 10	150 × 3	1,200
200	0.15	200 × 25	300 × 10	100 × 3	2,300
250	0.15	250 × 25	300 × 10	50 × 3	3,400
300	0.25	300 × 25	300 × 10	0 × 3	4,500
350	0.15	300 × 25	300 × 10	0 × 3	4,500
400	0.10	300 × 25	300 × 10	0 × 3	4,500
Order = 350					Exp. Profit = 3,567
100	0.10	100 × 25	350 × 10	250 × 3	−250
150	0.10	150 × 25	350 × 10	200 × 3	850
200	0.15	200 × 25	350 × 10	150 × 3	1,950
250	0.15	250 × 25	350 × 10	100 × 3	3,050
300	0.25	300 × 25	350 × 10	50 × 3	4,150
350	0.15	350 × 25	350 × 10	0 × 3	5,250
400	0.10	350 × 25	350 × 10	0 × 3	5,250

Table 2.
Expected profit for three order quantities: 250, 300, and 350.

quantity and revenues are also larger than the optimal quantity. However, larger ordering cost affects more on the expected profit. The expected profit of 350 is lower than the maximum. If the newsvendor orders too little (e.g., 250), the newsvendor can save salvages compared to the optimal quantity and revenue is not large.

2.3 Numerical example of normally distributed demand

Now take into account a continuous demand distribution. Suppose that the demand distribution is normally distributed with mean of 275 and standard deviation of 50. It is hard to compute the revenue and salvage for each order, because there are infinite scenarios of order quantity. The newsvendor can compute the expected profit, starting from the expected lost sales, which is expressed as follows:

$$E\left[(D-q)^{+}\right] = \sigma L(z), \tag{4}$$

Step	Item	Profit-based	CSL-oriented
1	Critical Fractile (or CSL)	0.68	0.9
2	Order Quantity	298.6	339.1
3	Expected Lost Sales	7.4	5.0
4	Expected Sales	267.6	270.0
5	Expected Left-over	31.0	69.1
6	Expected Profit	3,797.5	3,566.0

Table 3.
Expected profit for two approaches: Profit maximization vs. CSL-oriented.

where $L(z) = \phi(z) - z(1 - \Phi(z))$ [2]. Note that $\phi(z)$ is normal probability distribution and $\Phi(z)$ is cumulative distribution, respectively.

1. Compute the critical fractile, or CSL.

2. Compute the associated quantity with CSL, $norm.inv(CSL, \mu, \sigma)$.

3. Compute the expected lost sales, $\sigma L(z)$.

4. Compute the expected sales: = expected demand - expected lost sales.

5. Compute the expected left-over: = order quantity - expected sales.

6. Compute the expected profit: = $c^u \times$ expected sales - $c^o \times$ expected left-over.

The newsvendor can take two perspectives: internal profit maximization vs. higher CSL. **Table 3** shows computational steps to get the expected profits of both profit-based and CSL-oriented approaches, respectively. For profit-based approach, the critical fractile is computed and its associated order quantity is determined accordingly. The expected profit is $3,797.5. For CSL-oriented approach, the newsvendor is supposed to determine the desired CSL first. Suppose that the newsvendor would like to guarantee 90% probability of not running out, i.e., 90% of demand will be covered by the order quantity. Because of higher CSL, the order quantity is far larger than the optimal order quantity; lower expected lost sales; larger left-over. Henceforth, the expected profit is lower. The newsvendor can choose either order quantity based on your strategic direction.

3. The inverse newsvendor model

The inverse newsvendor model applies to revenue management, which deals with fixed capacity and has to determine demand allocation [7, 8, 10, 11]. Airline industry uses quantity (i.e., number of seats) for capacity, whereas hospital may use time unit for capacity. Time-based inverse newsvendor model can be addressed for time-sensitive service industries such as hospital and law-firm.

The inverse newsvendor can take into account both identical and non-identical service durations. When the inverse newsvendor takes into account all identical service durations, the decision reduces to the number of allocation, i.e., how many customers will be assigned. When the inverse newsvendor takes into account heterogeneous service durations, the decision reduces to setting priority problem. Who should be allocated first and who can be next on? [9].

3.1 Mathematical model for identical service durations

Let h be the given and fixed capacity in hour. Each customer requires service duration, T which follows normal distribution with mean of μ and standard deviation σ. Assume that all customers are homogeneous, i.e., they have the same mean and standard deviation. The inverse newsvendor has to decide the number of customers to be served, x to minimize the sum of expected overusage and underusage. Consider the unit overusage penalty, c^g and unit underusage penalty, c^ℓ. The objective function $\rho(x)$ is defined as follows:

$$\min_x \rho(x) = c^g E\left[\left(\sum_{k=1}^{x} T_k - h\right)^+\right] + c^\ell E\left[\left(h - \sum_{k=1}^{x} T_k\right)^+\right]. \tag{5}$$

$\sum_{k=1}^{x} T_k$ also follows normal distribution with mean of $x\mu$ and variance of $x\sigma^2$. Let $z = \frac{h - x\mu}{\sqrt{x}\sigma}$. Overusage $E\left[\left(\sum_{k=1}^{x} T_k - h\right)^+\right]$ and underusage $E\left[\left(h - \sum_{k=1}^{x} T_k\right)^+\right]$ are defined as follows [12]:

$$E\left[\left(\sum_{k=1}^{x} T_k - h\right)^+\right] = (\phi(z) - z(1 - \Phi(z)))\,\sigma, \tag{6}$$

$$E\left[\left(h - \sum_{k=1}^{x} T_k\right)^+\right] = (\phi(z) + z\Phi(z))\,\sigma. \tag{7}$$

Figure 1 depicts a graphical representation of an inverse newsvendor problem with $\mu = 2, \sigma = 0.8$, and $h = 9$. The optimal solution to (5), x^* is defined as follows [9]:

$$x^* = \lfloor \hat{x} \rfloor \text{ or } \lceil \hat{x} \rceil, \tag{8}$$

$$\text{where } \hat{x} = \left(\frac{-z\sigma + \sqrt{z^2\sigma^2 + 4\mu h}}{2\mu}\right)^2. \tag{9}$$

$$F_N\left(h; x^*, x^{*2}\right) = \frac{c^g}{c^\ell + c^g} = \Phi(z), \tag{10}$$

For the case of **Figure 1**, the optimal allocation can be either 4 or 5 by visualization and analytical solution, (8) and (9).

3.2 Numerical example for identical service durations

Consider an operating room (OR) with 8 or 9 hour capacity. When each patient requires 2 hour service durations on average, how many patients would be assigned in the OR daily? Overusage penalties would cover overtime pay to the attending surgeon(s), nurses, anesthesiologist, and other staff. Underusage penalties would cover opportunity cost when the OR is under-utilized, but be hard to measure. The inverse newsvendor can determine the optimal demand size if the newsvendor knows parameters of service duration and two penalties. Numerical studies show

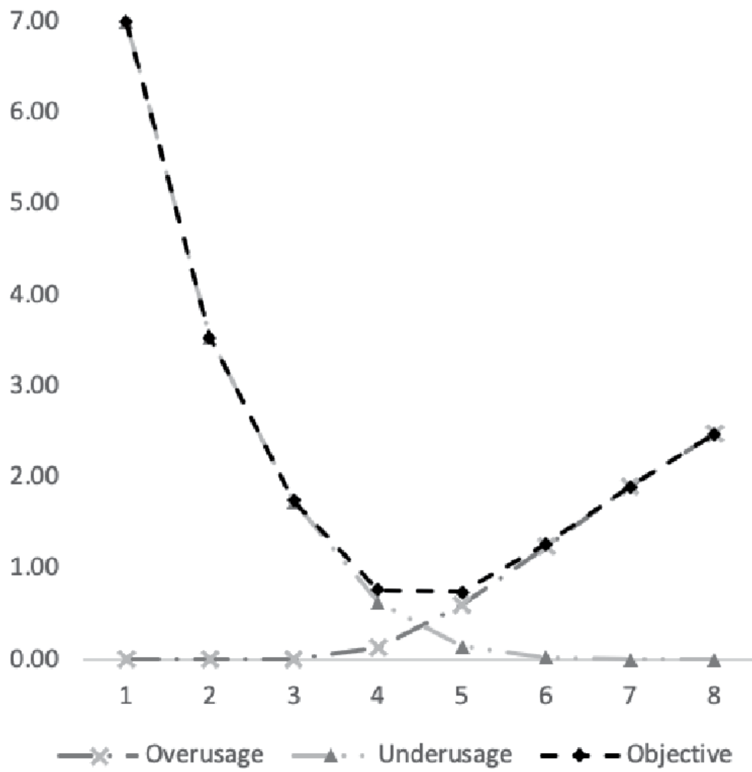

Figure 1.
Graphical representation of an inverse newsvendor model. The objective function for the case of $\mu = 2, \sigma = 0.8$, and $h = 9$. The overusage is an ever-increasing function of x, whereas the underusage is an ever-decreasing function of x. Hence, the objective function is a decrease-then-increase function.

Scenario	1	2	3	4	5	6	7	8
μ	2	2	2	2	3	3	3	3
σ	0.2	0.2	0.8	0.8	0.3	0.3	1.2	1.2
h	8	8	8	8	9	9	9	9
$c^g : c^\ell$	0.1:0.9	0.9:0.1	0.1:0.9	0.9:0.1	0.1:0.9	0.9:0.1	0.1:0.9	0.9:0.1
x	4.26	3.75	5.17	3.10	3.23	2.79	4.03	2.23
$\rho(\lfloor x \rfloor)$	0.16	0.20	0.32	0.25	0.21	0.30	0.42	0.33
$\rho(\lceil x \rceil)$	0.20	0.16	0.41	0.64	0.30	0.21	0.61	0.83
x^*	4	4	5	3	3	3	4	2

Table 4.
Patient allocation under different cost ratios, service durations and capacity.

impact of cost ratio and parameters on patient allocation. Consider the following data set in **Table 4**.

Table 4 summarizes numerical studies with varying mean, standard deviation, cost ratios, and capacity values. The inverse newsvendor can take into account two capacity levels: 8 or 9. Hospital may operate 8 hours each day or 9 hours if the inverse newsvendor expects high possibility of overtime. Each surgery duration requires 2 or 3 hours. Take into account two levels of standard deviation for each service duration. Two extremely different cost ratios are considered.

The ratio of capacity to the mean service duration, $\frac{h}{\mu}$ can be a base scenario. Actual allocation can be the base scenario, one more allocation, or one less allocation from the base scenario. For example, scenarios 1–4 have the ratio of 4 and scenarios 5–8 have the ratio of 3. When the inverse newsvendor has a non-integer value of ratio, the newsvendor can use either floor or ceiling value of the ratio. Actual allocations are 3, 4, or 5 for scenarios 1–4; 2, 3, or 4 for scenarios 5–8, respectively.

When $c^g > c^l$ (i.e., overusage is more penalized than underusage), the inverse newsvendor tends to allocate less patients (than the base) to avoid overusage penalty. On the contrary, when $c^l > c^g$ (i.e., underusage is more penalized than overusage), the inverse newsvendor tends to allocate more patients (than the base) to avoid underusage penalty. Allocating one more patient or one less patient would affect a lot on the objective function. As a matter of fact, allocating more (less) patients means ONE more (less) patient than the base scenario.

Variance may amplify impact of cost-ratio, which means there must exist interactive effect between variance and cost-ratio. When $c^g < c^l$ (e.g., scenarios 1, 3, 5 and 7), the larger variance, the more allocated patients. When $c^g > c^l$ (e.g., scenarios 2, 4, 6, and 8), the larger variance, the less allocated patients. For lower variance examples (scenarios 1, 2, 5, and 6), cost-ratio would not affect on allocation much.

3.3 Mathematical model for non-identical service durations

Suppose that there are N customers, of which index is $i = 1, 2, \cdots, N \in \mathcal{I}$, respectively and that individual service time T_i of customer i has mean of μ_i and standard deviation σ_i. New decision variable x_i is a binary variable, 1 if customer i is served, 0 otherwise. The number of customers to be served is $\sum_i x_i$. The total service time is defined as $\sum_i x_i T_i$. The inverse newsvendor problem with non-identical service durations can be represented as follows:

$$\min_{x_i, i \in \mathcal{I}} c^g E\left[\left(\sum_{i=1}^{N} x_i T_i - h\right)^+\right] + c^\ell E\left[\left(h - \sum_{i=1}^{N} x_i T_i\right)^+\right]. \tag{11}$$

The inverse newsvendor should evaluate $2^N - 1$ possible combinations to find the optimal number of customers to be served. To find the optimal solution based on numerical evaluation of (11), the inverse newsvendor can reformulate it using Stochastic Programming with discrete scenarios $\omega \in \Omega$. The inverse newsvendor can adopt the sample average approximation (SAA) approach to get a close approximation [13]. Let T_i^ω be the service time for customer i under scenario ω; u^ω underusage under scenario ω; o^ω overusage under scenario ω; p^ω probability of scenario ω, respectively. SAA formulation is given as follows:

$$\min \quad c^l u^\omega p^\omega + c^g o^\omega p^\omega \tag{12}$$

$$s.t. \quad \sum_{i=1}^{N} x_i T_i^\omega + u^\omega \geq h, \omega \in \Omega \tag{13}$$

$$\sum_{i=1}^{N} \mathrm{x}_i T_i^\omega - o^\omega \leq h, \omega \in \Omega \tag{14}$$

The inverse newsvendor can get the optimal solution of the SAA approach [9]. However, it is hard to derive a certain (intuitive) rule for the optimal allocation of customers. A heuristic to get a near-optimal solution in a reasonable time limit is prescribed: smallest-variance (SV) first, which is close to the optimal solution [9]. The heuristic is based on the discussion that partial expected values are associated with variability rather than central location measure such as mean or median.

Take advantage of the results from the case of identical service durations from Subsection 3.1. Suppose that n customers are about to be served. Let $\overline{\mu}$ be the sample average service time for n customers; $\overline{\sigma}$ the standard deviation of the sample average service times for n customers, respectively. If n is equal to the solution of (8) and (9) with $\overline{\mu}$ and $\overline{\sigma}$, the inverse newsvendor can stop adding customers to be served. The detail procedure of the heuristic with the SV selection rule is described as follows [9]:

- **Initialization.** Let $\mathcal{A} = \mathcal{A}^* = \{\}, \mathcal{N} = \{1, 2, \cdots, N\}$, and $Z_{opt} = \infty$.
- **Step 1.** Select i with the smallest variance. Remove i from $\mathcal{N}$ and add i to $\mathcal{A}$.
- **Step 2.** Compute the sample mean $\overline{\mu}$ and sample standard deviation $\overline{\sigma}$ of the set $\mathcal{A}$.
- **Step 3.** Plug $\overline{\mu}$ and $\overline{\sigma}$ into (8) and (9) to compute the optimal number of customers to be served, say x^*.
- **Step 4.** Compute the objective function value, say Z_{curr}. If $Z_{curr} < Z_{opt}$, let $\mathcal{A}^* \leftarrow \mathcal{A}$ and $Z_{opt} \leftarrow Z_{curr}$.
- **Step 5.** If $x^* \leq |\mathcal{A}^*|$ and $\mathcal{N} \neq \{\}$, go to Step 1. Otherwise, go to Step 6.
- **Step 6.** Let $\mathcal{A}^*$ be the set of optimally assigned customers and Z_{opt} be the heuristic results.

The inverse newsvendor can show how the SV heuristic works with the following example. The inverse newsvendor can use cost ratio of 0.5:0.5; 120 min blocks without loss of generality. **Table 5** shows all parameter values of ten customers: μ and σ. The SV heuristic will select customers as the following order: $10 \rightarrow 7 \rightarrow 9 \rightarrow 6 \rightarrow 8 \rightarrow \cdots \rightarrow 2$.

The followings are detail steps resulted from the SV selection rule.

- Initial Step. $\mathcal{A} = \mathcal{A}^* = \{\}; \mathcal{N} = \{1, 2, 3, \cdots, 10\}; Z_{opt} = \infty$
- Iteration 1. $\mathcal{A} = \{10\}; \overline{\mu} = 10.3; \overline{\sigma} = 1.80; x^* = 12 > |\mathcal{A}^*| = 1; Z_{curr} = 54.87; Z_{opt} = 54.87; \mathcal{A}^* = \{10\}$
- Iteration 2. $\mathcal{A} = \{10, 7\}; \overline{\mu} = 18.79; \overline{\sigma} = 3.07; x^* = 6 > |\mathcal{A}^*| = 2; Z_{curr} = 41.21; Z_{opt} = 41.21; \mathcal{A}^* = \{10, 7\}$
- Iteration 3. $\mathcal{A} = \{10, 7, 9\}; \overline{\mu} = 16.38; \overline{\sigma} = 4.09; x^* = 7 > |\mathcal{A}^*| = 3; Z_{curr} = 35.43; Z_{opt} = 35.53; \mathcal{A}^* = \{10, 7, 9\}$

Customer	1	2	3	4	5	6	7	8	9	10
μ_i	18.5	27.9	24.9	28.5	26.8	27.5	27.3	19.8	11.6	10.3
σ_i	6.5	21.7	17.3	7.5	18.8	5.7	3.9	6.4	5.6	1.8

Table 5.
Customer service duration information.

- Iteration 4. $\mathcal{A} = \{10, 7, 9, 6\}; \overline{\mu} = 19.16; \overline{\sigma} = 4.55; x^* = 6 > |\mathcal{A}^*| = 4; Z_{curr} = 21.67; Z_{opt} = 21.67; \mathcal{A}^* = \{10, 7, 9, 6\}$

- Iteration 5. $\mathcal{A} = \{10, 7, 9, 6, 8\}; \overline{\mu} = 19.3; \overline{\sigma} = 4.97; x^* = 6 > |\mathcal{A}^*| = 5; Z_{curr} = 11.82; Z_{opt} = 11.82; \mathcal{A}^* = \{10, 7, 9, 6, 8\}$

- Iteration 6. $\mathcal{A} = \{10, 7, 9, 6, 8, 1\}; \overline{\mu} = 19.16; \overline{\sigma} = 5.27; x^* = 6 = |\mathcal{A}^*|; Z_{curr} = 5.53; Z_{opt} = 5.53; \mathcal{A}^* = \{10, 7, 9, 6, 8, 1\}$

- Iteration 7. $\mathcal{A} = \{10, 7, 9, 6, 8, 1, 4\}; \overline{\mu} = 20.51; \overline{\sigma} = 5.64; x^* = 6 < |\mathcal{A}^*| = 7; Z_{curr} = 12.15; Z_{opt} = 5.53; \mathcal{A}^* = \{10, 7, 9, 6, 8, 1\}$. Stop.

4. The sequential newsvendor model

A sequential newsvendor has to determine the sequence of assigned customers and their arrival times, when the newsvendor already knows the total number of customers to be served in a fixed duration [12]. Once the sequential newsvendor determines the sequence, the arrival time of each customer can be the cumulative expected service time of all prior customers without loss of generality. Basically, this is a block scheduling problem that determines the starting times of blocks.

The sequential newsvendor model applies to time-sensitive service industries as the inverse newsvendor. The inverse newsvendor may decide the strategic level decision, whereas the sequential newsvendor decides the tactical level decision and relies on the inverse newsvendor decision. The newsvendor may use identical service durations for the strategic decision (e.g., capacity size, demand size) and non-identical durations for the tactical decision (e.g., setting priority).

4.1 Mathematical model and solution approach

Suppose that the sequential newsvendor has to serve $|I|$ customers (or customer groups) and that each customer $i \in I$ requires different service duration T_i, of which mean is μ_i and its standard deviation is σ_i. The sequential newsvendor has to determine its sequence and starting time of each patient i.

Use map $\Delta : I \rightarrow K$ to represent a set of sequences (or permutations), each of which $\delta \in \Delta$ assigns each customer to one and only one sequence position, hence $|K| = |I|$. Use subscripts $[k]$ for k^{th} block sequence position and i for customer to avoid potential confusion.

Decision variables must prescribe planned block durations and block sequence, δ. The sequential newsvendor determines the planned end time of block in the k^{th} position, given a sequence δ, prescribed by $y^{\delta}_{[k]}$. The planned end time of the block corresponds to the end of service durations and is important in deciding the number of hours that the server will be required to work. Define $B^{\delta}_{[k]} := T^{\delta}_{[1]} + \cdots + T^{\delta}_{[k]}$ as the random end time to complete all services assigned to blocks [1] through $[k]$ and compare it with the decision variable $y^{\delta}_{[k]}$.

Assume that one service begins as soon as the previous one ends [14–16]. This assumption appears to be reasonable because each customer can be prepared well in advance of his/her scheduled start time and successive services within each block is likely to be performed by the same server so that s/he would be available as well. However, expediting efforts is required if a planned service ends earlier than the planned end time. The sequential newsvendor can penalize the earliness.

The objective function penalizes the expected earliness $E\left[\left(y^{\delta}_{[k]} - T^{\delta}_{[k]}\right)^{+}\right]$ and expected lateness $E\left[\left(T^{\delta}_{[k]} - y^{\delta}_{[k]}\right)^{+}\right]$ of each block $k \in K$. The sequential newsvendor imposes earliness penalty c^{e} and lateness penalty c^{l}, respectively. The former represents the cost of expediting the start time of the next surgery; and the letter, the cost of delaying the start time of the next surgery. The sequential newsvendor can build a schedule that balances the expected costs of earliness and lateness associated with each block, defining objective function $f_{[k]}\left(y^{\delta}_{[k]}\right), k \in K, \delta \in \Delta$

$$f_{[k]}\left(y^{\delta}_{[k]}\right) = c^{e}E\left[\left(y^{\delta}_{[k]} - T^{\delta}_{[k]}\right)^{+}\right] + c^{l}E\left[\left(T^{\delta}_{[k]} - y^{\delta}_{[k]}\right)^{+}\right]. \tag{15}$$

The sequential newsvendor has to determine the optimal planned end time $\hat{y}^{\delta}_{[k]}$ of the k^{th} block, $k \in K$ and the optimal block sequence $\hat{\delta}$. **Figure 2** depicts a graphical representation of the sequential newsvendor model. For each sequence $\delta \in \Delta$, the objective function $\sum_{k \in K} f_{[k]}\left(y^{\delta}_{[k]}\right)$ should be minimized. The sequential newsvendor has to find the best solution out of all minimized solutions. The sequential newsvendor problem can be defined as follows:

$$\min_{\delta \in \Delta} \min_{y^{\delta}_{[k]}: k \in K} \sum_{k \in K} f_{[k]}\left(y^{\delta}_{[k]}\right) \tag{16}$$

$$s.t. \quad y^{\delta}_{[k-1]} \leq y^{\delta}_{[k]} \; k = 2, \cdots, |K|, \delta \in \Delta \tag{17}$$

$$y_{[k]} \geq 0 \qquad k \in K, \delta \in \Delta \tag{18}$$

Fix a sequence δ to find the optimal planned end time. Suppress this superscript for the sake of simplicity. (16) is separable with respect to $y_{[k]}$ [12]:

$$\min\left\{ f_{[1]}\left(y_{[1]}\right) + f_{[2]}\left(y_{[2]}\right) + \cdots + f_{[|K|]}\left(y_{[|K|]}\right)\right\} \tag{19}$$

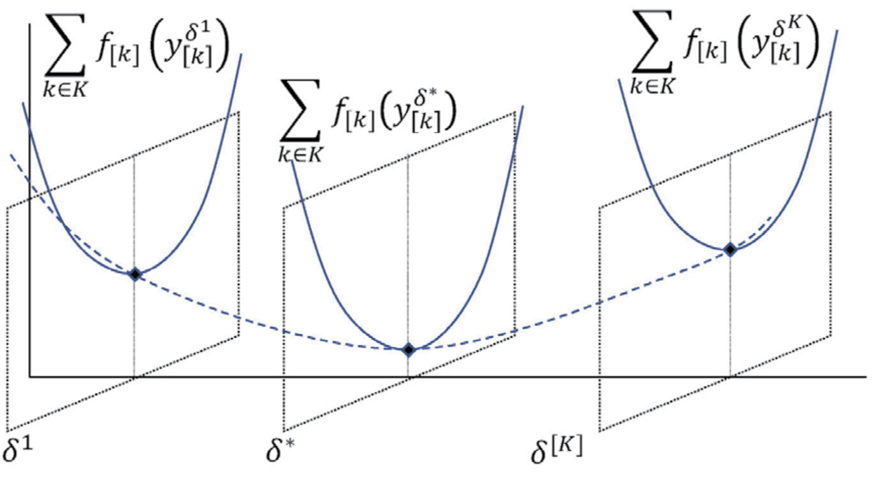

Figure 2.
Graphical representation of a sequential newsvendor model. For each sequence $\delta \in \Delta$, the objective function should be minimized.

$$\equiv \min f_{[1]}\left(y_{[1]}\right) + \min f_{[2]}\left(y_{[2]}\right) + \cdots + \min f_{[|K|]}\left(y_{[|K|]}\right). \tag{20}$$

Let $\overline{\mu}_{[k]} = \mu_{[1]} + \mu_{[2]} + \cdots + \mu_{[k]}$ be the mean of the random end time $B_{[k]}$ and $\overline{\sigma}_{[k]} = \sqrt{\sigma^2_{[1]} + \sigma^2_{[2]} + \cdots + \sigma^2_{[k]}}$ be the standard deviation of $B_{[k]}$, respectively. Random end time $B_{[k]}, k \in K$ is also normally distributed as follows:

$$B_{[k]} = T_{[1]} + T_{[2]} + \cdots + T_{[k]} \sim N\left(\overline{\mu}_{[k]}, \overline{\sigma}^2_{[k]}\right) \tag{21}$$

Henceforth, the optimal planned end time $\hat{y}_{[k]}$ of k^{th} block can be obtained as follows [17]:

$$\hat{y}_{[k]} = \overline{\mu}_{[k]} + z\overline{\sigma}_{[k]} \tag{22}$$

$$\Phi(z) = \frac{c^l}{c^e + c^l}. \tag{23}$$

The optimal objective function value for k^{th} block is given as follows [12]:

$$f_{[k]}\left(\hat{y}_{[k]}\right) = \left(c^e + c^l\right)\frac{\overline{\sigma}_{[k]}}{\sqrt{2\pi}}e^{-z^2}. \tag{24}$$

(24) is an increasing function of $\overline{\sigma}_{[k]}$. Hence, smallest-variance first rule is the optimal sequencing rule.

5. Conclusions

Three newsvendor models are addressed to match supply with demand, or vice versa. The traditional newsvendor model can answer how much to order, given that the newsvendor knows demand distribution. The inverse newsvendor model applies to the strategic level decision, e.g., how many customers should be allocated in a fixed capacity. Time-based newsvendor model has been used for service-oriented settings (e.g., operating rooms, law firm). The sequential newsvendor model determines the sequence of the assigned customers by the strategic inverse newsvendor model, and prescribes the corresponding expected arrival times of the customers. The optimal sequence should be a variability-based rule, because the objective function elements involve partial expected values: overage vs. underage, overusage vs. underusage, or earliness vs. lateness. The smallest-variance-first assignment rule is optimal to minimize the expected earliness and lateness when the newsvendor takes into account normally distributed service durations.

All newsvendor models keep balance between surplus (i.e., supply $>$ demand) and deficit (supply $<$ demand), accepting the fact that the newsvendor cannot match supply with demand all the time. Supply chain professionals may face with either case of surplus or deficit, not matched. When a product is highly profitable (or net profit is greater than net loss), the newsvendor tends to order more than the average to avoid the lost sales in the long run. On the contrary, when net loss is greater than net profit, the newsvendor tends to order less than the average in the long run. However, if the newsvendor is myopic, the newsvendor tends to order average demand without respect to cost structure or demand shape, so-called pull-to-center [18]. To avoid pull-to-center bias, supply chain professionals must understand how to get optimal decision considering cost structure and demand parameters for long-term perspective.

Abbreviations

CSL	Customer Service Level
OR	Operating Room
SAA	Sample Average Approximation
SV	Smallest Variance

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Chapter 4

Decision Making in the Context of Natural Disasters Based on a Geographic Information System and the Internet of Things (IoT)

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Abstract

Decisions within the company, managers in countries or regions are made by one or more groups of decision-makers. The management of natural disasters involves several specialized decision-makers (experts, firefighters, police officers, drivers,). The aim of the chapter is to improve decision making in the context of natural disasters situation. Zero risk in the world does not exist due to natural phenomena that occur randomly and appear suddenly. It is essential to manage the risks in the situation of natural disasters and also to confront the influence of natural disasters on the phenomenon of Soil-Structure Interaction. For this, this chapter presents a conceptual architecture of a knowledge base to manage the risks of natural disasters remotely by a Geographic Information system (GIS) and embedded systems. This architecture is based on the integration of data via different sources of information (GIS, satellites, electronic sensors and comments from experts). To properly manage this information, this chapter uses the ontology of Soil-Structure Interaction With Agents External (OSSIWAE) in the context of the Internet of Things (IoT). A case study is conducted on a prototype of a model for building a structure three-story for testing the usability of the proposed architecture.

Keywords: Risks of natural disasters, Soil-Structure Interaction; Geographic Information system, Ontologies, Internet of Things (IoT)

1. Introduction

Natural disasters (Flood, Storm, Earthquake, Extreme temperature, Landslide, wind…) are phenomena that occur every time and humans must find appropriate solutions to minimize the damage. With the increase in the use of embedded system and the web technologies in all fields. These technologies have enabled us to help find solutions that were not possible previously or it is difficult to access a certain types of disasters by decision makers. The aim of the chapter is to improve decision making in the context of natural disasters. Zero risk in the world does not exist due to natural phenomena that occur randomly and appear suddenly. It is essential to manage the risks of natural disasters and to inform the people concerned, the leaders, the citizens, firefighters, police officers, drivers… etc. However, the phenomenon of Soil-Structure Interaction poses real and important problems for the design of new structures that resist to natural disasters because of the heterogeneous mechanical behavior of the soil, which changes through the influence of external agents such as: temperature, water, rain snow (freeze–thaw phenomenon) earthquake (dynamic effect). For this purpose, this chapter presents a conceptual architecture of a knowledge base to manage the risks of natural disasters. The architecture of the system is based on the use of ontology, a Geographic Information system (GIS), a sensors electronic system and the documents of experts in the context of Internet of Things (IoT) in order to build a knowledge base on the influence of external agents on the phenomenon of Soil-Structure Interaction. In this chapter an ontology of Soil-Structure Interaction With Agents External (OSSIWAE) was proposed to capitalize the information on agents external in a real time in order to fully understand, analyze and estimate this phenomenon. The proposed ontology was validated by experts in civil engineering, who helped us to build this ontology. In order to validate the proposed architecture, a web application is developed that supports this architecture. The rest of this chapter is organized as follows. First the related works on the Geographic Information System and the ontologies for the management of natural disasters are detailed in Section 2. In Section 3, the ontology for representing the phenomenon of Soil-Structure Interaction with the connection of natural disasters (OSSIWAE) is presented. In Section 4, the architecture of a knowledge base of natural disasters is presented. Finally, the chapter ends with the implementation of a web platform applied on the prototype of a model for building a structure three-story in the context of Internet of Things (IoT) for testing the usability of the proposed architecture.

2. Related work

This section describes the proposed related work that used the Geographic Information System and the ontologies for the management of natural disasters.

2.1 Geographic information system for the management of natural disasters

[1, 2] Geographic Information Science is developed to manage and analyze spatial data, which is based on geomatics technologies, Geographic Information Science as a technology/system allows the storage of spatial information in the relational database. According to [3] Geographic information system (GIS) has emerged as a dominant tool for accumulating, analyzing and displaying spatial data and using this data for decision making in several areas. In addition to [3] Geographic Information System (GIS) is one the technologies that evolves to allow people to solve many geographic problem quickly, effectively and easily with the abilities to make analysis, especially location analysis in combination with traditional database systems.

There are several computer systems that manipulate geographic databases such as ArcGis, QGIS, MapInfo, SuperGis, Surfer...etc. and at the same time there are GIS web applications to make GIS accessible through web technologies.

Several works have shown the interest of GIS for the study of floods and risks. In [4], authors proposed a methodology by using the SAR data along with GIS for flood water mapping, monitoring and analyzing the propagation of flood water in a flood prone area. In [5], authors proposed an approach based on GIS for flood management strategy in a river basin; this approach consists of two main interlinked components the first is a proper flood management strategy, and the second is the determination of the flood-hazard areas. This work [6] demonstrated the importance of the use of earth observation (EO) products and geographic information systems (GIS) in disaster-risk management. [7] used the data collection methods and GIS applications to develop a detailed mapping of the main natural and human factors responsible for the flooding phenomenon. [8] used remote sensing and GIS to reduce flood damage in the study area by improving flood forecasting and flood defense. In [9], authors developed a flood sensitivity spatial decision support system (SDSS) that integrates the spatial analytical strengths of a GIS platform with the structured analytical hierarchy process (AHP).

This section demonstrates the importance of using a GIS for flood risk management, however, but few works that integrate embedded sensors and the semantic web with a GIS to effectively manage natural disasters.

2.2 The ontologies for the management of natural disasters

An ontology can be defined as an explicit specification of a conceptualization [10]. In recent years ontologies have been used in various fields of application to create knowledge bases (search engines, e-commerce, electronic library, etc.). Applications not only need to exchange data and information with each other but also need to agree on the semantics of that data and information. Knowledge can describe and explain its meaning using the following elements (class, instance, attribute, relation, etc.). The organization of these elements of description of knowledge can be done in the form of ontology. So an ontology is the set of individual instances of classes, specifying the specific values of the attributes as well as the restrictions on the attributes to constitute a knowledge base. According to Noy [11] there is not just one correct way to model a knowledge domain there are always varying alternatives, the best solution generally depends on the application carried out and the anticipated developments. In the context of the creation of ontologies in the field of soil science, in the field of structure and the field of disaster risk management, we mention: In [12], authors proposed an Ontology-Based Knowledge Network of soil/water physicochemical & biological properties (soil/water concepts) for the semantic representation of infiltration/percolation process of contamination water through soil structure and porous media. According to [13] Pile foundation is a basic form that can adapt to complex geological conditions and is widely used in high-rise buildings, bridges, ports, and other important structures, this work proposed an integrated evaluation system that can make reasonable evaluations of pile integrity where specific measured reflective wave curves. The evaluation system based on the ontology of pile integrity evaluation (OntoPIE), this ontology used for quantitative identification of pile defects and qualitative evaluation of pile integrity. THE OntoPIE represent the essential terms of the pile integrity evaluation system which includes the degree, length, depth, and integrity category of the pile defects. In [14], authors proposed an ontology of soil properties and processes for representing soil properties, processing and their interaction in order to make integrated decisions, and to combine the knowledge and expertise in multiple areas, such as roads, soil, buried assets, sensing, etc. [15, 16] proposed an ontology-based simulation environment in agriculture and natural resources for constructing models and representing equations and symbols in a formal ontology language, the utility of the approach by building moderately complex models of soil–water and nutrient management. This approach has the advantage of making models more explicit and better defining the meaning of symbols used in a model. [17] Proposed ontology of the flood domain and describes how they can be benefited to access, analyze, and visualize flood-related data with natural language queries. Flood ontology developed under three major ontological branches (i.e. Natural Hazard, Instrument, and Environmental Phenomena) Geological Hazards (e.g. earthquake), Meteorological Hazards (e.g. tornado), Diseases, Wildfires, and Floods. Flood ontology utilized in cyberinfrastructure systems for natural hazard preparedness, monitoring, response, and recovery. And to allow visual, intuitive, and collaborative development for domain experts who may have a limited technical background [18]. Aims to use the data from different sources to reason on them. Data comes from water sensors, satellite images, field studies, hydrological models, GIS, etc. to model risk management for flash floods. [19] proposed integrated watershed flood risk assessment ontology based on different perceptual models of watershed flood risk. This ontology represents the complex process involving physical systems and organizational systems in flood risk assessment [20]. Proposed the ontology named FloodOntology for floods forecasting based on continuous measurements of water parameters gathered in the watersheds and in the sewers and simulation models. FloodOntology is used for obtaining a structured and unified knowledge-base on the flooding risk forecasting. Three main domains are used hydrological, hydraulic and sensor networks. In [21], the authors identify the core literature available on flood ontologies and present a review on these ontologies from various perspectives [22]. Proposed the Ontology for River Flow and Flood Mitigation (ORFFM) for semantic knowledge formalization with semantic understandability of irrigation, disaster management, related administrative and agricultural domain concepts. This ontology allows the effective coordination, collaborative response activities leads to reduce the impact of a disaster and improve information representation among stakeholders.

The phenomenon of Soil-Structure Interaction poses real and important problems for the design of structures in order to resist to the natural disasters due to heterogeneous mechanical behavior of soil which changes through the influence of external agents such as: temperature, water, rain snow (freeze–thaw phenomenon) earthquake (dynamic effect). However the cited works are not considered this knowledge in ontology. For this purpose, we based on the existing ontologies and the Soil-Structure Interaction model proposed in literature in order to propose a new ontology to represent the phenomenon of Soil-Structure Interaction with the connection of external agents named OSSIWAE.

3. Ontology of soil-structure interaction with external agents proposed

In this chapter, the Protégé tool 5.2 is used to realize the ontology of OSSIWAE. There are several methods for developing ontology. To design this ontology, the iterative method for the development of the ontology, proposed by [11] is followed.

The development of the ontology is started by defining its domain and scope by answering the following questions:

What is the field that ontology will cover? The domain of the ontology is the concepts used in the domain of Soil-Structure Interaction and natural disasters, this ontology conceptualizes the concepts in different domain Soil, Natural Disasters, Structures and the relations between them. The relations which represent the interactions between Soil, natural disasters and structures are taken into consideration with sensors. The ontology therefore includes all the concepts of the external agents which influence on the structures such as the temperature, water, rain snow (phenomenon of freeze–thaw) the earthquake (the dynamic effect) … etc. And describe the concepts which link heterogeneous soil and structure information.

What are the development goals of ontology? The ontology is designed with the aim of formalizing and clarifying the semantics of the collection of information by electronic sensors. This formalization allows us to implement the semantics of information in Web tool dedicated to the actors involved in the decision process. And also to ensure the sematic integration of data via different sources of information (GIS, satellites, electronic sensors and comments of experts).

Reuse of existing ontologies:

The objective of this step is to reuse existing ontologies even if they have a different objective from ours. We can reuse all or part of these ontologies after having adapted them to our needs. Some concepts proposed by [12–14, 17] are reused.

Identification and structuring of ontology concepts:

To identify the main concepts of ontology, the concepts proposed by [12–14, 17] are extracted and enriched them with the concepts analyzed in the Soil-Structure Interaction model proposed in literature and the concepts proposed by civil engineering experts. These concepts are organized and structured in an ontology called "OSSIWAE". Finally, the Protégé editor is used to define this ontology (**Figure 1**).

This ontology has been validated by experts in civil engineering who have helped us to build and enrich the concepts of ontology.

We explain below some of the concepts identified in this ontology.

The top-level classes of the OSSIWAE ontology are Soil, natural disasters, structures (superstructure and infrastructure) and we have hierarchized each class with its subclass.

The class Soil its subclass are physical characteristics, mechanical characteristics and chemical characteristics. For example the class of physical characteristics its subclass are sand, silt and clay.

The class structures its subclass are superstructure and infrastructure, the class superstructure its subclass are column, beam, slab and wall, the infrastructure is foundation.

The class natural disasters its subclass are temperature, Humidity, Rain, water, Wind, snow, freeze–thaw (freeze–thaw phenomenon) earthquake (dynamic effect), volcano. And each class has the values for example the concept of Humidity (has value), Temperature (has value), Wind (has frequency and has direction).

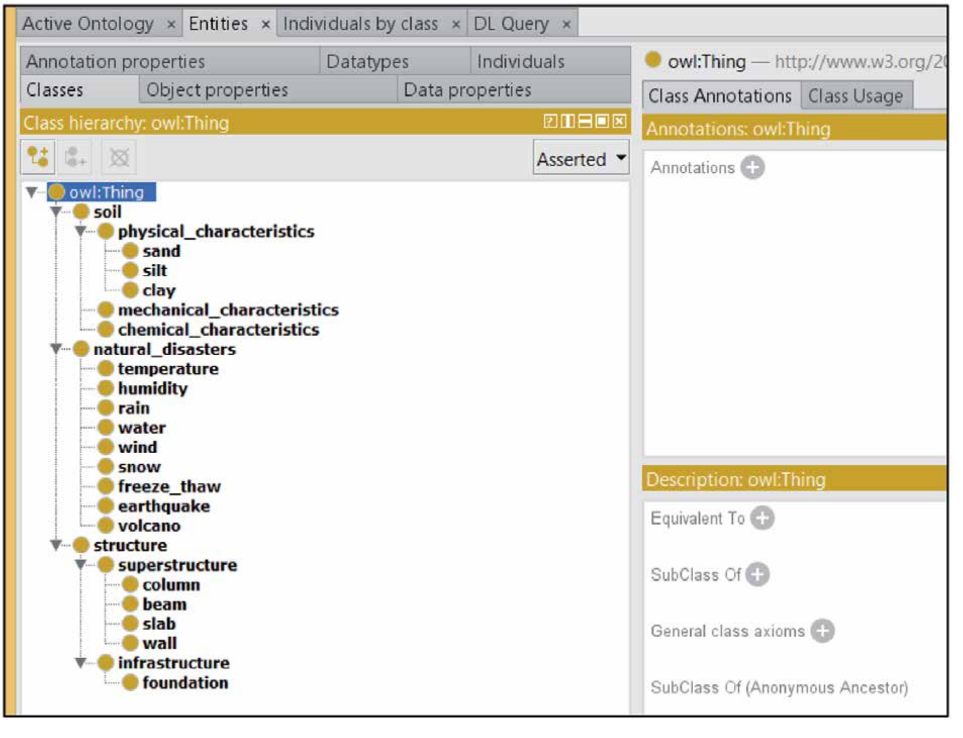

Figure 1.
The OSSIWAE ontology.

The impedance in Soil-Structure Interaction is the most important parameter, which represents the interaction between the structure and the soil, for this, this parameter is represented by relations in order to clarify the knowledge in ontology. Then these relationships used to capture useful information by sensors installed in different places in the soil and the structure. We have used the following four relationships for linking between the classes of ontology: soil liquefaction, Structural vibration, soil compaction and Structure dilatation.

4. Proposed architecture of a knowledge base of natural disasters

The proposed architecture is illustrated in **Figure 2**. The conceptual architecture is made up of four parts:

The first part is the Information gathering; this part uses GIS to map areas and so uses electronic sensors to collect information. It uses a set of sensors installed in

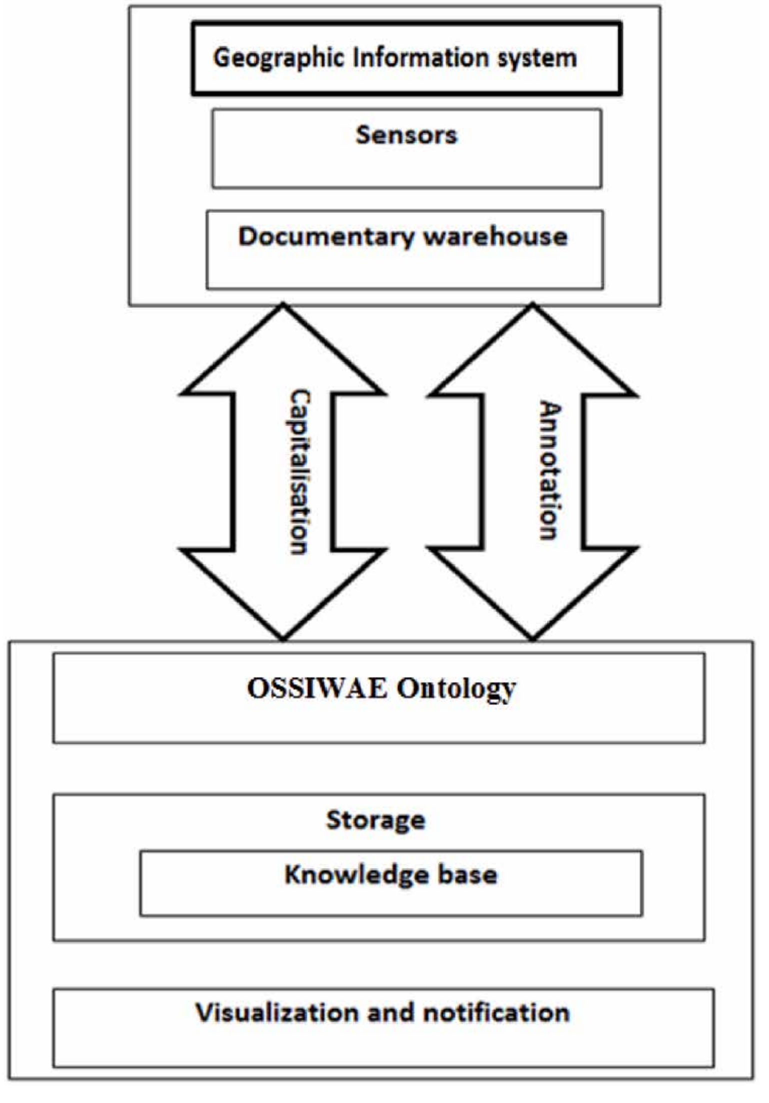

Figure 2.
Architecture of a knowledge base of natural disasters.

well-defined places in the structure and in the Soil. These sensors can communicate with each other. The collection of information also uses a documentary warehouse for the collection of documents (expert report, opinions, etc.). These documents are annotated by the ontology in order to extract additional information. Documentary warehouse allows experts to record the events produced in order to make the right decisions. In the previous work [23, 24] we have demonstrated the importance of annotating documents handled during the process of decision making.

The second part is the knowledge base, it is used to store the information sent automatically by the electronic sensors (high water level, vibration, temperature, humidity, rotation, acceleration, inclination, force, etc.) and linked this information to graphical information mapped by GIS and information annotated by experts. **Figure 3** gives the class diagram of the knowledge base. The validation phase for the classification of knowledge according to the criteria of value and veracity of knowledge for the group is important. According to [25] there are three categories of knowledge among the knowledge to be certified (validated, not validated and rejected), we used these three categories as annotative acts between the actors of the group to certify and validate their knowledge and the data collected. In this function the following annotative acts are used: a validated annotation, a rejected annotation and an invalidated annotation.

The third part is the OSSIWAE ontology. The ontology used to conceptualize the interaction between structure and soil. The ontology is used to semantically capture the information sent by the sensors and also to annotate the documents stored in the document repository. The OSSIWAE ontology described in Section 3.1.

The fourth part is the user interface, which allows users to view the evolution in real time of the graphs for each mapped area and send them the Short Message (SMS) of notifications to mobile phones for decision makers to inform themselves

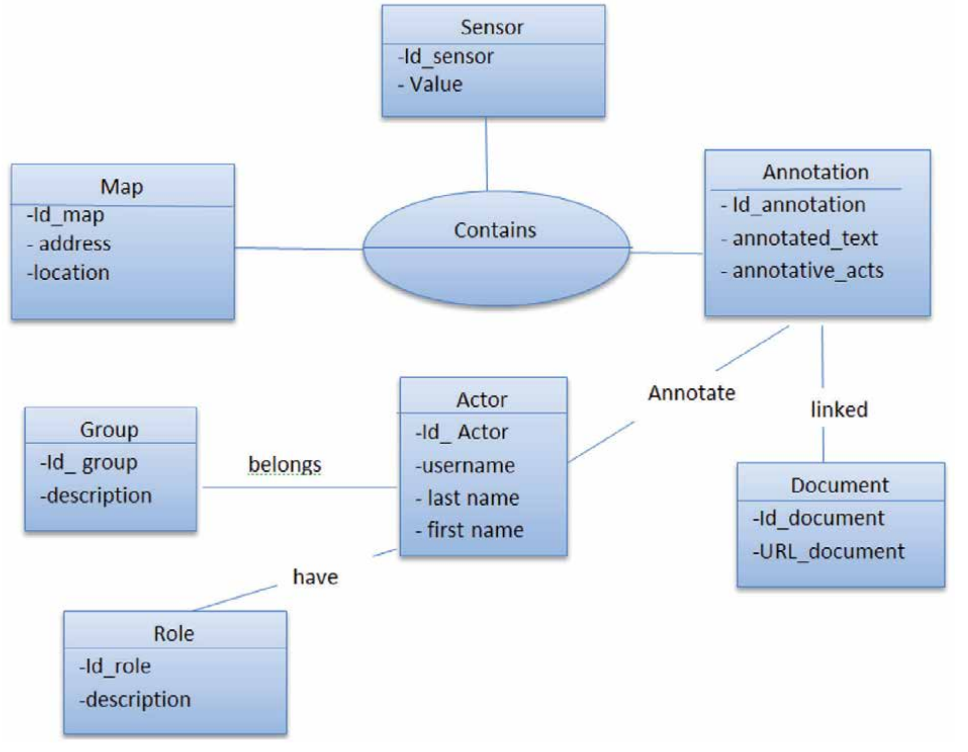

Figure 3.
The class diagram of the knowledge base.

and take the necessary measures. And also allows fully understanding, analyzing and estimating this phenomenon by experts.

5. Implementation

The main technologies used to develop this application are: jQuery it is a JavaScript library is used to facilitate the development of user interface. PHP language it is used for manipulation of data in the data base. Asynchronous JavaScript and XML (AJAX) is used to send data to server. MySQL server it is used for the creation of the database to store the information.

For the Geographic Information system (GIS) a web cartographic server was developed which allows for managing maps and data. This server makes it possible to share data and to link with the data via sensors and annotations. The HTML canvas element it is used to draw graphics, with using the JavaScript to add annotation, draw a line, draw a circle, draw a Text… on cards.

For the electronics system, the Arduino nano and uno with the different sensors used to capture the data in real time. The programming software of the Arduino board is used, which serves as a code editor in a language close to C to program this part.

For document annotation, an annotator was developed to annotate word and excel documents via ontology. These annotations are linked with the areas mapped by the GIS and the information collected by the sensors.

A model for building a structure three-story was prepared and then put on the soil. Vibrations are applied to simulate data collection via sensors (**Figure 4**) then these data are processed and display it in a web page to link with the relevant geographic map.

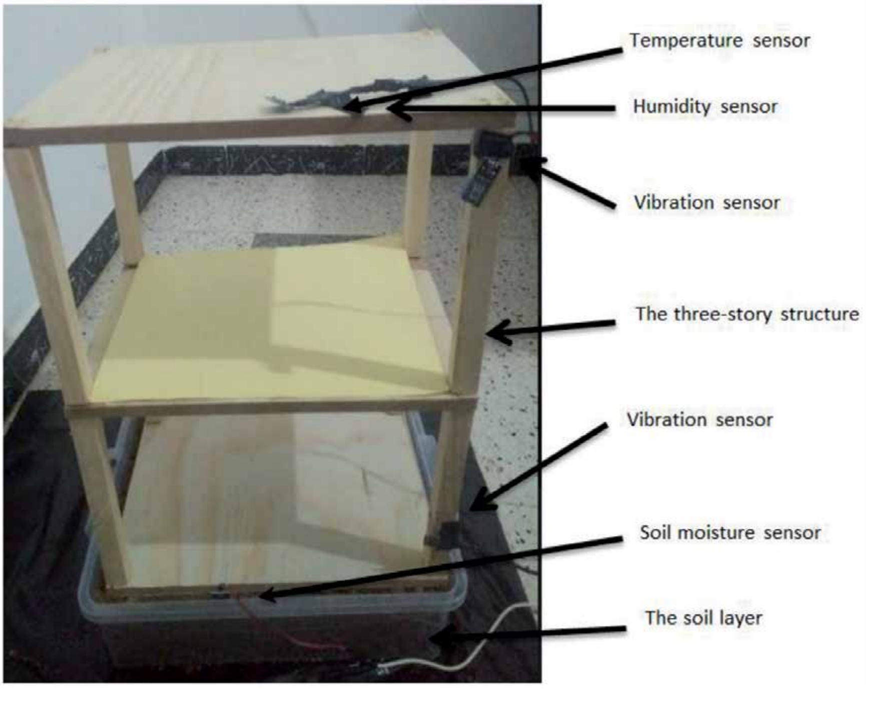

Figure 4.
Model of soil-structures interaction with sensors.

6. Conclusion

The risk management of natural disasters becomes a necessity to take the necessary measures at the right time and in the right place and for the construction of new structures weak and resistant to natural disasters. This chapter presents a conceptual architecture based on ontology, embedded systems and Geographic Information system for the creation of a knowledge base on the phenomenon of soil-structures interaction with the connections of external agents in real time in order to fully understand, analyze and estimate this phenomenon by experts. Considering that the ontologies play a critical role to solve the problem of the heterogeneity of external and multi-source information. An Ontology of Soil-Structure Interaction With Agents External (OSSIWAE) was proposed for managing and integrating the data coming from different sources of information (GIS, satellites, electronic sensors and comments from experts). To validate this architecture, a web platform was developed in the context of Internet of Things (IoT), which supports the different technologies used. Then, a case study is conducted on a prototype of a model for building a structure three-story to simulate data collection. Given the large number of mapping areas, in this chapter some sensors are installed. As a perspective we want to increase the number of sensors to capture other parameters.

List of acronyms and abbreviations

IoT	Internet of Things
GIS	Geographic Information system
OSSIWAE	Ontology of Soil-Structure Interaction With Agents External
SAR	Synthetic Aperture Radar
EO	Earth Observation
SDSS	Spatial Decision Support System
AHP	Analytical Hierarchy Process
ORFFM	Ontology for River Flow and Flood Mitigation
AJAX	Asynchronous JavaScript and XML
HTML	HyperText Markup Language
SMS	Short Message Service

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Chapter 5

Comparison of Cross-Entropy Based MCDM Approach for Selection of Material in Sugar Industry

Syed Abou Iltaf Hussain, Himanshu Chandra and Uttam Kumar Mandal

Abstract

One of the major problems faced in engineering is the selection of the material which is most suitable for the product. Material selection from a large number with diverse mechanical, physical and chemical properties and choosing the best material which is the most satisfying for making the job is a very complex process. Material selection is important as it determines durability, reliability and cost of the product. Selection of suitable material which gives maximum performance with minimum cost is often observed to be a multi-criterion decision-making (MCDM) problem with different objectives. This chapter presents an integrated approach to select the suitable material to be used as base of induction cookware which can give maximum performance with minimum cost. In the integrated approach the weights of the criteria are computed using the cross-entropy method and ranking of the alternatives is done using the different MCDM methods. The methods are further illustrated with an example and the result obtained from different cross-entropy MCDM methods are compared for finding the most suitable method for serving the purpose.

Keywords: Cross Entropy method, Different MCDM methods, Comparison, Spearman's Rank correlation coefficient, Coefficient of Determination

1. Introduction

In this present techno-economic scenario material selection poses one of the major challenges in industries. Selection of the improper material adversely affects the reputation of an organization and also reduces the profitability. Selection of the proper material is a step in the process of product design where it aims in increasing the performance with minimum cost. Material selection is also important from the perspective of sustainability of industries [1, 2].

In the recent years, traditional materials were replaced by more advance materials due to their mechanical and chemical properties. The materials were used for manufacturing from complex geometry to long lasting products. With the large number of readily available materials the process of material selection is done with the help of multi-criteria decision-making (MCDM) process.

Moreover, MCDM is the study concerned with optimal decision making and the modelling of deterministic systems. Its focus in the interdisciplinary field of application, clutching a wide range of quantitative techniques. Whereas, Industrial Engineering is about the enhancement, refinement, and installation of integrated systems of personnel, material, and equipment. Industrial engineering is also about processing of the information. MCDM integrated industrial engineering provide a rational approach to engineering and managerial problem solving through deliberate application of scientific methods. In the MCDM model, the set of available materials are called alternatives among which the best material is selected on the basis of the certain properties called criteria.

In practical scenario MCDM addresses the performance of different alternatives on the basis of information and resource limitations of a company or industry or organization, working towards the establishing of beneficial policies. The function of the decision maker is to guide the engineers, managers and administration by processing the information available in the industries.

1.1 Entropy based Multi-Criteria Decision Making (MCDM)

In today's hi-tech engineering world, MCDM have evolved as one of the most important tools of decision making in a complex situation. MCDM also help in taking decisions in a situation where there is little or no chance of any altercation. In the present socio-economic world where a decision of selecting the best is effected by a large number of criteria, MCDM plays a very important role in such aspects. Decision making is done based on various criteria which might be important equally or not. From the last statement it can be said that every criterion are weighted which help the decision maker in taking the decision. One of the major problems faced in MCDM problem is the assigning of weights to the criterion. Some of the different techniques of assigning weights to the criteria are 5Ws and H method, fuzzy method, cross-entropy method etc. Cook [3] and Vesna Čančer [4] used 5Ws and H technique; Kumar and Gag , Amiri *et al.*, Kemal Vatansever and Yiğit Kazançoğlu , Keshavarz Ghorabaee *et al.*, used fuzzy for determining the weights of different criteria. ZOU Zhi-hong *et al.* [5], Wei Liu and Jin Cui [6], Chia-Chang Hung and Liang-Hsuan Chen [7], Farhad Hosseinzadeh Lotfi and Reza Fallahnejad [8], Yuguo Qi *et al*. [9], Peiyue *et al.* [10], Kshitij Dashore *et al.* [11], Deepa Joshi and Sanjay Kumar [12], Anhai Li *et al.* [13], Harish Garg *et al.* [14], Zhang-peng Tian *et al.* [15], Elham Ebrahimi *et al.* [16], Harish Garg [17], Javier Martínez-Gómez *et al.* [18] used cross-entropy method for determining the weightage of the criteria for solving MCDM problem.

1.2 Application of MCDM in material selection

With increasing choice of materials and large number of manufacturing process available to the designers, the selection of an optimal material have become more complex and more challenging than before [19]. In order to address the issue of material selection researchers like Ashby proposed MCDM as one of the best tools. Ashby *et al*. [20] have identified three material selection strategies which are (a) free searching based on quantitative analysis, (b) checklist/questionnaire based on expertise capture, and (c) inductive reasoning and analog procedure. A large number of literature exist for selecting the suitable material for a product. Based on the Ashby work a lot of researches is carried out in this respect. Out of which some are reviewed. Milani *et al.* [21] studied the ways in which different criteria transformation techniques effects the result in TOPSIS method for selecting gear material. In the year 2006, R.V. Rao and J.P. Davim [22] developed a combined AHP-TOPSIS model for selecting material to be used in non-heat-treatable cover material. Shanian A and Savadogo O. [23, 24], successfully applied TOPSIS in selecting material for a particular product design with maximum performance and minimum cost. Again in the same year Shanian A and Savadogo O. implemented the ELECTRE-I method for selecting material to be used in Bipolar Plates for Polymer Electrolyte Fuel Cells Applications. In this chapter, ELECTRE-I gave the same result with or without negative criterion. In 2008, Sharif Ullah and Harib [25] proposed an intelligent method for selecting material where informations regarding the design configurations, working conditions and design-relevant information were not known. According to Karande and Chakraborty [26], material selection is also an important factor for a product to strive in the competition in market because improper material selection may result in failure to fulfil customer and manufacturer requirements. In 2013a, 2013b, Shankar Chakraborty and Prasenjit Chatterjee [27, 28], observed that in case of material selection the ranking performance of VIKOR is far better than the TOPSIS and PROMETHEE methods. In the chapter the authors also concluded that the best and the worst is solely dependent on the weights of the criteria. They further added that time for selecting the most suited material could be reduced by identifying the criterion with maximum weight. In their second chapter COPRAS and ARAS methods were termed as the most appropriate method for gear material selection as the result obtained from both the method are quite similar and also both the techniques are fool proof techniques.

1.3 Motivation

Decision making theory plays a vital role where decisions have to be taken in cases the performance parameter differs from each other by a very small margin. There are different decision making methods which takes in account different mathematical concepts such as the best alternative is one which in a best way can compromise the conflicting scenario (VIKOR), the alternative which is farthest from the non-benefit criteria is the best alternative (MOORA), the alternative having the highest relative weightage for the benefit criteria is the best alternative (COPRAS) and so on. Hence when a decision is taken with different MCDM methods, the result may differ for each method. Alternative which is best by one method may not be the best by some other method. In problems like material selection each wrong decision is associated with some penalty. For such cases the weights of the criteria are so calculated that it reduces the penalty for not choosing the actual best alternative instead of choosing the predicted best alternative. Moreover, selecting materials in sugar industry is well known MCDM problem. But, the literatures fail to answer which method to apply for material selection and the risk involved for choosing a method. The literatures also do not explain the accuracy degree to which two or more selection methods would agree to the same decision. The main aim of this chapter is find a material suitable for manufacturing equipment in the sugar industry by different MCDM methods and also to find the degree to which all the methods would agree to the decision.

1.4 Novelties

Lot of researchers have worked in the field of MCDM and developed novel approaches for precisely selecting alternatives. Some of the novelties developed in this chapter are as follows:

1. Application of CE integrated MCDM approaches are used for selecting material in sugar industry.

2. Comparison between the results obtained from CE based MCDM techniques.

3. Based on the comparison a predictive model is developed that can forecast the result by different CE integrated MCDM approaches.

1.5 Structure of the chapter

The chapter is organized into 7 sections. The first section is introduction which describes the importance of the material selection and the comprehensive literature related to the topic. Section 2 describes the preliminary concept of the methodologies used for the study. Section 3 summarises the steps of the MCDM methods and section 4 describes the case study that is considered for the present study. Section 5 is the comparative study of the result obtained from various MCDM methods. Section 6 discusses the summary of the findings and section 7 concludes the chapter.

2. Preliminaries

2.1 Multi-criteria decision making (MCDM)

Definitions 1: Decision can be defined as the rationale conclusions after evaluating the circumstances.

Definition 2: In perspective of cognitive science, selection of a particular action or a certain belief that is a subset of the alternatives is knows as Decision Making.

The process of selection of an action that belong to the subset of the alternatives is done by considering all criteria's which can either alter the judgement of same or dissimilar extent is called as Multi-Criteria Decision Making. In MCDM technique, the existing possibilities are the subset of alternatives or else, these are the choices out of which the finest possibility is to be selected by analysing various factors which could influence the outcome. All the alternatives are ranked in ascending order beginning from the finest to the worst and on the basis of factors which can influence the conclusions, these factors are known as criteria. Criteria can be defined as the factors which have direct influence on decision. In MCDM technique, there are number of criteria and which each of them effects the judgement and conclusion either to the similar or dissimilar extent.

2.2 Steps involved in decision making

2.2.1 GOFER method for taking decision

During 1980s, psychologist Leon Munn and some of his colleagues developed a technique called GOFER specifically for decision making [29]. The acronym for GOFER stands for a 5 decision making steps.

G: Goal - Selection of material
O: Options - Set of readily available materials
F: Facts - Performance with respect to the criteria
E: Effect - How the material selection are effected?
R: Review - Reviewing distinct facts and data associated to the options.

2.2.2 DECIDE method for taking decision

In the year 2008, another decision making technique was developed by Kristina Guo known as DECIDE [30]. This method consist of six parts namely:

D: Define the problem i.e. selection of material.

E: All the criteria and factors are established on basis of which the decision is made i.e. enlisting the criteria.

C: Enlisting the various available materials.

I: Discard the materials having high cost to benefit ratio.

D: A plan is developed for selecting the finest alternative.

E: Select the best material.

2.2.3 Working principle

All MCDM methods share some similar working principles upto certain extent, which are as follows:

1. Selection of Criteria:
    - All noted criteria must be in correlation to the alternatives.
    - The criteria are to be well-prepared along with the decision.
    - The criteria must have some relevance either equally or alike.
    - The criteria must not be dependent on each other in any sort of way.
2. Selection of Alternatives:
    - The alternatives which have been selected must be real in nature.
    - The alternatives which have been selected must be available.
3. Selection of method to provide weightage to the criteria:
    - Outranking Method – An outranking relation is to be built using a series of pairwise assessments of the alternatives.
    - Compensatory Method – Here, strengths and capabilities are embraced over the weakness.

2.2.4 Flowchart for decision making

See **Figure 1**.

2.3 Cross entropy (CE) method

In problems related to MCDM technique, the hardest job is to accurately assign weights to the various criteria with respect the ranked alternatives. Therefore, Cross Entropy Methods is often used to assign weights to the criteria. The cross entropy methods is nothing else but a generic form of a well-known Monte Carlo simulation that is used in complex estimation and optimization problems for error minimization. Y. R. Rubinstien was the first to suggest this approach in 1999 by extending his previous work done in 1997.

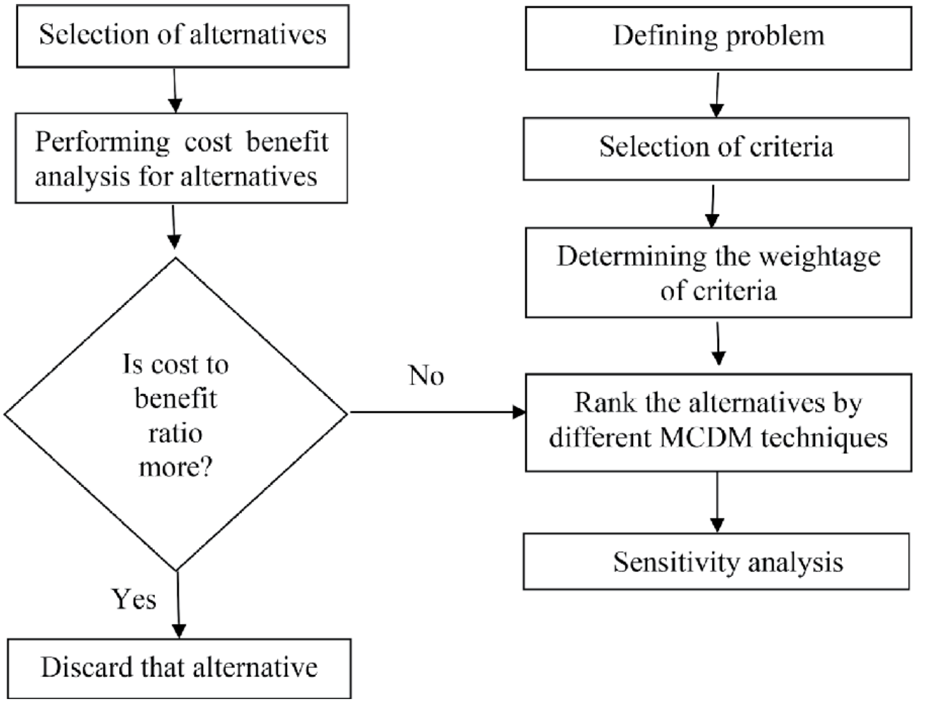

Figure 1.
Flowchart for decision making.

2.3.1 Algorithms for cross entropy method

Step 1: Feature weight β_{ij} is calculated for i^{th} alternative and j^{th} criterion as

$$\beta_{ij} = \frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}^2}, (1 \le \mathrm{i} \le \mathrm{m}, 1 \le \mathrm{j} \le \mathrm{n})$$

Step 2: The output entropy ε_j of the j^{th} factor

$$\varepsilon_j = -\kappa \sum_{i=1}^{m} \left(\beta_{ij} ln \beta_{ij}\right), (1 \le \mathrm{j} \le \mathrm{n})$$

$$\kappa = \frac{1}{\ln m}$$

Step 3: Calculation of variation coefficient of j^{th} factor ξ_j

$$\xi_j = \left|1 - \varepsilon_j\right|$$

Step 4: Calculation of weight of the entropy w_j

$$w_j = \frac{\xi_j}{\sum_{j=1}^{n} \xi_j}$$

2.4 Application of CE based MCDM techniques in engineering problem

Cross Entropy is an important method for determining the weights of the criteria. The penalty for selecting a non-best alternative over the best is less when criteria are weighted using the Cross Entropy method. In the year 1997, Y. R. Rubinstein first developed an adaptive variance minimization algorithm for estimating probabilities of rare events for stochastic networks which was later in the year 1999 was modified for solving combinatorial optimization problems. Then later the Cross Entropy method was used along with the MCDM problems for minimizing the penalty for not choosing the best alternative.

A lot of researches have been conducted where Cross Entropy method is used along with the MCDM method for decision making. Some of the literatures are reviewed and presented. In the year 2006, ZOU Zhi-hong *et al*. [5] applied CE method to determine the weightage of different criteria for evaluating water quality in a fuzzy environment. Wei Liu and Jin Cui [6], applied CE method along with MCDM model for evaluation of sustainable development of China's sport. Farhad Hosseinzadeh Lotfi and Reza Fallahnejad [8], proposed a method where entropy method can be used for for weighting different criteria of non-deterministic data such as interval valued data. Chia-Chang Hung and Liang-Hsuan Chen [7] developed a fuzzy TOPSIS decision model where weights of the criteria are calculated with the entropy method and the alternative are represented by intuitionistic fuzzy sets. In the year 2010, Yuguo Qi *et al.* [9] proposed a model where evaluation of power network structure is done by entropy based MCDM method under fuzzy environment. This method is a combination of both subjectivity and objectivity, and provides good platform for quantitative as well as qualitative analysis. Kshitij Dashore *et al*. [11] compared the results obtained from different MCDM techniques where the weights of the criteria are evaluated using CE method. The authors concluded that the same best alternative is obtained from TOPSIS, SAW and WPM methods.

2.5 Recent work of CE based MCDM

Some of the recent CE based MCDM works that have been reviewed are also presented in this chapter. In the year 2015, Anhai Li *et al*. [13] in their chapter applied entropy based MCDM methodsfor optimal selection of cutting tool material. Harish Garg *et al*. proposed a CE based Multi-Attribute Group Decision Making (MAGDM). The model thus proposed gives a useful way for dealing fuzzy MAGDM within attribute weights efficiently and effectively. Zheng-peng Tian *et al*. [15], developed a CE based decision making model to deal with interval valued neutrosophic sets. In the year 2016, Elham Ebrahimi *et al*. [16] compared the result obtained from fuzzy COPRAS and CE-COPRAS to evaluate the customer-company relationship. Javier Martínez-Gómez *et al*. [18] developed a MCDM model which includes compromised weighting method composes of Analytical Hierachy Process and Entropy method. The authors successfully applied CE- based MCDM method for material selection.

3. Different CE-MCDM techniques

From a set of alternatives, best quantitative solution is evaluated using ranking solution and is provided by MCDM process. In this research work, cross entropy method is applied due to the reason that is highly reliable for measuring information and deliver good accuracy while evaluating the weights of the feature attribute. MCDM problem can thus be expressed as a matrix:

$$M = \begin{matrix} & \begin{matrix} C_1 & C_2 & C_3 & & C_n \end{matrix} \\ \begin{matrix} A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{matrix} & \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & a_{m3} & \cdots & a_{mn} \end{bmatrix} \end{matrix}$$

$$W = \begin{bmatrix} w_1 & w_2 & w_3 & \cdots & w_n \end{bmatrix}$$

Here, A_1 , A_2 , A_3 … … A_m are the alternatives which are available and supposed to be ranked by decision maker C_1 , C_2 , C_3 … … C_n are the criteria which will govern ranking of the alternatives. a_{ij} shows the performance of alternative A_i on the basis of C_j and w_j is the weight of the criterion.

3.1 The complex proportional assessment (COPRAS) method

In 1994, Zavadskas and Kaklauskas presented the COPRAS method which is a reference ranking method for ranking different alternatives [28]. Alternative's performance is primarily considered in COPRAS method with respect to various criteria. Therefore, the method aims to select the finest decision considering the ideal-best as well as the ideal-worst solutions. Steps used to rank those alternatives by using COPRAS method are as follows:

Step 1: Calculation of normalized decision matrix (n_{ij}):

$$n_{ij} = \frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}}$$

Step 2: Calculation of weighted normalize decision matrix (W_{ij}):

$$W_{ij} = n_{ij} * w_j$$

Where w_j is the weightage of criterion C_j.

Step 3: Calculation of S^+ and S^-:

S^+ and S^- are the summation of weighted normalized value that are evaluated for benefit criteria as well as non-benefit criteria.

$$S_i^+ = \sum_{j=1}^{n} W_{ij}.(\mathrm{i} = 1, 2, 3 \ldots \mathrm{m})$$

Where W_{ij} is the weighted normalize elements for all the benefit criteria

$$S_i^- = \sum_{j=1}^{n} W_{ij}.(\mathrm{i} = 1, 2, 3 \ldots \mathrm{m})$$

Where W_{ij} is the weighted normalize elements for all the non-benefit criteria

Step 4: Evaluating relative weightage of each alternative Q_i:

$$Q_i = S_i^+ + \frac{\sum_{i=1}^{m} S_i^-}{S_i^- \quad \sum_{i=1}^{m} \frac{1}{S_i^-}}$$

Step 5: Determining the priority order (Pr_i):

$$Pr_i = \frac{Q_i}{max \quad Q_i}$$

Maximum value of Pr_i is given maximum priority and ranked 1, second largest value of Pr_i is given second priority and ranked 2 and so on.

3.2 The MOORA method

MOORA (Multi Objective Optimization on the Basis of Ratio Analysis) was developed by Brauers in 2004 for solving different complex and conflicting decision matrix. Performance measures of alternatives with respect to different criteria are represented by the decision matrix of MOORA. Steps governing the ranking of different alternatives by MOORA methods are:

Step1: Calculation of normalized decision matrix (n_{ij}):

$$n_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}}$$

Step 2: Calculation of weighted normalize decision matrix (W_{ij}):

$$W_{ij} = w_j \times n_{ij}$$

Step 3: Evaluating of Priorities (Q_i):

$$Q_i = \sum_{j=1}^{n} W_{ij}$$

Priorities is the difference between the sum of benefit criteria and non-benefit criteria.

Step 4: Ranking of alternatives:

Maximum value of the variable Q_i is provided the maximum priority and ranked 1, second largest of Q_i is provided the second priority and ranked 2 and so on.

3.3 The VIKOR method

VIKOR method, developed for evaluating decision making problems with conflicting as well as non-commensurable criteria by Serafim Opricovic. This method assumes accepts compromise with conflicting resolution. VIKOR methods ranks various alternatives and evaluates the solution called as compromise which is the closest value to the ideal.

Step 1: Calculation of $f_j^* \ and \ f_j^{\Lambda}$

$$f_j^* = Min(a_{ij}), (\ j = 1, 2, 3, \ldots n)$$

$$f_j^{\Lambda} = Max(a_{ij}), (j = 1, 2, 3, \ldots n)$$

Where a_{ij} stands for elements of decision matrix

Step 2: Calculation of relative matrix (R_{ij})

$$R_{ij} = \frac{f_j^* - a_{ij}}{f_j^* - f_j^{\Lambda}}$$

Step 3: Calculation of weighted normalized decision matrix (W_{ij})

$$W_{ij} = R_{ij} \times w_j$$

Step 4: Calculation of γ_j by the concept of Manhattan distance.

$$\gamma_j = \sum_{j=1}^{n} W_{ij}, (i = 1, 2, 3, \ldots m)$$

Step 5 : Calculation of δ_j by the concept of Chebyshev distance.

$$\delta_j = Max(W_{ij}), (i = 1, 2, 3 \ldots m)$$

Step 6: Calculation of priority values ρ_j.

$$\rho_j = \frac{V(\gamma_j - \gamma^*)}{(\gamma^{\Lambda} - \gamma^*)} + (1 - V)\frac{(\delta_j - \delta_j^*)}{(\delta_j^{\Lambda} - \delta_j^*)}$$

Where, $\gamma^* = min(\gamma_j)$

$\gamma^{\Lambda} = max(\gamma_j)$

$\delta_j^* = \min(\delta_j)$

$\delta_j^{\Lambda} = \max(\delta_j)$

$V = \frac{n+1}{2n}$, n is the no. of criterion

Step 7: Ranking of various possible alternatives

According to values of ρ_j, the alternative values are ranked from ascending order. Here, the smallest is the best alternative and the largest is considered as the worst alternatives.

3.4 The TOPSIS method

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was developed in 1981 by Hwang and Yoon. The primary objective of TOPSIS was to determine the finest alternatives by minimizing the positive-ideal solution's distance and maximizing the negative-ideal solution's distance [31]. All the various alternative solutions shall be ranked on the basis of their closeness to ideal solution i.e., the closest alternative to the ideal is considered as the best solution whereas, the least close alternative to the ideal is considered as the worst solution. Steps governing the ranking of the alternatives by TOPSIS method are:

Step 1: Calculation of normalized decision matrix (n_{ij})

$$n_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}}$$

Step 2: Calculation of weighted normalize decision matrix (W_{ij})

$$W_{ij} = w_j \times n_{ij}$$

Where w_j is the weight of the criterion C^j.
Step 3: Calculation of Positive Ideal Solution (P_{is}) and Negative Ideal Solution (N_{is})

$$P_{is} = \begin{cases} Max(W_{ij}), (\ j = 1, 2, 3, \ldots .n) \, for \ benefit \ criteria \\ Min(W_{ij}), (\ j = 1, 2, 3, \ldots .n) \, for \ non - benefit \ criteria \end{cases}$$

$$N_{is} = \begin{cases} Max(W_{ij}), (\ j = 1, 2, 3, \ldots .n) \, for \ non - benefit \ criteria \\ Min(W_{ij}), (\ j = 1, 2, 3, \ldots .n) \, for \ benefit \ criteria \end{cases}$$

Step 4: Calculation of separation measures (S_m^+) for P_{is} and (S_m^-) for N_{is}

$$S_m^+ = \sqrt{\sum_{j=1}^{n} (W_{ij} - P_{is})^2}, (1 \le i \le m, 1 \le j \le n)$$

$$S_m^- = \sqrt{\sum_{j=1}^{n} (W_{ij} - N_{is})^2}, (1 \le i \le m, 1 \le j \le n)$$

Separation measures are measured using Euclidean distance method.
Step 5: Calculation of relative closeness to the ideal solution (RC_{is})

$$RC_{is} = \frac{S_m^-}{S_m^+ + S_m^-}$$

Step 6: Arrangment of the RC_{is} values in descending order and ranking from the largest value to the smallest value.

3.5 The modified TOPSIS method

The Modified TOPSIS method is a revised version of the TOPSIS model. In the Modified TOPSIS model the Pis and Nis do not depends on the weighted decision matrix. Steps for ranking alternatives by Modified TOPSIS method is as follows:
Step 1: Calculation of normalized decision matrix (n_{ij})

$$n_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}}$$

Where a_{ij} is the performance of value of alternative A_i on the basis of criterion C_j.
Step 2: Calculation of Positive Ideal Solution (P_{is}) and Negative Ideal Solution (N_{is})

$$P_{is} = \begin{cases} Max(n_{ij}), (\ j = 1, 2, 3, \ldots .n) \, for \ benefit \ criteria \\ Min(n_{ij}), (\ j = 1, 2, 3, \ldots .n) \, for \ non - benefit \ criteria \end{cases}$$

$$N_{is} = \begin{cases} Max(n_{ij}), (\ j = 1, 2, 3, \ldots .n) \, for \ non - benefit \ criteria \\ Min(n_{ij}), (\ j = 1, 2, 3, \ldots .n) \, for \ benefit \ criteria \end{cases}$$

Step 3: Calculation of separation measures $\left(S_m^+\right)$ for P_{is} and $\left(S_m^-\right)$ for N_{is}

$$S_m^+ = \sqrt{\sum\nolimits_{j=1}^{n} w_j \left(n_{ij} - P_{is}\right)^2}, (1 \le i \le m)$$

$$S_m^- = \sqrt{\sum\nolimits_{j=1}^{n} w_j \left(n_{ij} - N_{is}\right)^2}, (1 \le i \le m)$$

Separation measures are measured using Euclidean distance method.
Step 4: Calculation of relative closeness to the ideal solution (RC_{is})

$$RC_{is} = \frac{S_m^-}{S_m^+ + S_m^-}$$

Step 5: Arrangment of the RC_{is} values in descending order and ranking from the largest value to the smallest value.

4. Application

4.1 Material selection in sugar industry

A few researchers and product designer have studied the failure rate in the sugar industrial equipment. From their study they have found that in India, the failure due to corrosion of the equipments' cost a sum of about US$250 million [32]. A comparison of better corrosion resistance material was done in [33]. [34] has suggested the use anti-corrosive medium such as sulphanilamide, sulphapyridine and sulphathiazole for better performance. The corrosion effect of the sugar-cane juice on the carbon steel roll was studied in [35] along with the effect of austenitic stainless steel on the welded carbon steel roll. In [36], the authors studied the characteristics and corrosion behaviour of high Chromium White Iron. [37] studied the abrasion corrosion test for Iron-Chromium-Carbon shielded metal arc wielding for its used in the sugar industry whereas [38] studied the wear mechanism ploughed by silica in sugar cane roller shell.

4.2 The problem

The problem that mostly faced by the designers is to choose the suitable material for manufacturing equipment in the sugar industry. The different materials and the selection criteria are taken from [39] which are given in the form of **Table 1**.
The different criteria used for selecting the alternatives are as follows:

1. Yield strength (C^1): Yield strength is the most important criteria for material selection. It is a positive criterion. Yield strength does not allow the equipment to deform plastically.

2. Ultimate tensile strength (C^2): It is a measure of material's toughness. It is a positive criterion.

3. % of Elongation (C^3): It is the measure to withstand the operating load. It is a positive criterion.

Alternatives	Criteria	
J4 (A^1)	Yield strength (C^1)	Ultimate tensile strength (C^2)
JSLAUS (A^2)	Percentage of elongation (C^3)	Hardness (C^4)
204Cu (A^3)	Cost (C^5)	Corrosion resistance (C^6)
409M (A^4)	Wear resistance (C^7)	
304 (A^5)		

Table 1.
List of alternatives and the selection criteria.

4. Hardness (C^4): It is the measure to resist plastic deformation due to the applied force. It is a positive criterion.

5. Cost (C^5): It is the monetary value for purchase of the material. More the cost of material, lesser the chance to buy the material. Hence, it is a negative criterion.

6. Corrosion resistance (C^6): It is the measure of the material ability to reduce the binding energy in metals. It is a positive criterion.

7. Wear resistance (C^7): It is the measure of the material ability to resist the wearing. It is a positive criterion

The value of the properties is listed in **Table 2** and it acts as the decision matrix for selection of materials.

4.3 Weighting of criteria

Criteria are weighted by Cross Entropy method (**Table 3**).

4.4 Ranking by COPRAS method

According to COPRAS method alternative 4 i.e. 409M carbon alloy is the best alternative for manufacturing of equipment in sugar industry (**Table 4**).

Alternatives	Criteria						
	C^1	C^2	C^3	C^4	C^5	C^6	C^7
A^1	382	728	48	98	112	0.16	2.75
A^2	420	790	58	97	210	0.31	2.63
A^3	415	795	55	96	120	0.05	2.50
A^4	270	455	32	78	184	0.40	4.00
A^5	256	610	60	86	89	0.01	2.59

Table 2.
Decision matrix.

Criteria	C^1	C^2	C^3	C^4	C^5	C^6	C^7
Weight	0.09872	0.09669	0.09926	0.08166	0.1261	0.4034	0.09418

Table 3.
Table of weights of the criteria.

Material	S_i^+	S_i^-	Q_i	Pr_i	Rank
A^1	0.16619	0.0197534	0.19027	70.72	3
A^2	0.23815	0.0370377	0.25098	93.28	2
A^3	0.12303	0.0211644	0.14549	54.08	4
A^4	0.25441	0.0324521	0.26906	100.00	1
A^5	0.09213	0.0156969	0.12242	45.50	5

Table 4.
Table for ranking of alternatives by COPRAS method.

4.5 Ranking by MOORA method

According to the MOORA method alternative 4 i.e. 409M carbon alloy is the best alternative for manufacturing of equipment in sugar industry (**Table 5**).

4.6 Ranking by VIKOR method

According to the VIKOR method alternative 5 i.e. 304 carbon alloy is the best alternative for manufacturing of equipment in sugar industry (**Table 6**).

4.7 Ranking by TOPSIS method

According to TOPSIS method alternative 4 i.e. 409M carbon alloy is the best alternative for manufacturing of equipment in sugar industry (**Table 7**).

Material	Q_i	Pr_i	Rank
A^1	0.292	70.94	3
A^2	0.384	93.25	2
A^3	0.216	52.41	4
A^4	0.412	100.00	1
A^5	0.167	40.65	5

Table 5.
Table for ranking of alternatives by MOORA method.

Material	γ_j	δ_j	ρ_j	Rank
A^1	0.487	0.155	0.360	3
A^2	0.808	0.310	0.870	5
A^3	0.421	0.097	0.218	2
A^4	0.605	0.403	0.815	4
A^5	0.182	0.099	0.004	1

Table 6.
Table for ranking of alternatives by VIKOR method.

Material	S_m^+	S_m^-	RC_{is}	Rank
A^1	0.183	0.123	0.401	3
A^2	0.084	0.230	0.732	2
A^3	0.266	0.058	0.179	4
A^4	0.052	0.296	0.850	1
A^5	0.297	0.052	0.150	5

Table 7.
Table for ranking of alternatives by TOPSIS method.

Material	S_m^+	S_m^-	RC_{is}	Rank
A^1	0.183	0.123	0.599	3
A^2	0.084	0.230	0.268	2
A^3	0.266	0.058	0.821	4
A^4	0.052	0.296	0.150	1
A^5	0.297	0.052	0.850	5

Table 8.
Table for ranking of alternatives by modified TOPSIS method.

4.8 Ranking by modified TOPSIS method

According to Modified TOPSIS method alternative 4 i.e. 409M carbon alloy is the best alternative for manufacturing of equipment in sugar industry (**Table 8**).

5. Comparative analysis

The 5 different MCDM techniques are compared using the Spearman's rank correlation coefficient (r_s).

5.1 Comparison by r_s

Spearman's rank correlation coefficient (r_s) is the method of comparing the ranks of alternatives obtained from different test. Using r_s, the similarity between two sets of rankings can be measured. The value of r_s usually lies between -1 and 1, where the value of 1 denotes a perfect match between two rank orderings. **Table 10** shows the Spearman's rank correlation coefficient values when the rankings of the material alternatives as obtained employing all the considered MCDM methods are compared between themselves and also with respect to the rank ordering.

From the table it is observed that the value of r_s varies from -0.9 to 1.0. The value of $r_{s\ for}$ a MCDM method when compared with itself is always 1. Hence from the **Table 10** we can conclude the rank obtained from different MCDM models may or may not be in agreement with each other.

5.2 Comparison by R^2

R^2 is a statistic that will give some information about the goodness of fit of a model. In regression analysis, the coefficient of determination is a statistical measure of how well the regression line approximates the real data points. R^2 lies in between 0 to 1. If the value R^2 is 1 then it interprets that the predicted value is exactly equal to the actual value. When the result obtained from different MCDM methods are compared with each other the value of R^2 is shown in **Table 11**.

When the results obtained from different MCDM techniques are compared using regression analysis the maximum value of R^2 obtained is 1 among different combinations of COPRAS, MOORA, TOPSIS and Modified TOPSIS and the least value is 0.81 between VIKOR and COPRAS, MOORA and Modified TOPSIS. From the **Table 11** it can be concluded that there is some penalty for choosing a wrong MCDM method for ranking of alternatives. **Figures 2–11** are the comparative figure of different MCDM techniques.

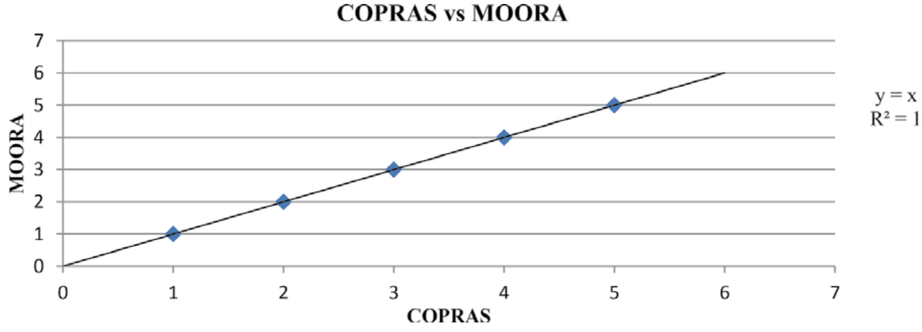

Figure 2.
Comparison of result obtained from COPRAS and MOORA.

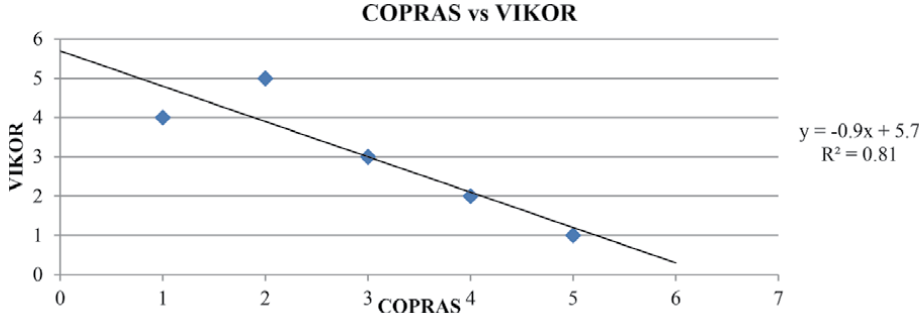

Figure 3.
Comparison of result obtained from COPRAS and VIKOR.

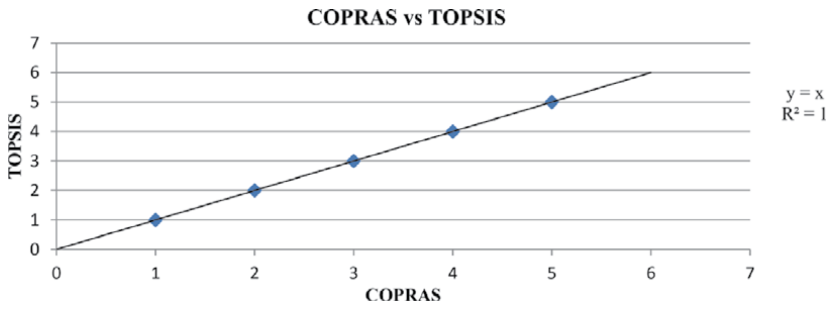

Figure 4.
Comparison of result obtained from COPRAS and TOPSIS.

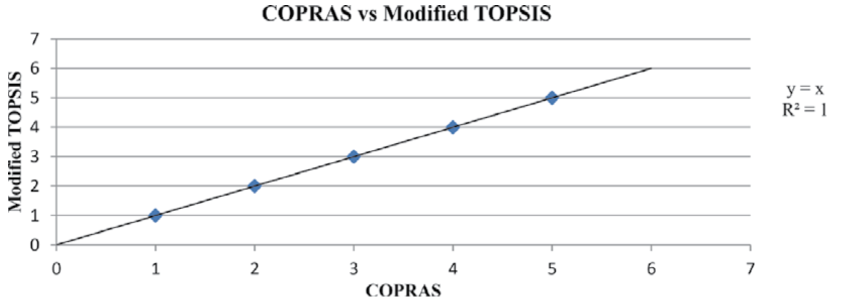

Figure 5.
Comparison of result obtained from COPRAS and modified TOPSIS.

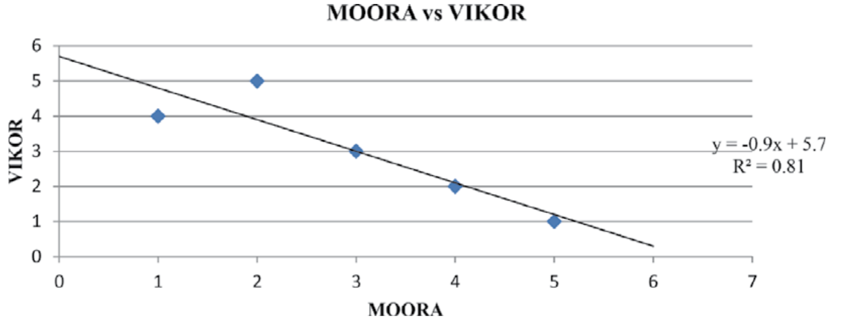

Figure 6.
Comparison of result obtained from MOORA and VIKOR.

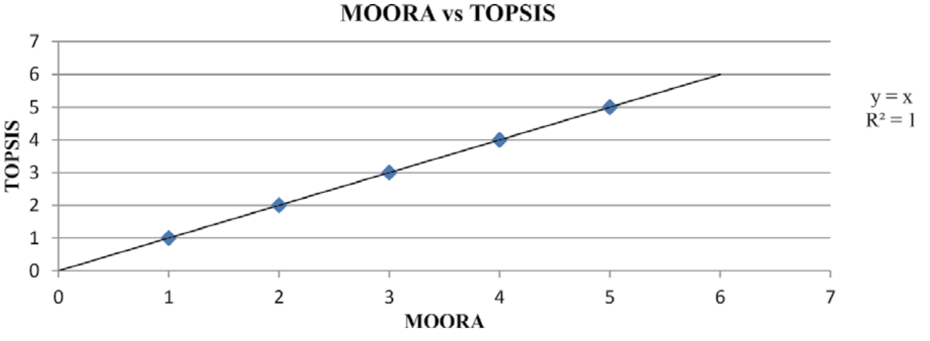

Figure 7.
Comparison of result obtained from MOORA and TOPSIS.

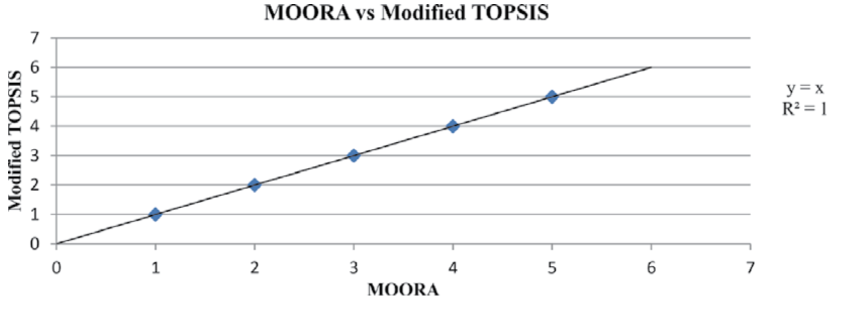

Figure 8.
Comparison of result obtained from MOORA and modified TOPSIS.

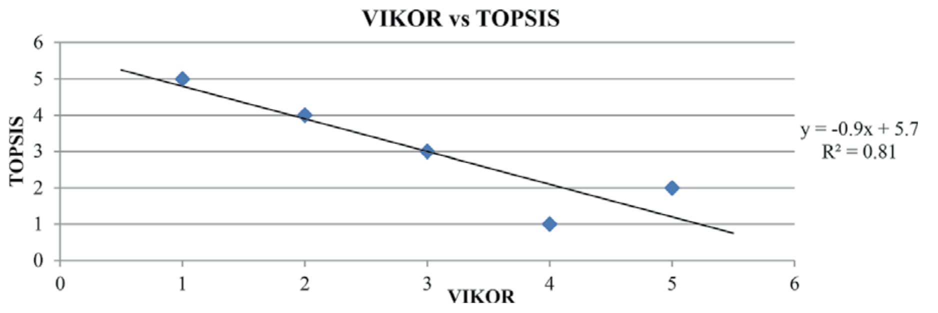

Figure 9.
Comparison of result obtained from VIKOR and TOPSIS.

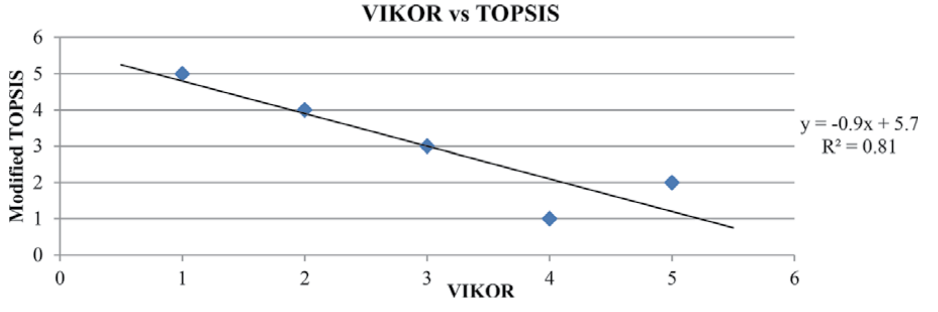

Figure 10.
Comparison of result obtained from VIKOR and modified TOPSIS.

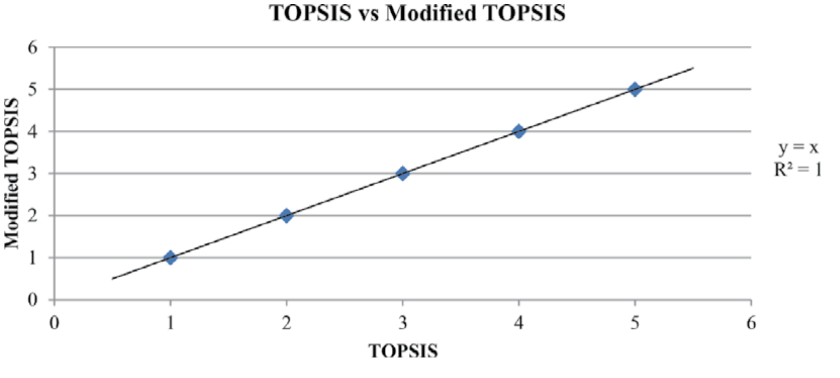

Figure 11.
Comparison of result obtained from TOPSIS and modified TOPSIS.

6. Discussion

As the weights of criteria is the most important parameter for the decision maker to choose the best alternative from a bunch of alternatives. So, in order to compute the best alternative, different integrated cross entropy based MCDM are implemented. The result obtained from different MCDM techniques is then compared with the existing result [39]. The result thus obtained from VIKOR method matches with the existing literature whereas the result obtained from other methods fail to match. From the **Table 9** and **Figure 12**, it was observed that the 4 out of the 5 Multi-Criteria Decision Making methods except VIKOR gives exactly the same result. Hence, it is validated and it can be conclude that 80% of the time alternative 4 is the best alternative for the given problem. But, result obtained from VIKOR

Material	COPRAS	MOORA	VIKOR	TOPSIS	Modified TOPSIS
A^1	3	3	3	3	3
A^2	2	2	5	2	2
A^3	4	4	2	4	4
A^4	1	1	4	1	1
A^5	5	5	1	5	5

Table 9.
Ranking of alternatives by different MCDM methods.

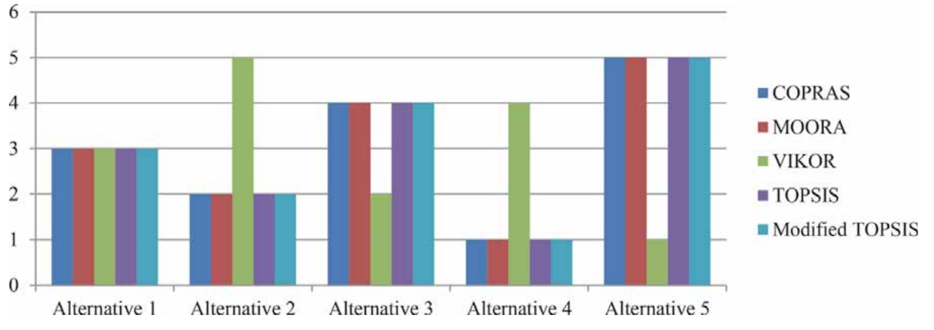

Figure 12.
Ranking by different MCDM methods.

	COPRAS	MOORA	VIKOR	TOPSIS	Modified TOPSIS
COPRAS	1	1	-0.9	1	1
MOORA		1	-0.9	1	1
VIKOR			1	-0.9	-0.9
TOPSIS				1	1
Modified TOPSIS					1

Table 10.
Spearman's rank correlation coefficient.

matches with the [39]. Therefore, a need of comparative analysis arose. The different cross entropy based MCDM methods are compared using Spearman's Rank Correlation Coefficient. From the comparative analysis, the value of r_s is tabulated in the **Table 10**. The regression coefficient value R^2 is tabulated in **Table 11**. From both the table it was found that the result obtained from the VIKOR method strongly disagrees with the result that obtained from the COPRAS, MOORA, TOPSIS and modified TOPSIS. Whereas the result obtained from COPRAS, MOORA, TOPSIS and modified TOPSIS are a perfect match. The reason behind this is that ranking of alternatives totally based on the values of the criteria of the alternatives. If the values of the criteria are changed then there is huge probability of the change in rank of the alternatives.

6.1 Benefits of the present study in industrial information

Benefits of implementing the present study in the industry

	COPRAS	MOORA	VIKOR	TOPSIS	Modified TOPSIS
COPRAS	1	1	0.81	1	1
MOORA		1	0.81	1	1
VIKOR			1	0.81	0.81
TOPSIS				1	1
Modified TOPSIS					1

Table 11.
Table of value of R^2.

- Decisions regarding operational research could be made with confidence.
- The present study can provide opportunities for improvement.
- Archive critical historical data for analysis and reference
- When everyone has unfettered access to the exact and precise predictive model then decision could be taken easily and in short duration which shall act in the favour of the industry.

7. Conclusion

In the present study, an approach to select the best material from a bunch of materials under different criteria is implemented. Although many researches have been conducted in this field, yet no literature exist which can pin point the method to be used for a certain problem. In the present study with the aim of choosing the best alternative, the criteria are weighted using the cross entropy method. Based on their weights the alternatives are ranked and it was observed that the ranking of alternatives is the same for 4 methods out of the 5. From the present study it can be concluded that the alternative 4 i.e 409M carbon alloy is the best alternative.

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List of abbreviations

MCDM	Multi-criteria decision-making
MAGDM	Multi-Attribute Group Decision Making
AHP	Analytical hierarchy process
CE	Cross entropy
COPRAS	Complex Proportional Assessment
MOORA	Multi Objective Optimization on the Basis of Ratio Analysis
VIKOR	VlseKriterijumska Optimizacija I Kompromisno Resenje
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution

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Chapter 6

Plithogenic SWARA-TOPSIS Decision Making on Food Processing Methods with Different Normalization Techniques

Nivetha Martin

Abstract

Decision making (DM) is a process of choosing the optimal alternative with the maximum extent of criteria satisfaction. The challenging aspect in making optimal decisions is the suitable choice of multi-criteria decision-making (MCDM) methods that consider the initial input as the expert's opinion on criteria satisfaction by the alternatives. This initial decision-making matrix representation discriminates MCDM as fuzzy, intuitionistic, neutrosophic to handle the decision-making environment that is characterized by uncertainty, impreciseness, and indeterminacy, respectively. A generalized kind of representation by plithogenic sets optimizes the decision-making risks. This chapter aims in developing SWARA-TOPSIS with plithogenic representations and discusses the efficiency of this integrated approach over the method of TOPSIS with equal criterion weight. A comparative analysis of four different normalization techniques is likewise made. The proposed plithogenic integrated MCDM model is validated with the decision making on four food processing methods. The final ranks of the alternatives are also compared under the proposed plithogenic SWARA-TOPSIS and TOPSIS models with different normalization techniques. The results witness the efficiency of the proposed model over the existing models.

Keywords: optimality, MCDM, SWARS-TOPSIS, plithogeny

1. Introduction

Multi-criteria decision-making (MCDM) methods are classified into multi-attribute decision-making and multi-objective decision-making in which the former determines the optimal alternatives and the latter finds the optimal alternatives that optimize the objective. The MCDM methods comprise a sequence of steps to derive the optimal solution to the decision-making problem. DM is the system of choosing the best alternative satisfying all the criteria to a great extent with the expert's assist, but the crucial thing is finding the criterion weight. At some circumstances, the criterion weights are assumed to be equal but it is not so in all the cases. The criterion weight states the significance of criteria and henceforth, the calculation of criterion weight is very essential. There are many methods to find the criterion weights such as analytic hierarchical process (AHP), analytic network process (ANP), best worst method (BWM), full consistency method (FUCOM), and stepwise weight assessment ratio analysis (SWARA). The method of SWARA appears to be simple and flexible in comparison with other methods of determining the criterion weight based on human expertise and it has several applications in prioritizing sustainability indicators of energy systems [1]. The method of TOPSIS (the technique for order of preference by similarity to ideal solution) is commonly used to rank the alternatives as it yields the best results in comparison with other methods and it has been discussed in a fuzzy environment by Neelima et al. [2] and Ansari et al. [3]. Babak et al. [4] and Houssine et al. [5] discussed TOPSIS under intuitionistic fuzzy and neutrosophic [6] environments.

The method of SWARA was used in combination with crisp COPRAS [7], fuzzy COPRAS [8], crisp VIKOR [9, 10], neutrosophic VIKOR [11], WASPAS [12], Delphi [13], ARAS, GRA [14], TOPSIS in different decision-making setting. The integrated approach of SWARA-TOPSIS was inferred to yield better results based on the study on its applications in supplier selection [15], reducing ecological risk factors [16], prioritizing the failures in a solar panel system. This integrated approach was discussed in the environments of fuzzy [17], intuitionistic, and neutrosophic [18, 19]. Ahmet et al. [20], Miranda et al. [21], and Nazanin et al. [22] discussed different data normalization techniques. To give a comprehensive picture of representing the expert's opinion, this integrated approach is discussed under plithogenic environment in this paper, which is not explored so far to the best of the knowledge. At recent times, researchers develop novel plithogenic MCDM methods. In these plithogenic decision-making models, the plithogenic operators together with the contradiction degree are used to find the aggregate opinion of the experts regarding the criterion satisfaction rate of the alternatives.

In this research work, plithogenic SWARA-TOPSIS is developed by applying plithogenic intersection operator to the expert's opinion on the initial decision-making matrix. The efficiency of different normalization techniques of the weighted matrices is determined by applying them to two different cases. The first case is plithogenic TOPSIS with equal criterion weight, and the second is plithogenic SWAR-TOPSIS. The comparison of both the cases will certainly unveil the efficiency of the proposed approach. The remaining content is segmented as follows, Section 2 presents the methodology; the section consists of the application of the proposed method to the decision-making of food processing technology; Section 4 discusses the result and the last section concludes the work (**Table 1**).

AHP	analytic hierarchical process
ANP	analytic network process
ARAS	additive ratio assessment method
BWM	best worst method
COPRAS	complex proportional assessment
FUCOM	full consistency method
GRA	gray relational analysis
SWARA	stepwise weight assessment ratio analysis
TOPSIS	technique for order of preference by similarity to ideal solution
VIKOR	VlseKriterijuska Optimizacija. I Komoromisno Resenje
WASPAS	weighted aggregated sum product assessment

Table 1.
List of acronyms.

2. Methodology

The method of plithogenic SWARA-TOPSIS is used to find the ranking of the alternatives. The steps involved are as follows:

Step 1: The initial decision-making matrix of order $u \times v$ with u alternatives and v criteria is constructed from the expert's perspective. This matrix consists of the criterion satisfaction by the alternatives, and the representation is made by using linguistic variables such as very high, high, moderate, low, and very low. The linguistic terms are not confined to these values alone. In general, a minimum of two expert's opinions is considered in framing the initial decision-making matrix. The aggregate expert's opinion is obtained using plithogenic intersection operators based on the representations (Fuzzy/intuitionistic/neutrosophic) of the linguistic variables.

Plithogenic Fuzzy Intersection $a \bigwedge_F b$.

Plithogenic Intuitionistic Intersection $(a_1, a_2) \wedge_{IFS} (b_1, b_2) = (a_1 \wedge_F b_1, a_2 \vee_F b_2)$

Plithogenic Neutrosophic Intersection $(a_1, a_2, a_3) \wedge_P (b_1, b_2, b_3) = \left(a_1 \vee_F b_1, \frac{1}{2}[(a_2 \wedge_F b_2) + (a_2 \vee_F b_2), a_3 \wedge_F b_3]\right)$

$$a \bigwedge_F b = ab, a \vee_F b = a + b - ab$$

Step 2: The criterion weights are obtained by the method of SWARA, which are as follows:

i. The criteria are arranged in descending order by the experts based on their significance.

ii. The relative importance of the criterion placed in (h-1)th position over hth gives the comparative importance of the average value s_h

iii. The relative weights w_j of the evaluation criteria is determined

$$w_h = \frac{q_h}{\sum_{k=1}^{v} q_k}$$

where q_j, the recalculated weight

$$q_h = \begin{cases} 1 & h = 1 \\ \frac{q_{h-1}}{k_h} & h > 1 \end{cases} \text{ and } k_h = \begin{cases} 1 & h = 1 \\ s_{h+1} & h > 1 \end{cases}$$

Step 3: After finding the criterion weights by the method of SWARA, the aggregate normalized weighted matrix $D = (d_{ih})$ is determined by using any of the normalization techniques before which the criteria are classified as benefit criteria and cost criteria, where the former must be maximized and the latter to be minimized. The four normalization techniques are shown in **Table 2**.

Step 4: The positive ideal solution $D^+ = \left(d_1^+, d_2^+, d_3^+, \ldots d_v^+\right) = \max\,(d_{ih})$ for benefit criteria and $\min\,(d_{ih})$ for cost criteria. The negative ideal solution

$D^- = \left(d_1^-, d_2^-, d_3^-, \ldots d_v^-\right) = \min\,(d_{ih})$ for benefit criteria and $\max\,(d_{ih})$ for cost criteria.

Normalization technique	Benefit criteria	Cost criteria
Linear scale transformation max method (NT1)	$\frac{x_{ih}}{x_{i\ max}}$	$\frac{x_{i\ min}}{x_{ih}}$
Linear scale transformation max-min method (NT2)	$\frac{x_{ih-}\min x_{ih}}{\max x_{ih} - \min x_{ih}}$	$\frac{\max x_{ih} - x_{ih}}{\max x_{ih} - \min x_{ih}}$
Linear scale transformation sum method (NT3)	$\frac{x_{ih}}{\sum_{i=1}^{u} x_i}$	$1 - \frac{x_{ih}}{\sum_{i=1}^{u} x_i}$
Vector-normalization method (NT4)	$\frac{x_{ih}}{\sqrt{\sum_{i=1}^{u} {x_{ih}}^2}}$	$1 - \frac{x_{ih}}{\sqrt{\sum_{i=1}^{u} {x_{ih}}^2}}$

Table 2.
Normalization techniques.

Step 5: F_i^+, the distance between the alternatives and the positive ideal solution F_i^- is the distance between the alternatives and the negative ideal solution is calculated as follows:

$$F_i^+ = \sqrt{\sum_{h=1}^{v} \left(d_h^+ - d_{ih}\right)^2}; i = 1, 2, \dots u$$

$$F_i^- = \sqrt{\sum_{h=1}^{v} \left(d_h^- - d_{ih}\right)^2}; i = 1, 2, \dots u$$

Step 6: The relative closeness to the ideal solution $R_i = \frac{F_i^-}{\left(F_i^+ - F_i^-\right)}$ is determined and the preferential ranking of the alternatives is made by the values of R_i. The alternatives with high scores are ranked from high to low.

3. Application to decision making on food processing methods

The proposed plithogenic SWARA-TOPSIS is illustrated with the decision making on the food processing technology. Food processing industries are the flourishing kind of industries in recent times. The lifestyle of the present generation has increased the consumption of processed food to a maximum extent. The consumers of processed food are quite steadily increasing as it is becoming inevitable. In general, these food industries employ various food processing technology for consumer acceptability and also introduce modern technology to meet the customer needs [23, 24].

The decision-making environment consists of four alternatives and five criteria that are stated as follows in **Table 3**.

The initial linguistic decision-making matrices given by two decision-makers are as follows:

Expert I

Methods Criteria	Z1	Z2	Z3	Z4	Z5
P1	M	H	M	H	M
P2	L	H	M	L	M
P3	M	H	VH	M	H
P4	VH	H	H	H	VH

Alternatives	Criteria
Chemical processing (P1)	Capital costs (Z1)
Biological processing (P2)	Microbial prevention (Z2)
Thermal processing (P3)	Time efficiency (Z3)
Non-thermal processing (P4)	Nutrients conservativeness (Z4)
	Longevity of shelf life (Z5)

Table 3.
Alternatives and criteria of the decision-making environment.

Linguistic terms	Neutrosophic representations
Very High (VH)	(0.95, 0.1, 0.1)
High (H)	(0.8, 0.2, 0.1)
Moderate (M)	(0.5, 0.5, 0.5)
Low (L)	(0.3, 0.7, 0.8)
Very Low (VL)	(0.1, 0.9, 0.9)

Table 4.
Quantification of linguistic terms.

Expert II

Methods Criteria	Z1	Z2	Z3	Z4	Z5
P1	H	VH	H	H	M
P2	VL	M	H	L	M
P3	H	VH	H	M	VH
P4	VH	VH	VH	H	H

Neutrosophic representations are used to quantify the linguistic values as given in **Table 4**.

The plithogenic aggregated expert decision matrix is

Methods Criteria	Z1	Z2	Z3	Z4	Z5
P1	0.397	0.5766	0.397	0.5678	0.3076
P2	0.073	0.397	0.397	0.167	0.3076
P3	0.397	0.5766	0.5766	0.3076	0.5766
P4	0.579	0.5766	0.5766	0.5678	0.5766

Case I: The criterion weights are assumed to be equal and the alternatives are ranked based on the scores of R_i obtained by using four different normalization techniques.

Normalization technique	Normalized weighted decision-making matrix						R_i	Rank
		Z1	Z2	Z3	Z4	Z5		
Linear scale transformation max method	P1	0.2	0.137704	0.196948	0.106694	0.2	0.664386	3
	P2	0.137704	0.137704	0.057926	0.106694	0.137704	0	4
	P3	0.2	0.2	0.106694	0.2	0.2	0.700953	2
	P4	0.2	0.2	0.196948	0.2	0.2	1	1
Linear scale transformation max-min method	P1	0.071937	0.2	0	0.2	0	0.51547	3
	P2	0.2	0	0	0	0	0	4
	P3	0.071937	0.2	0.2	0.07016	0.2	0.716921	2
	P4	0	0.2	0.2	0.2	0.2	1	1
Linear scale transformation sum method	P1	0.14509	0.054222	0.040776	0.070525	0.034789	0.613146	2
	P2	0.189903	0.037333	0.040776	0.020743	0.034789	0	4
	P3	0.14509	0.054222	0.059224	0.038206	0.065211	0.602772	3
	P4	0.119917	0.054222	0.059224	0.070525	0.065211	1	1
Vector-normalization method	P1	0.101952	0.107303	0.0802	0.129641	0.066565	0.605883	3
	P2	0.181971	0.07388	0.0802	0.03813	0.066565	0	4
	P3	0.101952	0.107303	0.116482	0.070232	0.124776	0.607144	2
	P4	0.057003	0.107303	0.116482	0.129641	0.124776	1	1

Case II: The criterion weights are obtained by using the method of SWARA: Expert I

Criteria	S_h	K_h	W_h	q_h
Z1	1	1	1	0.288
Z3	0.25	1.25	0.8	0.23
Z2	0.3	1.3	0.62	0.179
Z4	0.15	1.15	0.54	0.156
Z5	0.07	1.07	0.51	0.147

Expert II

Criteria	S_h	K_h	W_h	q_h
Z1	1	1	1	0.33
Z3	0.35	1.35	0.74	0.24
Z2	0.4	1.4	0.53	0.17
Z4	0.25	1.25	0.42	0.14
Z5	0.17	1.17	0.36	0.12

Criteria	Z1	Z2	Z3	Z4	Z5
Weight	0.31	0.24	0.17	0.15	0.13

Normalization technique		Normalized weighted decision-making matrix					R_i	Rank
		Z1	Z2	Z3	Z4	Z5		
Linear scale transformation max method	P1	0.057002	0.24	0.117048	0.147711	0.069351	0.922045	3
	P2	0.31	0.165245	0.117048	0.043444	0.069351	0	4
	P3	0.057002	0.24	0.17	0.080021	0.13	0.940439	2
	P4	0.039084	0.24	0.17	0.147711	0.13	1	1
Linear scale transformation max-min method	P1	0.111502	0.24	0	0.15	0	0.672361	3
	P2	0.31	0	0	0	0	0	4
	P3	0.111502	0.24	0.17	0.05262	0.13	0.869149	2
	P4	0	0.24	0.17	0.15	0.13	1	1
Linear scale transformation sum method	P1	0.22489	0.065067	0.03466	0.052894	0.022613	0.754312	1
	P2	0.29435	0.0448	0.03466	0.015557	0.022613	0	4
	P3	0.22489	0.065067	0.05034	0.028655	0.042387	0.105651	3
	P4	0.185871	0.065067	0.05034	0.052894	0.042387	0.291429	2
Vector-normalization method	P1	0.158026	0.128763	0.06817	0.097231	0.043267	0.749931	2
	P2	0.282055	0.088656	0.06817	0.028597	0.043267	0	4
	P3	0.158026	0.128763	0.099009	0.052674	0.081105	0.425359	3
	P4	0.088355	0.128763	0.099009	0.097231	0.081105	0.85551	1

4. Results

The results obtained in both the cases are summarized as follows in **Table 5**, and the relative closeness scores under both the cases are presented in **Figures 1** and **2**.

Based on the rankings of the alternatives obtained under both the cases, it clearly gives the preferential ranking of the alternatives. In almost all the cases, nonthermal

Normalization technique	Case I	Case II
Linear scale transformation max method	P4 > P3 > P1 > P2	P4 > P3 > P1 > P2
Linear scale transformation max-min method	P4 > P3 > P1 > P2	P4 > P3 > P1 > P2
Linear scale transformation sum method	P4 > P1 > P3 > P2	P1 > P4 > P3 > P2
Vector-normalization method	P4 > P3 > P1 > P2	P4 > P1 > P3 > P2

Table 5.
Ranking of the alternatives under cases I and II.

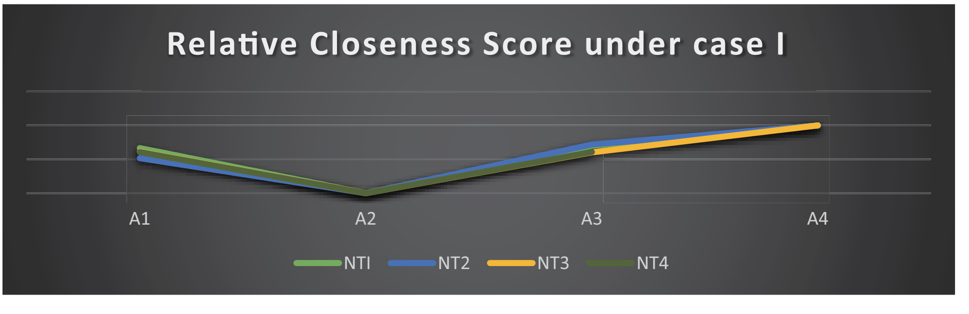

Figure 1.
Relative Closeness Score under case I.

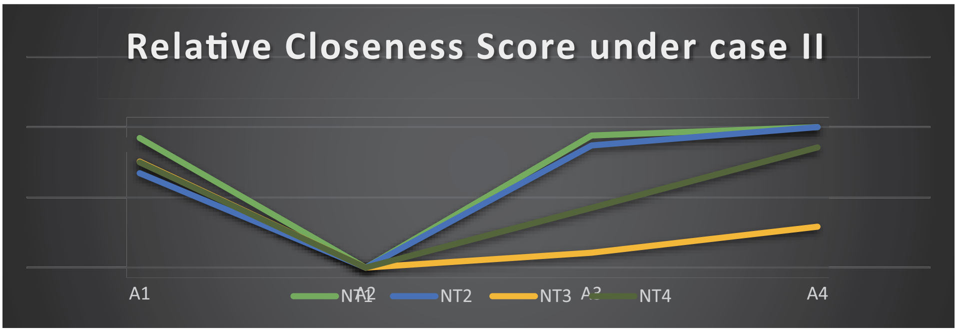

Figure 2.
Relative Closeness Score under case II.

processing technology acquires the first preference and chemical processing technology acquires the last preference. This ranking is validated under both the cases when various normalization techniques are used. The aggregate decision matrix obtained by using the plithogenic aggregate operators adds to the consistency of the proposed model. The ranking results differ only in both the cases under the normalization technique of the linear scale transformation sum method.

5. Conclusion

An integrated plithogenic SWARA-TOPSIS decision-making model is developed in this paper. A comparative analysis of various normalization techniques under two cases is made to determine the most preferred and least preferred food processing technology. The application of plithogenic to such a hybrid method is the novelty of this decision-making model. The proposed model shall be extended by using other plithogenic kinds of aggregate operators. This research work will certainly encourage the researchers to explore the applications of the proposed approach in various dimensions. The results obtained will also benefit the decision-makers in making an optimal selection on food processing technology.

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Chapter 7

Innovation Methodologies to Activate Inclusive Growth in the Organization

Garazi Carranza Ruiz de Loizaga
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Abstract

Digitalization is transforming the way we move and produce, encouraging the industry to use the best available technologies focusing on people. Non technological innovations, especially, Workplace Innovation (WI) will play a key role in the digital revolution and acceleration of the technological advances, improving the competitiveness of the companies. This draws attention to the importance of the innovation culture and employee engagement focused on improving employee motivation and working conditions, thereby improving labor productivity, organizational efficiency, innovation capacity, market reactivity, and, as a result, business competitiveness. WI is a combination of structural and cultural practices that boosts employees' participation, improving the quality of work and organizational performance. These strategies aim to promote innovative work behavior to create, introduce and apply new ideas, processes and products. To address these issues this chapter analyses WI in rail sector and defines WI Scheme for rail sector. A theoretical background is presented based on a sample of 203 railway entities across European Union (EU). Then, data analysis and results are examined and the guide to implement WI scheme is defined. Finally, the results of the research, including limitations and concluding remarks are discussed.

Keywords: workplace innovation, business management, decision management, innovation, organizational innovation, open culture

1. Introduction

In recent years, the transformation of the organizational culture has become a disruptive way for companies to grow and innovate. Business practitioners, researchers and leaders are paying attention to innovation in the workplace to improve the organizational performance. Additionally, the COVID-19 crisis has highlighted the importance of digitalization and the need to fast-track the progress in technological innovations developed up to date. Consequently, the industry, no matters from which sector, needs to engage in the process of continuous improvement for being prepared to the new revolution in order to maintain their competitive advantage. In this situation, the role of Workplace Innovation (WI) is considered as an engine to improve organizations' ability to continuously generate innovations.

Rail is synonymous of technology, efficiency and sustainability. The railway industry is an important sector for Europe, with a turnover of 492 billion of euros. Since 2017, the industry's annual growth has been 3,6 and is expected to grow further at a rate of 2,3% until 2025 [1]. However, due to COVID-19 crisis the transport demand has been reduced by approximately 90% affecting the railway sector. The decrease of passenger and freight volumes results in postponements and cancelations of orders, as well as a lower services volume [1]. Although the railway sector has been affected by the consequences of the pandemic, there is a need to highlight rail transport plays a vital role in preserving the environment due to the low CO2 emissions, as well as supporting European society and its economy [2]. In this sense, the competitiveness and productivity growth of the railway industry depends, among other factors, on the company's ability to innovate, and rail research is a key driving force for Europe to maintain its competitiveness in technological development.

Social, economic and technological changes have driven the railway's sector migration towards the Open Innovation model. In spite of the great pressure from the business environment trends, stakeholders from the rail industry are still reluctant to open up their innovation strategy. WI has not been the sector's priority up to date, as it has been focused primarily on technological innovation to adapt to market demands. Therefore, the biggest challenge has been focused on providing innovative products offering quickness and flexibility to respond the changing customer's demands.

Technological innovation needs to be implemented together with non-technological innovation and WI presents an opportunity for this. This chapter develops and tests a research model based on WI concept on railway's companies by considering the literature and research related to the employees' personal innovation behavior, organizational practices, process practices as well as the impact on company performance. WI scheme developed for rail sector, is an overview of the results obtained by RailActivation project, which has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 861887. The chapter analyses the key competences and skills that presently characterize the rail industry, and to draw a general picture of how these are developed, in which context, and through which particular mentoring process. Then, data analysis and results are examined to develop the WI scheme and a guide to implement it is defined. Finally, the research findings are discussed, including the limitations and concluding remarks.

2. Theoretical background

Workplace Innovation (WI) is a relatively new concept [3], being a combination of structural and cultural practices that enable employees to participate in the organizational change and renewal. Hence, improving the quality of working life and organizational performance [3]. According to the European Commission (EC) to stay at the competitive edge, companies need to invest not only in technological innovation but also in non-technological practices. Workplace Innovation can mean many things such as a change in business structure, human resources management, relationships with clients and suppliers, or in the work environment itself. It improves motivation and working conditions for employees, which leads to increased labor productivity, innovation capability, market resilience and overall business competitiveness. All enterprises, no matter their size, can benefit from WI.

The EC, by means of the European Workplace Innovation Network-EUWIN, launched in 2013, has also published a guide-to-guide companies on the implementation of WI. The network is quite active and connects nowadays more than 10,000 companies and other stakeholders. The guide refers to high performance jobs when:

1. Jobs are empowered and self-managed teams.

2. Flexible organizational structures, people-centered management practices and streamlined systems and procedures are based on trust.

3. Systematic opportunities for employee-driven improvement and innovation are available.

4. Leadership is co-created and distributed combined with 'employee voice' in strategic decision-making.

5. The enterprising behavior, the culture of innovation, the high levels of employee engagement, and the organizational and individual resilience, which flourish only when the other four combines to shape experience and practice across the whole organization.

WI focuses on work organization as a means of innovation and employee involvement, which aims to improve work quality and organizational performance. These techniques are designed to encourage employees to deliberately develop, implement and apply new ideas, process and products [4]. WI lies at the intersection of skills, technology and human resources management [5]. According to the literature, we can see the European workers percentage involved in improving work organization or processes is not really high (47%) [6].

The drivers for WI implementation are divided into two main groups [7]. On the one hand, the improvement of the organization economic goals and performance quality (e.g., increase of productivity, manufacturing quality, customer service, financial performance and profitability etc.). On the other hand, the quality of working life and employee engagement (e.g., increases employee motivation and well-being, playing a particularly important role in reducing stress, enhancing job satisfaction and mental health, and improving retention etc.).

The Employee Participation and Organizational Change (EPOC) analysis evidenced direct employee participation impacts on productivity, innovation and quality. The EPOC analyzed 6000 workplaces in Europe, and confirmed organizations with semi-autonomous groups had 68% reductions in costs, 87% of these entities reduced production times, 98% improved their products/services, and 85% increased their sales [8]. Furthermore, Swedish study evidences flexible organizations were more productive (+20–60%), had a lower rate of staff turnover (−21%) and had a lower rate of absence due to illness (−24%) [9]. The benefits of WI and the effect on entity efficiency and performance is as well evidenced by a review of sixte American articles, with improvements of between 15% and 30% in the performance of those companies [8].

Therefore, WI not only aims at promoting innovation capacities but also allows the companies to remain innovative and adapt to changes quickly and smoothly. WI strengthens an organizations' capacity to innovate by fostering both high-quality employment and good organizational performance [10]. Only the 25% of innovation is related to technological research, while the remaining 75% is related to management organization and work practices at the business level [8, 11, 12]. According to the literature, leaders are those in charge of building an innovative climate and motivate the team towards innovation [13]. This means, the innovative behaviors and attitudes that are conducive to innovative projects are boosted by leaders [14].

According to the research conducted among companies about WI, it can be seen there a positive relation between non-technological innovation and organizational performance, all resulting in more dynamism, innovation capacity and competitiveness. However, the influence of combined organizational factors and individual employee behavior adoption has not been thoroughly analyzed in the railway sector.

3. Analyzing workplace innovation in EU rail sector

3.1 Data and sample

The entities selected for this study belong to the European railway sector. The data used was collected randomly by an online survey drawn out based on the results of the benchmark and European WI concept and indicators [15]. The survey was divided into three sections: individual level, organizational level and process level. Furthermore, the effects of these three sections on the company's WI is also considered, in a results level.

The typology of questions used has been varied, using open answers, multiple-section, one-choice questions and Likert scale to measure the degree/disagree level.

Data was collected over 54-day period (between 02/12/2019 and 24/01/2020) and the final sample included 203 respondents from 16 European countries. This variety of countries enriches the sample of respondents shown in **Figure 1**.

Regarding the quantitative analysis, considering that European Rail Industry employs nearly 400,000 people [1] the study has a confidence level of 95% and a margin of error of 7%.

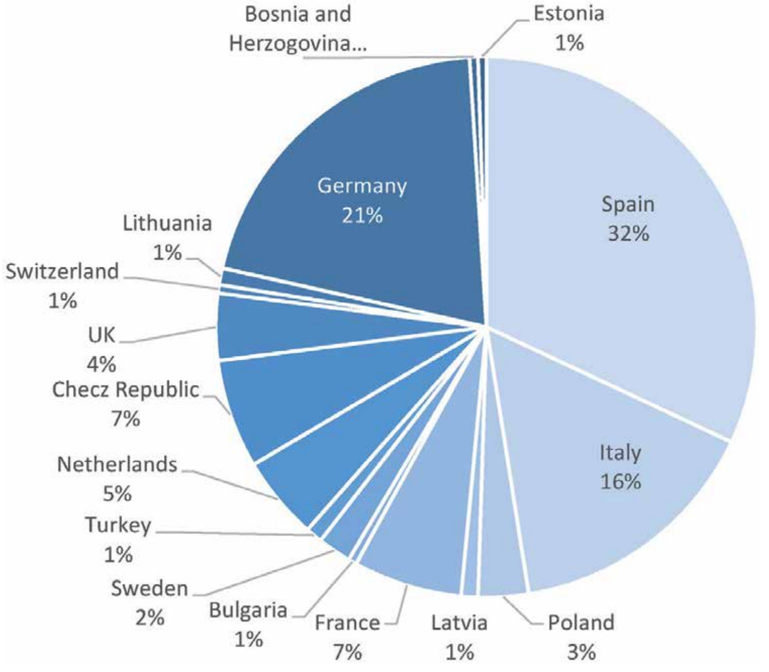

Figure 1.
Sample description (countries).

3.2 Definition of the general trends of WI in the European railway sector

The analysis aimed to examine which organizational, process and individual factors play a role in innovation adoption at the employee's level.

3.2.1 Organizational level

Organizational variables concern the context in which work is carried out. As long as WI is lacking, technological innovation is regarded a necessary but not sufficient prerequisite for change and improvement. As a result, WI refers to the essential organizational adjustments that will enable employees to properly incorporate and apply technological innovation. Most of the respondents (79,5%) indicated that during the last three years their companies had introduced new product or new process to the market. Furthermore, 60,2% of the respondents confirmed that additionally, their entities introduced organizational and marketing innovation strategies as shown in **Figure 2**.

The majority of the product and process innovations were developed by the companies' themselves, and these innovations resulted from collaborative work with other entities and institutions. Companies should go beyond their internal processes and develop cooperation with external organizations or professionals. This means combining their internal knowledge with external knowledge to move forward in their strategy. In this sense, it should be highlighted that not many rail entities focus their innovation on modifying other entities innovative solutions and this is shown in **Figure 3**.

Figure 4 shows how each company has its own approach to organize their innovations. Based on the results, most of the entities involve different departments in

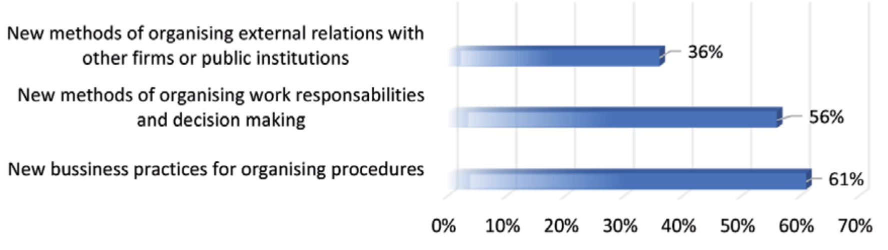

Figure 2.
Innovations introduced during the last three years in EU entities.

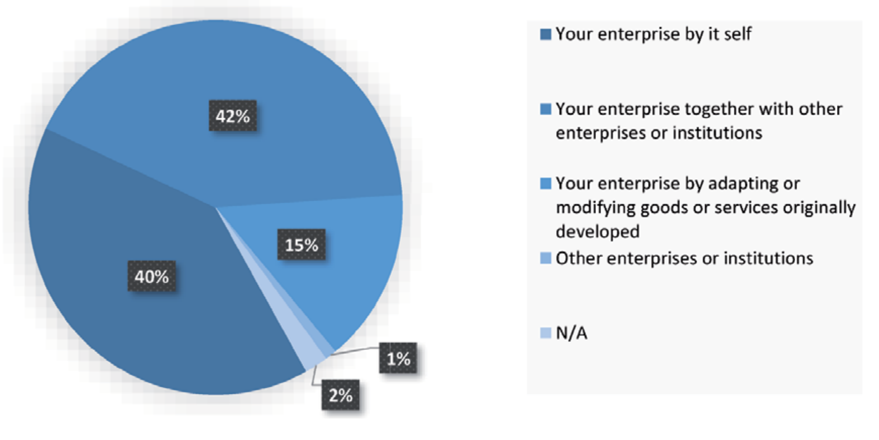

Figure 3.
Innovation's development in EU rail entities.

their innovation processes. However, in most of the cases, the engineering department is the one that leads the innovations.

Among organizational innovation, entities mostly implement new business practices for organizing procedures (62,3%). More than half of the respondents confirmed their organization had used new methods for organizing work assignment and decision making in their enterprises. These improvements were focused on the use of a new system of employee responsibilities, teamwork, decentralization, integration or de-integration of departments, as well as education/training systems. The remaining 40,7% introduced new methods of organizing external relations with other firms or public institutions. These changes were mostly focused on the use of alliances, partnerships, outsourcing or subcontracting.

The improvement of quality goods or services (60%), the reduction of time to respond to customer or supplier needs (57,5%), and the improvement of the ability to develop new products or processes were assigned the highest priority among the objectives for firms addressing organizational innovations over the previous three years (47%). An open culture will allow to face the challenge of launching innovative products, offering quickness and flexibility to respond to changing demands from their customers, as shown in **Figure 5**.

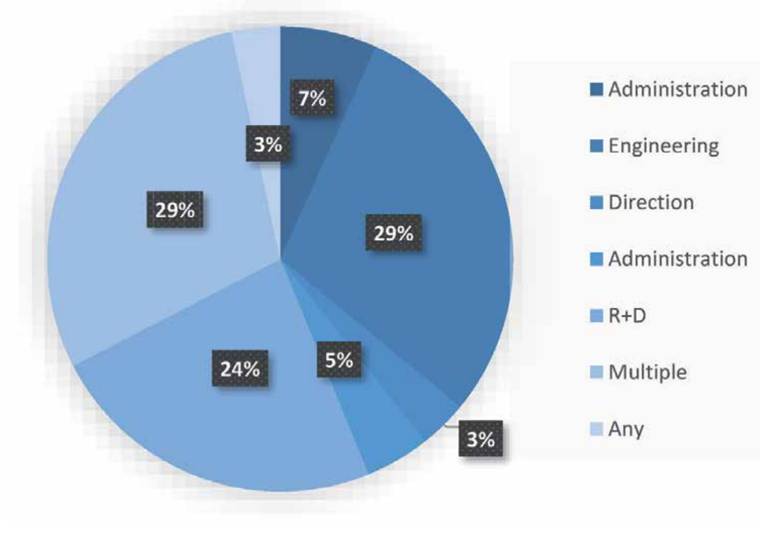

Figure 4.
Departments in charge of the product and process innovations development.

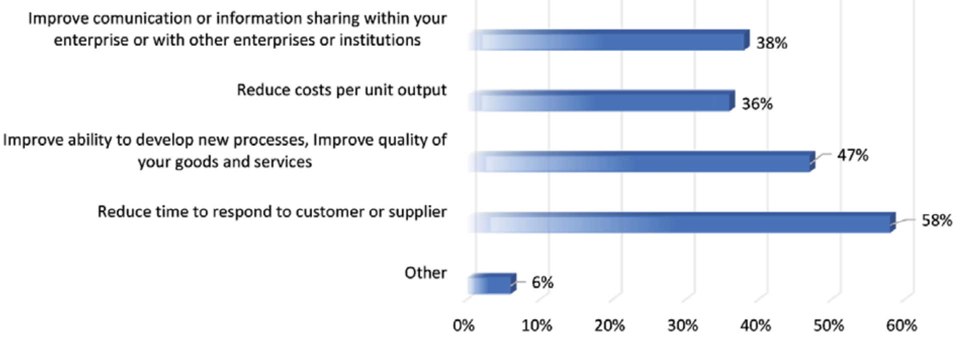

Figure 5.
Objectives for organizational innovations introduced in EU railway enterprises during the last three years.

Companies that work in the railway sector are prompt to introduce changes in their internal processes. In particular, great changes in relation to the use of technology, the way to coordinate and allocate the work to employees, the remuneration system, recruitment policies and in the working time arrangements have been confirmed (**Figure 6**).

As mentioned in Section 2, WI is a complex process which depends on various organizational and management factors. With regards the changes in the external processes, these seem to be less important than the internal ones. More than half of the respondents have confirmed their organizations had adopted new strategies for organizing job responsibilities and decision making. The most used information methods are internal sources and public sector sources. Both of them are used by more than a half of the respondents. Market sources (e.g. suppliers of equipment, materials, components, or software) and opinion of clients or customers from the public sector are very frequent also (both have more than 40% of positive answers). Nevertheless, information provided by consultants and commercial labs were not considered relevant source of the information for innovation projects, as shown in **Figure 7**.

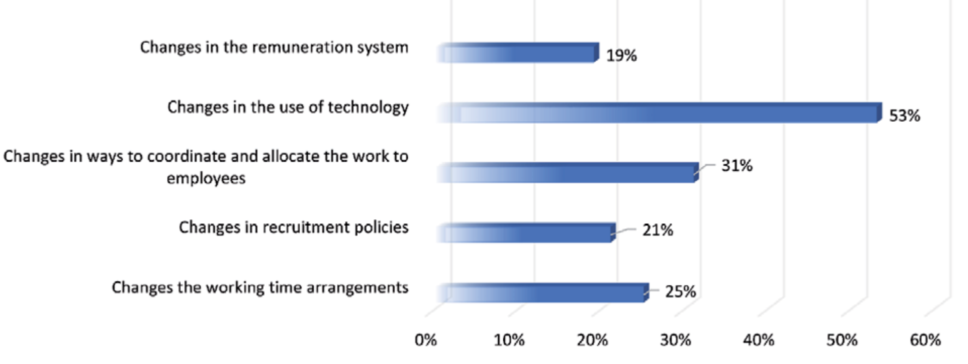

Figure 6.
Internal changes introduced in EU railway enterprises during the last three years.

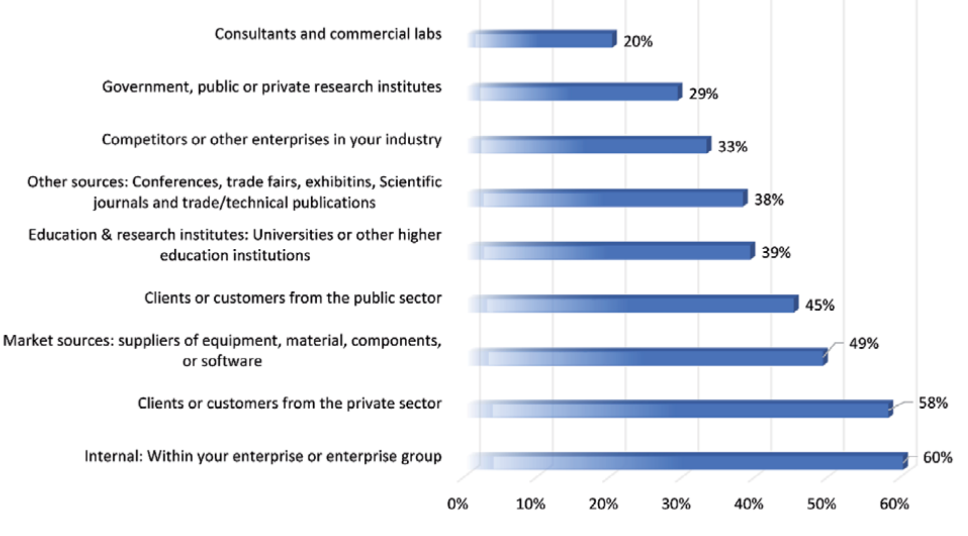

Figure 7.
Information sources used for new innovation projects or contributed to the completion of existing projects during the last three years.

According to the achieved results, brainstorming sessions are the most common tools the entities implement in their innovation practices (61,9%), followed by multidisciplinary or cross functional work teams (56,7%). These methods are based on staff rotation through different departments, financial and non-financial incentives, and public recognition, among others (**Figure 8**).

The most common method to involve the employees are regular meetings between employees and immediate managers (73%). The Committees or task forces are less common, as well as the communication methods such as internal newsletters, notice boards and email. Additionally, open meetings to all employees, suggestions schemes for collection of ideas and employee surveys are the most used ones by big entities (**Figure 9**).

3.2.2 Process level

At process level is measured the development of new approaches/practices as a result of the implementation of various WI instruments, analyzing the effect of methods on the staff's ability to generate new ideas. Autonomy and participation concern the degree to which employees can decide the way their work is carried out.

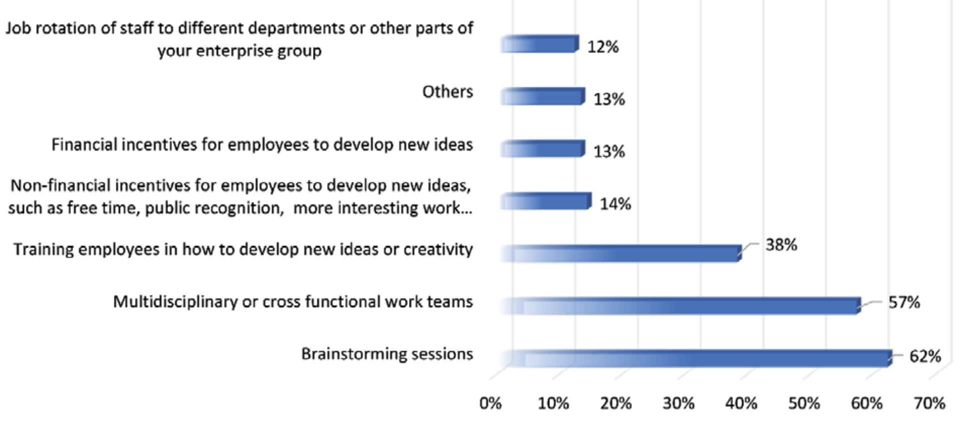

Figure 8.
Methods of staff stimulation in order to develop new ideas or creativity.

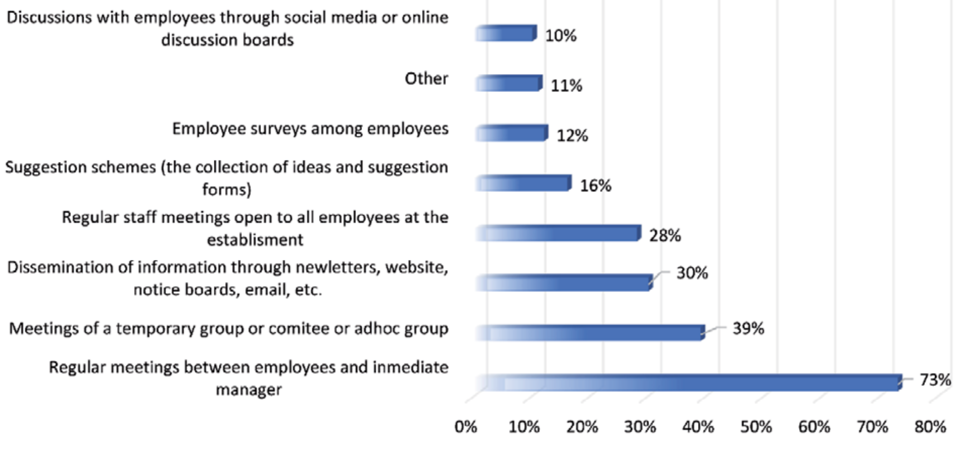

Figure 9.
Methods of involving employees into enterprises' innovation activities.

Almost half of respondents indicated that daily work decisions are taken in collaboration between employees and managers. However, the number of employees involved in the follow up is not really relevant. Normally, it is the manager the responsible of monitoring the tasks, as it is shown in **Figure 10**:

Innovation behavior concerns the extent to which employees feel they are involved in the development of innovation. For all job levels, highest percentage of employee's involvement was in the development of process innovation (58,45%), as well as for product innovation (57,67%). However, the study reveals that employees do not feel really engaged in organizational innovation. **Table 1** shows the obtained results.

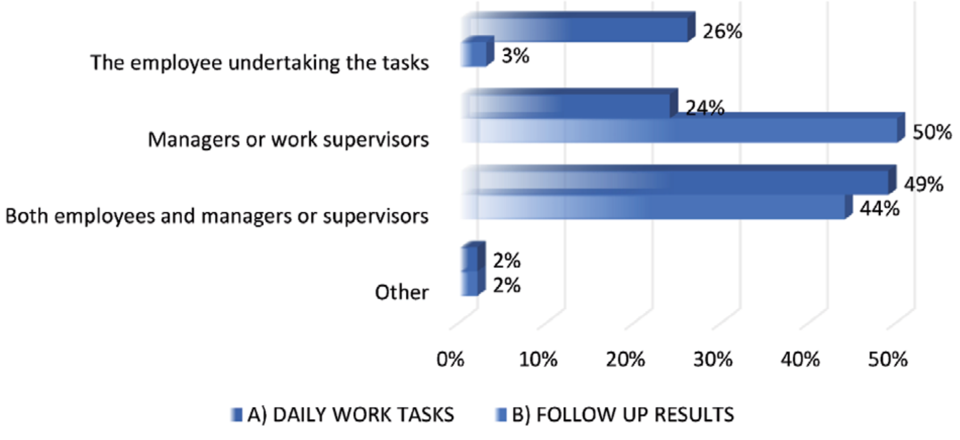

Figure 10.
Difference between decision taking for daily work tasks and follow up results.

Developed innovation	Position						Total (row)
	Assistant		Director		Manager		
	f	%	*f**	%	*f**	%	*f*
Product innovation							
No	13	56,5%	13	32,5%	30	38,0%	56
Yes	10	43,5%	27	67,5%	49	62,0%	86
Total	**23**	**100,0%**	**40**	**100,0%**	**79**	**100,0%**	**142**
Process Innovation							
No	9	39,1%	15	37,5%	35	44,3%	59
Yes	14	60,9%	25	62,5%	44	55,7%	83
Total	**23**	**100,0%**	**40**	**100,0%**	**79**	**100,0%**	**142**
Marketing Innovation							
No	8	34,8%	23	57,5%	46	58,2%	77
Yes	15	65,2%	17	42,5%	33	41,8%	65
Total	**23**	**100,0%**	**40**	**100,0%**	**79**	**100,0%**	**142**
Organizational Innovation							
No	17	73,9%	20	50,0%	53	67,1%	90
Yes	6	26,1%	20	50,0%	26	32,9%	52
Total	**23**	**100,0%**	**40**	**100,0%**	**79**	**100,0%**	**142**

**f =frequency.*

Table 1.
Type of developed innovation/role in entity income crosstabulation.

Figure 11 show the position perspective on involvement of employees into development of different types of innovations.

Existing approaches to the organizations' Knowledge and Information Management (KIM) were also evaluated. These aspects are focused on keeping and sharing best practices among the entity. In most of the cases (66,8%), there is an established procedure for keeping records of the good practices or lessons learned. Additionally, 56,7% of the entities that implemented these documenting procedures for monitoring external ideas or technological developments are doing it as a part of the responsibilities of general staff and 28,4% are using staff assigned specifically to this task, as shown in **Figure 12**.

Organizations have the need for new models of relationships based on sharing and making information accessible, the exchange of ideas and open collaboration. Most of the respondents had their own technology surveillance systems (69,9%) for monitoring market trends and technological developments. Among the methods used for monitoring external sources, the following are highlighted: Internet (58,6%), seminars and trade fairs (57,1%) and personnel training (49%). Other methods such as visits to other workplaces, reading publications in both professionals' journals and research and scientific magazines are not relevant for rail industry (**Figure 13**).

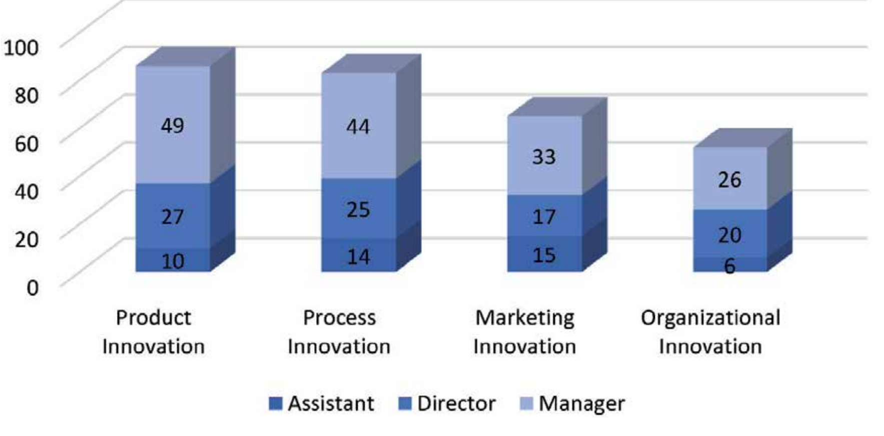

Figure 11.
Position perspective on involvement of employees into development of different types of innovations (in frequency of participation).

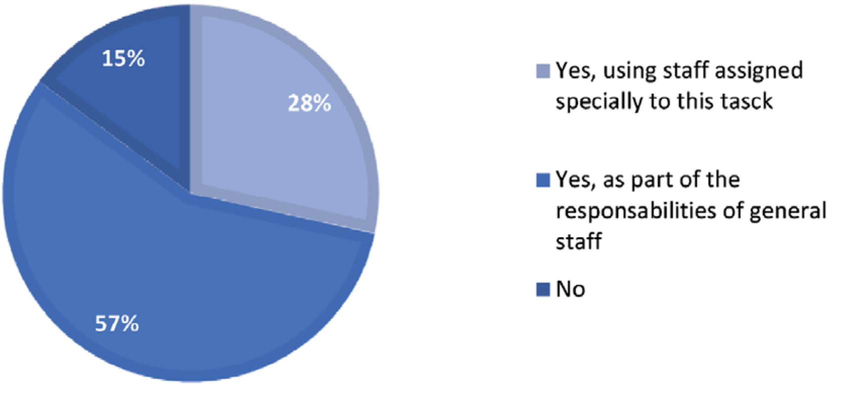

Figure 12.
Particularities of KIM in EU railway enterprises (organization of work of employees who document and keep records of their good work practices.

3.2.3 Individual level

The individual level refers to the attitudes of the employees towards innovation, as well as their individual characteristics, such as age and gender. The only type of innovation in which women have a higher chance than men of being involved is management innovation, which accounts for around 19% of the difference. The drawn-up cross-tabulation (**Table 1**) allows us to see that all age groups are participating in the development of all four types of innovation.

Table 2 shows that the middle-aged employees (36–55 years old) have the highest frequency of participation in innovation development. However, if we

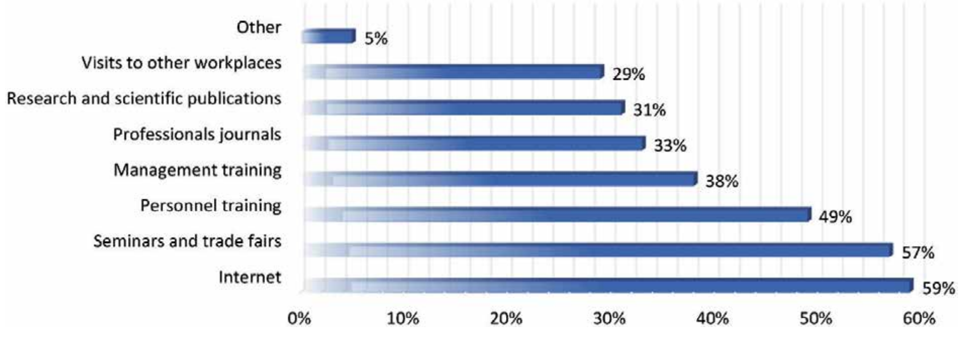

Figure 13.
Methods and instruments used for monitoring of external ideas or technological developments for new or changed products, processes or services.

Developed innovation	Age						Total (row)
	18–35		36–55		56–65		
	f	%	*f**	%	*f**	%	*f*
Product Innovation							
No	13	65,0%	42	36,5%	15	46,9%	70
Yes	7	35,0%	73	63,5%	17	53,1%	97
Total	**20**	**100,0%**	**115**	**100,0%**	**32**	**100,0%**	**167**
Process Innovation							
No	13	65,0%	55	47,8%	9	28,1%	77
Yes	7	35,0%	60	52,2%	23	71,9%	90
Total	**20**	**100,0%**	**115**	**100,0%**	**32**	**100,0%**	**167**
Management Innovation							
No	9	45,0%	66	57,4%	19	59,4%	94
Yes	11	55,0%	49	42,6%	13	40,6%	73
Total	**20**	**100,0%**	**115**	**100,0%**	**32**	**100,0%**	**167**
Organizational Innovation							
No	12	60,0%	75	65,2%	21	65,6%	108
Yes	8	40,0%	40	34,8%	11	34,4%	59
Total	**20**	**100,0%**	**115**	**100,0%**	**32**	**100,0%**	**167**

Table 2.
Type of developed innovation/age crosstabulation.

look at the average probability of participation in the innovation development for different age groups, the 56–65 years old participants are those who have the highest probability of being involved in innovation development (50%). The second highest involvement in innovation development is among young employees (41,25%), and the lowest (37,63%) is among middle-aged employees (36–55 years).

4. Workplace innovation scheme for rail industry

The Scheme pretends to be a flexible itinerary that will drive the company to better competitiveness using WI. The analysis in Section 3 evidences that companies must pay attention to the environment to identify the barriers that prevent teams to be more productive. Therefore, managers must believe in the WI and commit the team, as they will be the responsible of implementing the new tools and measure results to progressively move towards a full open culture that promotes digital transformation.

The driver for Workplace Innovation includes economic as well as social and human aspects, such as:

- Strategic orientation: to be innovative and competitive, organizations need to react to in their environment such as client and competitor behavior, new technological developments, and legislation, etc. this requires purchasing of new knowledge from outside, networking and cooperation with external partners.

- Organizing smarter: the ability of the company to invent new combination of organization, staff deployment and technical applications with a clear focus on the renewal or improvement of work processes.

- Flexible work: increasing flexibility of work through increasing the employability of the staff, facilitating flexible working time and/or contracts, self-rostering, etc. with attention to individual arrangement on working time, work performance, personal development and flexible employment.

- Product-market improvement: innovation by searching for new markets and clients, and the improvement of products and services.

These elements were already part of the questionnaire used in the consultation analysis and are also the basis of the WI Pilot Scheme. The Scheme will drive the company through an itinerary to understand where they stand on WI focusing on the following three interrelated aspects shown in the **Figure 14**:

- The Organization as such

- The employee

- The approach to technological and market developments

The company can select the blocks based on their specific needs, some companies will go for all the blocks, while others will select and implement only those they

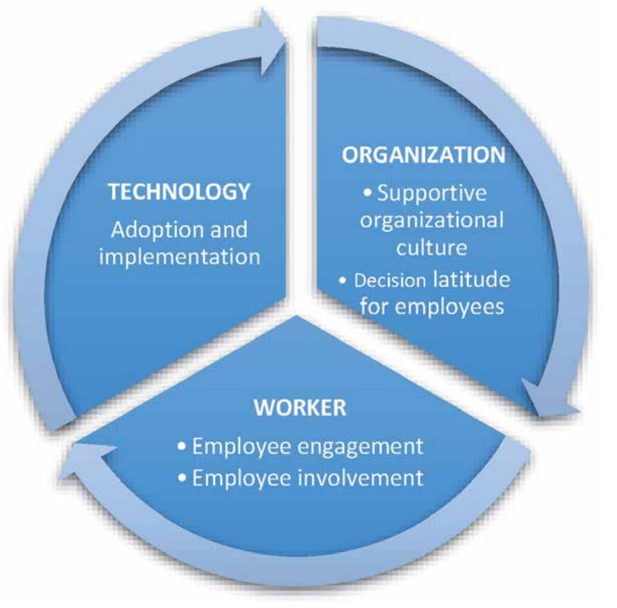

Figure 14.
Workplace innovation scheme.

Figure 15.
WI scheme for rail sector.

want to improve. The blocks and the itinerary suggested to improve the Workplace Innovation within a company are the following ones shown in **Figure 15**:

4.1 Block 1: employees

In this block or step, the company will analyze, and address aspects directly related to employees within a company. The main purpose is to check how the employees feel within a company and focus on a better engagement and involvement. **Table 3**, shows the structure suggested for the Block on Employees, based on the previous research. Seven relevant aspects are suggested to be considered in a company to check the status of WI under the Block Employees:

4.2 Block 2: organization

Following the same logic as for the Block on Employees, the following results have been raised by the people participating in the survey and, on this basis, these are the eleven key factors suggested to review and consider for improving WI oriented to the organization (**Table 4**):

Block 1. Employees. Aspects to consider	Block 1. Employees. Some ideas to do it
• Innovation culture among employees	• Encourage innovation culture: Be honest and open, share ideas, explore initiatives without fear of retribution, allocate time for the employees to break from routine roles to inspire new thoughts.
• Cross functional teams	• Promote the development of cross actions among different teams: employees from different parts of the business; brainstorming sessions, improvements to processes together, etc.
• Encourage different perspectives	• Look for employees who understand business vision, align with its culture – which is not necessarily the same one, may have different perspectives, come from diverse backgrounds, etc.
• Gender issues	• Take it into consideration. Average of women in the railway sector. Identify their responsibilities, their positions in the company, etc.
• Training / Professional career	• To know the level of education of employees. Contrast it with the needs of the company and detect gaps. Identify training needs and support individual training and individual training plans for employees. Trainings about creativity, innovation, etc.
• Employees from different positions work together	• Employees from different positions and responsibilities get together to improve the work organization and processes of different departments.
• Clear responsibilities	• The responsibilities of the employees should be clear, defined and shared, aiming to avoid the lack of motivation among the staff.

Table 3.
Workplace innovation under the block employees.

4.3 Block 3: technology and market

Based also in our research, these are the eleven topics that are suggested as key topics to assed WI under Block 3 (**Table 5**):

4.4 How to implement WI scheme for rail sector?

The Pilot Scheme can be implemented by each company on an individual basis, the recommendation would be for each company to create a small team devoted to WI (including employees from different profiles and responsibilities) that follows up the situation of the company (**Figure 16**). The time devoted to the implementation of the Scheme should be decided by each company. The following three steps are suggested:

More in detail, the following is suggested:

Step 1. Workplace Innovation Kick off. The idea is to check the initial situation of the company regarding Workplace Innovation. An internal analysis including a Strengths, Weaknesses, Opportunities and Threats (SWOT) matrix as a result could be very useful. This will help to better contextualize and decide a further approach. The SWOT matrix allows a strategic analysis useful for a further planning to achieve the objectives or expected results. The Strengths and Weaknesses are related to internal factors while the Opportunities and Threats depend on external factors, as shown in the table.

Based on the initial SWOT produced, a meeting where the results are shared with the rest of employees is suggested. On this basis, an updated matrix can be proposed and at the same time, decide where the weaknesses and strengths regarding Workplace Innovation are. Following this, the company will decide if they go for the three blocks of the Pilot Scheme or for any of them.

Block 2. Organization. Aspects to consider	Block 2. Organization. Some ideas to do it?
• Provide support for sharing ideas	• Many large companies already have methods to allocate time and means to their employees to break from routine roles, to inspire new thoughts, etc. by means of meetings, suggestion boxes, suggestion area on the internal intranet.
• Generational change	• Employees' age and their position, what are the reasons behind, when it is necessary to transfer knowledge from the most experienced personnel to other workers, etc.
• Procedure to assess new ideas from employees.	• Ensure there is a specific process which everyone understands for assessing each new idea. This must be supported by acknowledgement and feedback in a timely manner. Introduce a new idea or *what if*? section to regular meetings, brainstorming sessions.
• Implement employees' ideas and suggestions in a fast and regular way.	• When employees see that they are influencing the direction of the business, they will be extremely motivated to continue sharing ideas, working towards the success of the idea and encouraging productivity of other employees.
• Suggest rewards to employees	• Rewards can be for individuals or even for teams or for the whole workforce. The important thing is that employees see that their efforts to improve the business are appreciated. They could be non-financial incentives such as free time, recognition, more interesting work, etc. Or financial with a specified in advance remuneration system.
• Establish a collaboration space	• Provide a dedicated area that will promote interaction with employees.
• Improve communication or information sharing	• Dissemination of information can be done through newsletters, website, notice boards, email, etc. depending on the type of information that is shared. Discussions with employees through social media or in online discussion boards, employee surveys among employees, etc.
• Establish a feedback culture at all organization levels	• This fact provides company members with feedback on their work. It also encourages them to participate in relevant decisions of the company.
• Promote and Share Good Practices/ lessons learnt	• Keep records of their good work practices or lessons learned and share it with other employees.
• Clarify which are the departments or areas in charge of innovation	• There are different options: to have a department where the innovations are centralized, to make innovations in for each department, to coordinate all actions, etc.
• Work Teams	• See if the work is done individually or in teamwork. Design the best protocols, carry out the work in the most efficient and satisfactory way, choose their own members, choose their own leaders, decide on their day-to-day and weekly tasks themselves, know who is the responsible for the quality of their work, members that perform several different tasks in the team etc.

Table 4.
Workplace innovation under the block organization.

Results:

- Create a Workplace Innovation team in the company.
- Produce a SWOT analysis regarding the WI.

Block 3. Technology and market. Aspects to consider	Block 3. Technology and market. Some ideas to do it?
• New product/services identification	• Which new product/services have been introduced in the market by the company and when, not only by the company itself, but also by competitors, stakeholders, etc.
• Marketing innovation	• Study the marketing situation in the company. Know the new trends, see how they can be adapted. Innovating in the way of communicating internally is also a key activity.
• Communication or information sharing with other enterprises or institutions	• Improve communication or information sharing with other enterprises or institutions. Both at the marketing level and at the relational level.
• Co-Development product/processes	• Co-Development with other enterprises or institutions, sharing of objectives, possible cooperation or alliances, participation in innovation projects, etc.
• Proactive approach to business	• Maintain the business model of the company continually updated and matching with changing conditions.
• Benchmarking in a systematic way	• Establishment of a methodology to monitor external ideas, technological developments, new or modified processes or services.
• Use more collaborative information sources	• Active participation in conferences, trade fairs, exhibitions scientific journals and trade/technical publications, professional and industry associations, etc.
• New business practices to organize internal procedures	• New practices such as: supply chain management, business reengineering, knowledge management, lean production, quality management, etc.
• Review and reformed if necessary	• Review for instance: the logistics, delivery or distribution methods for your inputs, goods or services.
• Review the production costs strategy	• It should be continuously adapted, agile to the changes that are made in the production process.
• Changes in the use of Technology	• Invest in having the latest technology that could allow companies to stay competitive and provide the best quality of services or products as possible. Also, apply new technologies at communication level to improve the communication and connection with employees, leaders, and co-workers anytime and anywhere. Systems like Project Management Software, CRM, etc., that can help and improve internal processes.

Table 5.
Workplace innovation under the block 3, technology and market.

- Workshop with employees to share the SWOT and results.
- Update SWOT and decide for the block of the Pilot Scheme to implement.

Step 2. The company will implement the Pilot Scheme and provides recommendations for action. Based on the results gathered under Step 1, the company will implement the Pilot Scheme. The Company can select one of the blocks, two or all. The company should easily check their strong the strong and weak points for the blocks suggested and decide how to implement reinforcement and corrective actions respectively.

Results:

- Implement the pilot scheme, all Blocks or the ones they consider based on the results from Step 1.

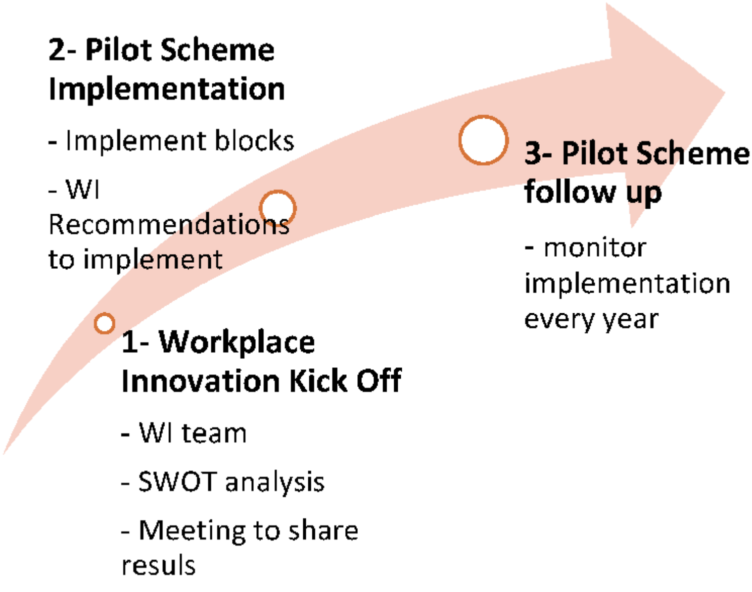

Figure 16.
WI scheme for rail sector, steps for implementation.

Step 3. A follow up is suggested every year. This monitoring is very important to ensure implementation of results and potential updates to include.

Results:

- Follow up every year if possible.

5. Conclusions

At the heart of all transitions are teams and leaders who have the courage to think openly to create a long-term perspective. The literature confirms the digital transformation is influenced by the culture of innovation, the high levels of employee commitment and the capacity for organizational and individual transformation. Digital transformation is the key to business competitiveness in a changing and increasingly demanding market [16]. However, a culture that encourages innovation and creativity is needed to succeed in the railway technological transformation. While the technological investment increases, the digital revolution raises new requirements for completing the transition successfully. In this sense, one of the challenges in the digital age is the adaptation of values, procedures and experiences that characterize the entity through its employees.

A tentative conclusion from the analysis is that employee engagement is an essential driver of WI [17]. The analysis has shown that four elements are relevant for a successful innovation adoption: participatory implementation, innovation behaviors, usefulness of innovation and results demonstrability.

At the organizational level, the results revealed that organizational factors have different impacts on innovation climate. Employee-driven creativity influences the daily evolution of WI practices and gradual improvements, most railway organizations do not use their autonomy to improve WI practices [16]. These findings depart from the WI existing studies that suggest job autonomy can be relevant to guide one's behavioral intentions and has influence positively the company performance [16, 18]. However, within the process level, the result suggests that participatory implementation plays a key role in WI Implementation. This result is in line with previous research, which confirm teamwork, internal cooperation and dialog will facilitate react more quickly to new ideas and challenges. In the correlation analysis it can be seen that the priority of the railway industry is to ensure the future by responding to business dynamics, rather than building an organizational model based on efficiency or quality or working life [16]. However, considering the change is unavoidable, railway organizations must to changes in order to be prepared for the future. There is evidence that participatory work environments and mechanisms for employee voice are associated with higher levels of innovative behavior [6]. Participatory implementation at the process level is positively related to results demonstrability and usefulness of innovation [16].

As a result, the railway industry's management practices should involve autonomous coordination. This means that instead of only suggesting ideas, the management should engage, stimulate and support the team. Then, based on their experience and point of view, employees would be able to recommend how the ideas should be developed [6, 17]. WI's current challenge thus, is to bridge the gap between employees and management.

As expected, there is a positive relation between innovation behavior and usefulness of innovation. But what's more important is that participatory implementation has an effect on all aspects of employees' perceptions of innovation (results demonstrability and usefulness of innovation). These results are aligned with previous research that evidences individual creativity has positive and significant effect on innovative behavior [19]. Finally, it can be seen there is no significant influence between the perception of innovation or innovation adoption among employees, not having a relevant role in WI autonomy and participation.

The main conclusions reached after the intensive consultation and test of the WI Scheme for rail sector is that the defined scheme is appropriate for Rail sector and it is suitable for other sectors. It is simple and flexible enough to be implemented in companies, that at the same time, can select and implement following an easy process the block or blocks they consider more relevant to better implement WI. The WI Scheme reached a great number of stakeholders and companies from different sectors. The follow up actions on the impact reached showed that the companies had a very positive reaction on the Pilot Scheme. Some observations can be made from these cases and confirm the railway industry is closely involved in the transformation towards WI practices at the process level. Within the scheme, the Block on Employees are the most relevant when implementing Workplace Innovation within an organization, followed by the organizational one and by far, the technology focused one.

However, in order to have a good implementation of the WI Scheme employees of each function should participate regardless of their role, and age, and involving several business functions as innovation goes beyond boundaries. The Scheme and Methodology is easy to use in other contexts too, when a need arises. Main obstacles that could arise are; if in the Scheme, only of technical profiles focused on product innovation are involved; if there is not enough recognition of the value of communication & management and the focus on tasks and less on getting as complete an overview as possible.

Therefore, a tentative conclusion of the analysis is that the change in the working system must be combined with a greater participation of the employees. Employees can commit to an innovative culture through the development of personal competences, but above all, it is important that employees have enough information to know where the company wants to evolve.

Future research would be necessary to analyze the preconditions for participatory structures within work teams. This is an essential factor in the WI since it is also related to the innovative behavior of employees and their commitment to the company. Companies in the sector need committed workers who are willing to face the industrial revolution of the sector. The European railway industry has the potential to be highly competitive, but it will not be so in a few decades if the transformation of workplaces is not promoted in order to attract engage and retain young talents [16]. As previously stated, the railway industry is traditional sector and in order to adapt to the changing environment it has capacities to implement innovative culture that allow continuous change in response to consumer demands. Furthermore, further research on the factors that could influence railway efficiency in the future as a result of COVID-19 should be made in order to facilitate the acceleration of railway strategies ensuring long term sustainability of the sector.

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Availability of data and material

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

List of acronyms

WI	Workplace Innovation
OI	Open Innovation
SMEs	Small and medium entities
SWOT	Strengths, Weaknesses, Opportunities and Threats
EUWIN	European Workplace Innovation Network

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Chapter 8

Improved Probabilistic Frequent Itemset Analysis Strategy of Learning Behaviors Based on Eclat Framework

Xiaona Xia

Abstract

Interactive learning environment is the key support for education decision making, the corresponding analytics and methodology are the important part of educational technology research and development. As an important part and the research challenge, learning behaviors are uncertain and produce complex data relationships, which makes the learning analysis process more difficult. This chapter studies the feasibility of Eclat framework applying in educational decision making and get the corresponding the data analysis results. We take probabilistic frequent itemsets and association rules as research objectives, extract and standardize multiple data subsets; Based on Eclat framework, using data vertical format, we design and improve the models and algorithms in the process of data management and processing. The results show that the improved models and algorithms are effective and feasible. On the premise of ensuring robustness and stability, the mining quality of probabilistic frequent itemsets and association rules is guaranteed, which is conducive to the construction of key execution topology of learning behaviors, and improves the accuracy and reliability of data association analysis and decision prediction. The whole analysis methods and demonstration processes can provide references for the study of interactive learning environment, as well as decision suggestions and predictive feedback.

Keywords: Learning Analytics, Decision Making, Eclat Framework, Probabilistic Frequent Itemsets, Association Rules, Decision Prediction, Interactive Learning Environment

1. Introduction

Content resources, interaction patterns, collaborative models, organizational planning and influencing factors related to learning processes constitute learning behaviors, which are also key elements to describe learning behaviors [1, 2]. The learning processes supported by online technology and data technology ensure the completeness and continuity of learning behavior data. Massive learning behaviors is an important part of education big data, which provides the possibility for the full development of learning analytics [3, 4]. Learning behavior data can be divided into two categories: horizontal format and vertical format from the perspective of data structure and feature attributes. These two categories are inseparable about the components of learning behaviors, which are the atomic units to describe learning behaviors, such as url, forumng, questionnaire, etc. The horizontal format of learning behaviors is a vector set composed of multi-dimensional attributes, and the vertical format is a vector set composed of multi-level learners. From the perspective of horizontal format, the researches define learning behaviors as the collection of learners, appropriate learning analytics and tools are used to carry out data statistics and rule exploration. However, it is difficult to calculate and compare the influences of components of learning behaviors, which is not conducive to the construction of a new education mode, and it is relatively difficult to implement the calculation and comparison of the influences of learning behaviors more passive.

Learning behaviors represent continuous learning processes, and there are associated needs and execution results [5]. The analysis of learning behavior based on vertical format can provide more intuitive and accurate characteristics for the study of the groupness and individuality of the learning behavior components. However, the analysis process based on the vertical format is a complex problem with multiple factors. It is impossible to find a suitable decision making and prediction framework. Through sampling, the breadth and depth of data processing are limited, and it is difficult to achieve a feasible decision. Due to the shortcomings and gaps in technology and model, learning behaviors constitute data and potential relationships cannot be gotten fully mining and complete analysis. In terms of research methods and application practices of learning behaviors, there are still many problems to solve [6, 7].

In this chapter, vertical data is analyzed for an online learning behavior big data set. The vertical data analysis of learning behaviors is carried out from the data structure and characteristics. Based on Eclat framework, a probabilistic frequent itemset learning algorithm is designed, and its feasibility and reliability are demonstrated and compared. Within the effective performance indicators, the probabilistic frequent itemsets and association rules are calculated and mined from the learning behavior components, and the correlation is demonstrated. Then we explore the rules and characteristics of learning behaviors, and provide decision feedback and suggestions for the design improvement and relationship of learning behaviors.

2. Related work

Mining probabilistic frequent itemsets is a branch of data analytics. There are explicit or implicit association data, which is the key basis for prediction, decision making and recommendation of other learning behavior components. On the current big data platform, the decision algorithm and recommendation algorithm based on frequent itemsets mining are used to track data. However, due to the particularity and complexity of learning behaviors, as well as the autonomy and randomness of learning processes, there is no general technical means to ensure the integrity and sufficiency to implement the analysis and calculation with the goal of decision making and prediction. In this regard, it is necessary to participate in benign learning behavior component construction and recommendation. The research on frequent itemsets has shown an urgent technical demand in the field of education big data. There have been relevant results to demonstrate the urgency and reality of empirical methods and technical means.

The research on probabilistic frequent itemsets of learning behavior components, after combing the relevant theoretical and application results, mainly focuses on the data statistics and association rules of horizontal format, which is reflected in the following aspects:

2.1 Frequent itemset mining based on apriori

Frequent itemset mining based on Apriori takes the construction of itemset association rules as the premise. The mining process is based on the horizontal format and completes the extraction of rules through iterative search strategy. After data connection and pruning, the itemsets satisfying the association rules are formed [8–11]. If one itemset satisfies the minimum support and a certain confidence, it is defined as a frequent itemset. Apriori algorithm is used to analyze the relevance of learning behaviors, the main idea is to select the learning platform, locate the components of learning behaviors, realize the association between learning behaviors and learning effects, define learning behavior as "cause", and define learning effect as "result". The traditional Apriori algorithm is improved flexibly. With the help of clustering, weighted balance, decision tree evaluation and other means, the data tracking are realized. The research target is to optimize learning behaviors and improve learning efficiency. However, the frequent itemset mining process of Apriori needs to scan the original data many times. When the original data is large, the number of times of iterative scanning is too much, which seriously affects the efficiency of the algorithms.

2.2 Frequent itemsets mining based on FP-growth

Frequent itemset mining based on FP-growth also uses horizontal data format, but the data structure is essentially different. The process of data analysis is mainly divided into two steps: constructing FP tree and mining frequent itemsets. Through the construction of FP tree, the expression of itemsets associated transaction is realized, that is, one path of FP tree corresponds to a transaction, and the transaction is composed of items. Different transactions may have the same items, which makes the path of FP tree overlap. The more overlapped, the greater the path compression space, the higher the access efficiency of FP [12–15]. FP-growth is used to mine frequent itemsets of learning behaviors. Its main idea is similar to Apriori. According to the research target of learning behaviors, users require to select the data set of learning behaviors, define the itemsets and research target, put forward hypothesis test, explore the rules by means of classification, clustering and decision making, draw a conclusion, and verify the existing education and teaching according to the data analysis results, but there are some problems. Due to the diversity, randomness and complexity of learning behaviors, FP-growth algorithm has obvious limitations in the study of learning behaviors. When the itemsets of learning behavior are too many or the relationships are complex, it will lead to too many sub nodes of FP tree, which will greatly reduce the efficiency of the algorithms, and can not get accurate and complete frequent itemsets. FP-growth algorithm is very difficult to learn.

2.3 Frequent itemsets mining based on Eclat framework

Compared with Apriori and FP(Frequent Pattern)-growth, The fundamental difference of Eclat is that the algorithm analysis of Eclat uses vertical data format, and is essentially a deep optimization search mechanism. The rule search space is effectively divided into subspace sets through concept lattice and equivalence relationships. The support calculation of each itemset does not require repeated retrieval of the entire dataset [16–19]. The main idea of using Eclat framework to study learning behaviors need the support of big data set of learning behaviors, through data transposition and standardization processing, we can get the itemsets and the transaction set. On this basis, the relevant models and algorithms of Eclat framework are improved and redesigned. On the premise of support, confidence and promotion, frequent itemsets and association rules are mined. Taking the final frequent itemsets and association rules as the references. Vertical data analysis and research based on Eclat framework can improve the speed of data search, association and analysis, and also improve the reliability of data validation results to a certain extent.

However, the Eclat framework is rarely used in the data processing of learning behaviors. Therefore, the improvement of algorithms and models has no effective results, which is directly related to the difficulty of technology caused by the complexity of learning behaviors. If Eclat is used to transpose and intersect all items and transactions, or if the number of items and transactions is too large, the efficiency of the algorithms will be affected. Therefore, the mining of frequent itemsets in Eclat framework should be assisted by other algorithms and tools, which is more practical. This chapter will integrate the advantages and feasible attempts in the application of Eclat framework, such as technical improvement, model design, tool application, etc., so as to provide more effective methods for the follow-up study of big data of learning behaviors and others.

3. Elements of learning behaviors and research problems

We select a big data set of learning behaviors of UK open university in four periods in recent two years, and the data scale reaches hundreds of millions. From the perspective of course category, we realize the tracking and comparison of learning behaviors of the same category and different categories, and make adaptive decision. The courses are divided into two categories: Literature and Technology. For each category, two courses are selected, namely L1 and L2, T1 and T2. Different courses have different periods of learning behaviors, with the help of assessment, the learning effects are achieved. There is correlation between learning behaviors and learning effects, and there is mutual restrictive and driving relationships between the components of learning behaviors. The empirical problems and testing strategies are established between learning behaviors and learning effects, the research conclusions and decision making reflection are the basis for the improvement and optimization of data-driven learning behaviors.

Tables 1–4 show the components and indicators of learning behaviors corresponding to the four courses of L1, L2, T1 and T2. The four tables involve four learning periods: P1, P2, P3 and P4. The data distribution of the tables indicates that not all courses have learning behavior in each period. The indicators involve two statistics: the median and the mode, which are used to investigate the population trend. Different indicators are selected according to different types of components. "assessment" represents the assessment method of courses, that is composed of enumeration components, mainly including CT (Computer Test), TT (Teacher

P2		P4	
forumng	668	content	1080
homepage	369	resource	8
content	147	subpage	16
resource	1	url	0
assessment	TT	assessment	TT
final_result	pass	final_result	pass

Table 1.
Components and indicators of L1.

P3		P4	
forumng	23	forumng	26
homepage	106	homepage	112
collaborate	0	collaborate	0
content	17	content	24
page	0	page	0
quiz	276	quiz	312
resource	32	resource	34
subpage	56	subpage	54.5
url	4	url	4
assessment	TT	assessment	TT
final_result	With-drawn	final_result	With-drawn

Table 2.
Components and indicators of L2.

P2		P3		P4	
dualpane	3	dualpane	0	dualpane	0
forumng	112.5	forumng	73.5	forumng	126
homepage	195	homepage	160.5	homepage	189
collaborate	0	collaborate	1	collaborate	1
content	506	content	447.5	content	466
wiki	117	wiki	86.5	wiki	126
page	0	page	0	page	0
quiz	137	quiz	113	quiz	108
resource	7	resource	11	resource	9
subpage	22	subpage	17	subpage	19
url	27	url	27.5	url	22
assessment	TT	assessment	TT	assessment	TT
final_result	withdrawn	final_result	withdrawn	final_result	pass

Table 3.
Components and indicators of T1.

Test) and exam (computer and Teacher joint test); "final_result" represents the result of the course assessment and is also an enumeration type, including four components: excellent, pass, fail and withdrawn. "assessment" and "final_result" measure the group tendency of courses. Other components are the main parts of the interaction processes. They all describe the interaction frequency, which has the autonomy and randomness of learners. The strength of interaction frequency is assessed by the median to investigate the distribution range.

From **Tables 1–4**, we can see that the concentration of group selection of "assessment" is very obvious. Most of the learners have completed the course assessment by teachers, but the assessment results are quite different, and the assessment results of the same course in different learning periods are also different. About P4 of L2, as same as P2 and P3 of T1, learners tend to give up the assessment.

P1		P2		P3		P4	
dataplus	0	dataplus	0	dataplus	0	dataplus	0
dualpane	2	dualpane	0	dualpane	0	dualpane	0
forumng	229.5	folder	1	folder	1	forumng	150
glossary	0	forumng	183	forumng	143	glossary	0
homepage	282	glossary	0	glossary	0	homepage	229
content	795	homepage	234	homepage	201	htmlactivity	4
elluminate	8	collaborate	1	oucollaborate	1	collaborate	1
wiki	13	content	566	oucontent	482	content	638
page	9	wiki	11	ouwiki	8	wiki	9
questionnaire	3.5	page	7	page	7	page	2
quiz	581.5	questionnaire	3	questionnaire	0	questionnaire	2
resource	32	quiz	543	quiz	521	quiz	557
subpage	219.5	repeatactivity	0	resource	22	repeatactivity	0
url	23	resource	26	subpage	162	resource	25
assessment	TT	subpage	180	url	12	subpage	184
final_result	Pass	url	13	assessment	TT	url	14
		assessment	TT	final_result	pass	assessment	TT
		final_result	pass			final_result	excellent

Table 4.
Components and indicators of T2.

In P4 of T2, most of the learners obtain excellent assessment results, and most of them pass the course. From "assessment" and "final_result", the group indicators of Literature courses and Technology courses are similar.

As for other components of learning behaviors, it can be found from the data that the category of components and the participation of isomorphic components show strong discrete characteristics. The results show that the types of interaction components in two learning periods of L2 and three learning periods of T1 are consistent, and the median is relatively close, which indicates that the distribution of learners' participation in these interactive components is basically consistent. The two learning periods of L2 have the same "final_result" mode, and the assessment results of T1 have obvious differences. The comparison of the types or numbers of interaction components related to the same course in different learning periods directly shows the differences. The interactions are significantly different, and there is a gap in the median of the same interaction component, such as "content" of two learning periods of L1. At the same time, the types of interaction components that belong to Literature or Technology courses are subject to the courses. The learners of L1 and L2 have their own interactive components, and T1 and T2 are the same.

Therefore, their interaction components of L1, L2, T1 and T2 reflect the autonomous learning characteristics, and the component constraints of assessment methods and results realize the differentiation of learners. The problems and relationships are shown in **Figure 1**, which is divided into the following four steps:

1. The mining of frequent itemsets will take different interaction components as reference items, and realize the analysis and mining of frequent itemsets based on reference items according to certain probability;

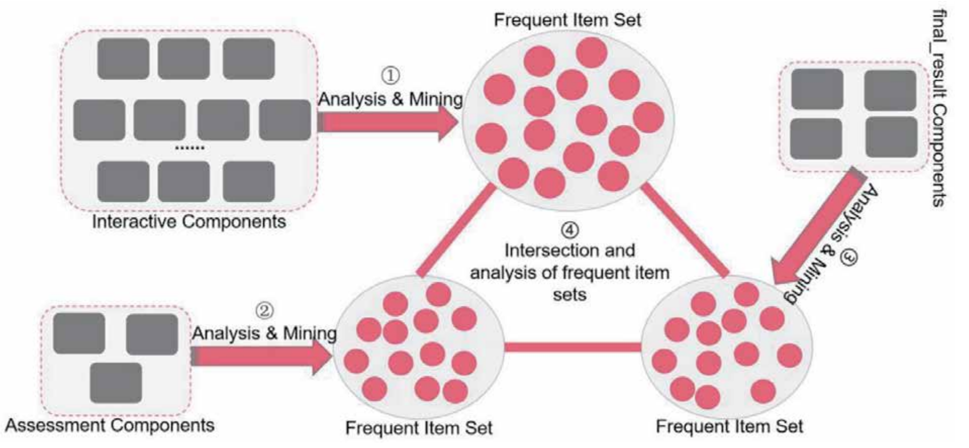

Figure 1.
The research problems and logical relationships.

2. Taking three enumeration methods of "assessment" as component reference items, according to certain probability, the frequent itemsets analysis and mining based on reference items are realized;

3. The four enumeration methods of "final_result" are component reference items. Based on a certain probability, the analysis and mining of frequent itemsets based on reference items are realized;

4. Based on a certain probability, the intersection of the three groups of frequent itemsets obtained from (1), (2) and (3) is solved and analyzed, and the inherent association logic and restrictive conditions are evaluated. On this basis, the rule of data-driven learning behaviors, prediction direction and decision making are explored.

The certain probability in the four steps depends on the selected algorithm requirements and measurement support. Based on the improved Eclat framework, we complete the four steps of the research problems, uses the three indicators "Support", "Confidence" and "Lift" to realize constraints, analyzes threshold and test criteria, and mines probabilistic frequent itemsets and association rules.

4. Improved Eclat framework

For the four learning behavior datasets corresponding to L1, L2, T1 and T2, the execution results of the reference items can be described in the form of probability, but not the "Support" calculation mode. The expected "Support" of reference items should be used to describe the execution frequency of uncertain components [20], that is a feasible and target analysis strategy, which is the model basis for improving the Eclat framework.

4.1 Related models

The Related Models for the improvement of Eclat framework are as follows.

4.1.1 Expected "Support" of reference items

Given a probabilistic data set with N reference item instances, the expected "Support" of a reference term X is expressed as the cumulative value of the probability in the probabilistic data set. The calculation formula is $\exp ect - \sup(X) = \sum_{i=1}^{N} p_i(X)$.

4.1.2 Frequent itemsets

Based on the expected "Support" of a reference item, a probabilistic data set with Nreference item instances is given, if it meets $\exp ect - \sup(X) \geq N \times \min\_RST$, the reference item X is a frequent item set. $\min\_RST$ is the minimum relative "Support" threshold, which is calculated by the ratio of the minimum absolute "Support" threshold to the reference item instance. Generally, this value can be specified according to the data distribution.

4.1.3 Probability frequency

Combined with the conditions of frequent itemsets, given a probabilistic data set with N reference item instances, the probability frequency of the reference term is defined as: $proF(X) = proF\{\exp ect - \sup(X) \geq N \times \min\_RST\}$.

4.1.4 Probabilistic frequent itemsets

Given a probabilistic data set with N reference item instances, if meeting $proF(X) \geq \min\_proF$, the reference item X is a probabilistic frequent itemset, $\min\_proF$ is the minimum frequent probability threshold, which can also be specified according to the data distribution.

4.2 Algorithm design

Many algorithms for mining frequent itemsets mostly use horizontal data format with transaction as vector [5, 21]. The uncertainty of learning behavior data makes the analysis of learning behavior need vertical data format. One complete learning behavior of learners constitutes a transaction. Based on Eclat framework, it is suitable to adopt *tidlist* data structure, and add a probability parameter to each item of learning behaviors to indicate the possibility of a specific transaction.

The vertical data format of learning behavior data is a binary tuple $(x, tidlist(x))$, which represents the item set of learning behaviors, and x is the identifier of each item, that is, the number of each learning behavior, $tidlist(x)$ is the list of items of x. If each item contains an identifier i_i and an existence probability $p_X(i_i)$, $tidlist(x)$ is expressed as a tuple $\{(i_1, p_x(i_1)), (i_2, p_x(i_2)), \cdots, (i_i, p_x(i_i))\}$. In the algorithm design of vertical data format, it is necessary to complete the calculation of probability frequency. Here we use two-dimensional array $P_x[i,j]$ to represent the probability quality function, which means the X probability of the i occurrence in the previous j reference items. Therefore, the calculation process of probability frequency is described as PFC(Frequent Pattern Calculation) program.

PFC program

Input: Item set $X(i_i, p_X(i_i))//1 \leq i \leq |I|$, I represents the maximum number of transactions.

Output: $P_x[i,j]$
Process

1. PFC()
2. For j=0 to $|I|$
3. $P_x[0,j]$=1
4. EndFor //Initialize the first row units of $P_x[i,j]$ of a to 1
5. For j=0 to $|I|$
6. For i=0 to $\min\_Value(j, \min\_RST)$// $\min\_Value(j, \min\_RST)$ is used to compare j and min_RST, then return the minimum value.
7. If $i>j$ then $P_x[i,j]$=0
8. Else if $i>j$ then $P_x[i,j] = \prod_{i=1}^{j} p_x(i_i)$
9. Else if $i<j$
10. Then $P_X[i,j] = P_X[i-1, j-1] \cdot p_X(i_j) + \max(P_X[i, j-1], P_X[i-1,j]) \cdot (1 - p_X(i_j))$

/*This formula is a kind of dynamic decision programming, and the maximum probability frequency is obtained by the adjacent units.*/

11. End If
12. End If
13. End If
14. End For
15. End For
16. Output: $P_x[i,j]$

Based on the calculation results of probability frequency, Eclat algorithm is designed. There are three main steps:

Firstly, according to the vertical data format, the transactions and corresponding items are extracted from the learning behavior data set, with the help of bi-directional sorting strategy, transactions are initialized. The items are stored according to *tidlist*. Then, it analyzes the “Support” of the transactions stored in *tidlist*, and discards the transactions with lower “Support” (support $<min\_RST$).

Secondly, the items of learning behaviors are pruned and optimized, and the $k-$item set from *tidlist* is extracted by intersection, and the probability frequency of $k-$item set is realized by multiplication operation.

Thirdly, mining probabilistic frequent itemsets recursively in candidate itemsets. In the mining process, pruning strategy based on *tidlist* is implemented to reduce the search time complexity. Furthermore, based on the projection of $k-$frequent itemsets, the probability data composed of frequent itemsets are obtained.

These three steps constitute a recursive process, and the whole algorithm process is described as LB(Learning Behavior)-Eclat program.

LB-Eclat Program

Input: $T//T$is the data set for storing vertical data formats.
Process:

LB-Eclat(T)

While all $X_i \in T$

  $I_i = \varphi$

  While $X_j \in T \&\& \; \exp ect - rup(X_i) > \exp ect - rup(X_j)$

    $X_{ij} = X_i \cup X_j$

    $tidlist(X_{ij}) = tidlist(X_i) \cap tidlist(X_j)$

    Call PFC(X_{ij})//call PFC program

    If $P_X[i,j] \geq min\_proF$

    Then $T = T \cup \{X_{ij}\}; \; I_i = I_i \cup \{X_{ij}\}$

  End While

End While

While $I_i \neq \varphi$

  LB-Eclat(I_i)

End Whille

Output: all probabilistic frequent itemsets.

---

5. Experiments

The learning behavior components shown in **Tables 1**-4 are different in scale and sparsity. Combined with the density of learning behavior components, the specific situation is shown in **Table 5**. In order to realize the comparison and test of the algorithms, the traditional Eclat algorithm and the Eclat algorithm based on descending "Support" (DES Eclat) are selected to carry out the experiments.

L1-P2	sparse density	L1-P4	sparse density	L2-P3	moderate density	L2-P4	dense density
T1-P2	sparse density		T1-P3	sparse density	T1-P4	moderate density	
T2-P1	moderate density	T2-P2	dense density	T2-P3	moderate density	T2-P4	dense density

Table 5.
Density of data sets.

5.1 Performance Indicators

Based on the Eclat framework, the traditional Eclat algorithm, des-Eclat algorithm and LB-Eclat algorithm are written into Python 3.7 and run in the same experimental configuration. In the whole experiment process, we set different $\min\_RST$ to mine frequent itemsets, and record the indicators generated in the whole processes, which are mainly reflected in the running time of the algorithm, the proportion of memory and the number of probabilistic frequent itemsets.

The test of each indicator is divided into three series according to the sparsity of the data set. The comparative statistical results of corresponding time are shown in **Figures 2**–4. The larger the $\min\_RST$, the smaller the time curve distribution of each subgraph. It can be seen from **Figure 2** that the algorithm execution results of sparse density dataset based on the same value show that the traditional Eclat algorithm has advantages. The special sorting of data of DES-Eclat and LB-Eclat increases the time complexity, and the analysis process increases the data time. The execution time of LB-Eclat algorithm is the lowest in **Figures 3** and **4**, which

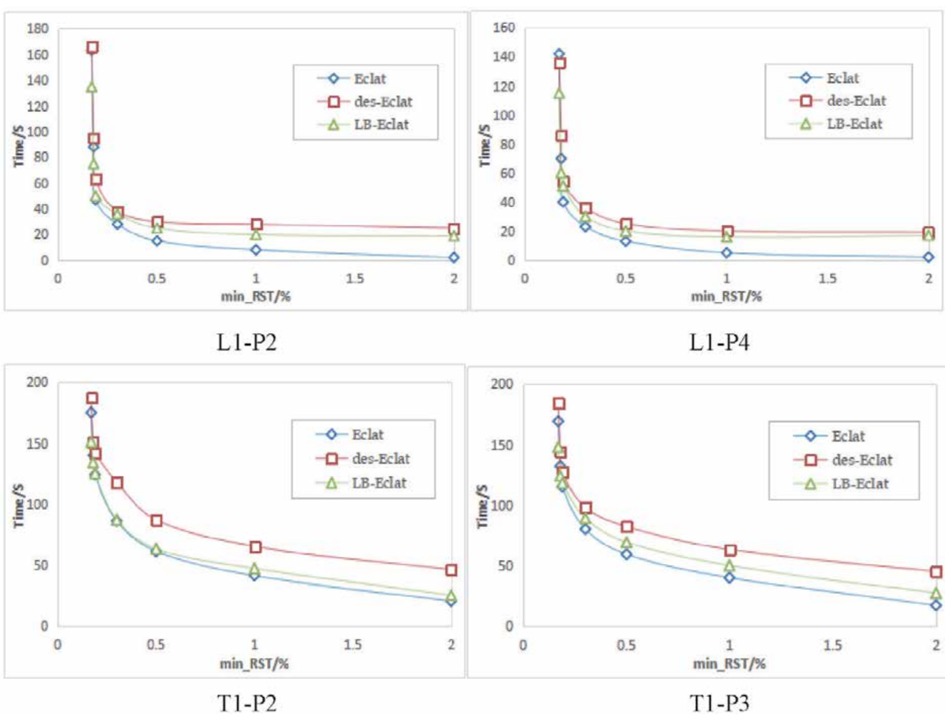

Figure 2.
Comparison of running time of three algorithms on sparse density datasets.

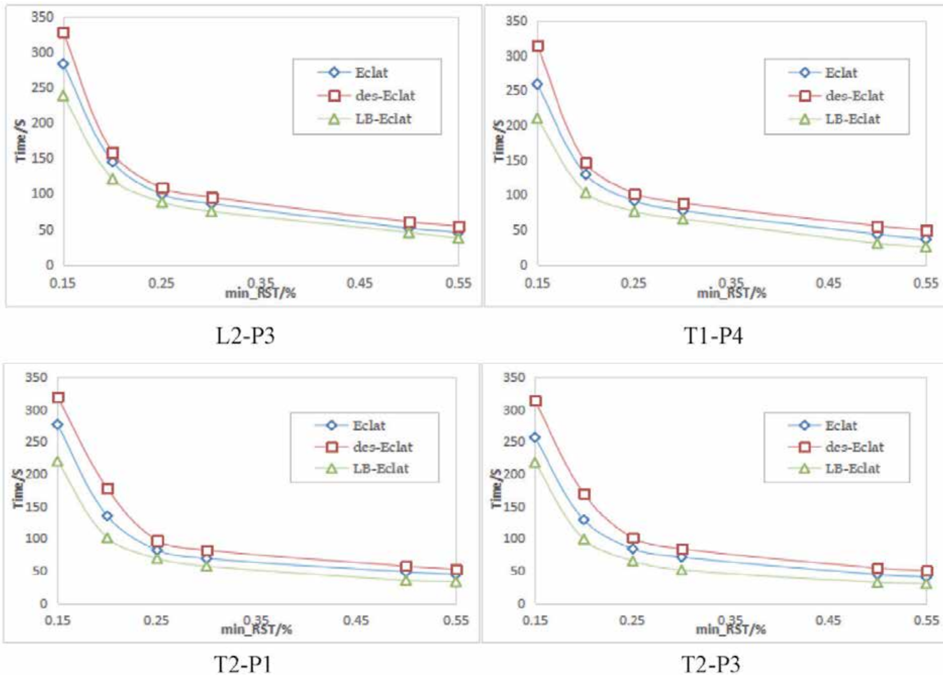

Figure 3.
Comparison of running time of three algorithms on moderate density datasets.

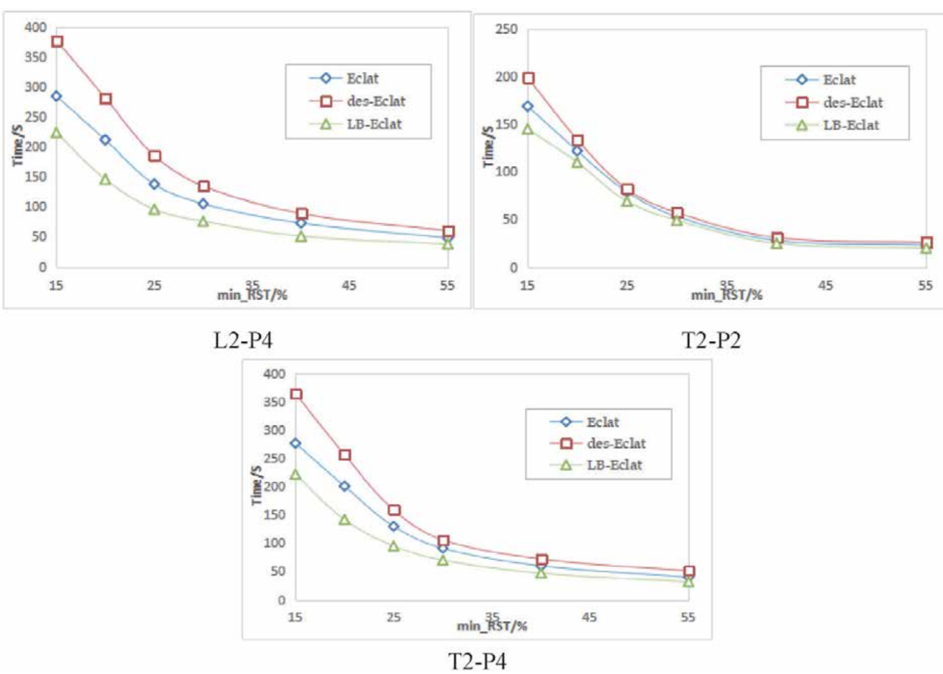

Figure 4.
Comparison of running time of three algorithms on dense density datasets.

indicates that the improvement of the algorithm is more conducive to the analysis of data sets with higher density, and is more effective for mining and processing frequent itemsets of learning behaviors. It can not be found from the time that the DES-Elat algorithm based on the reverse order strategy has a long running time.

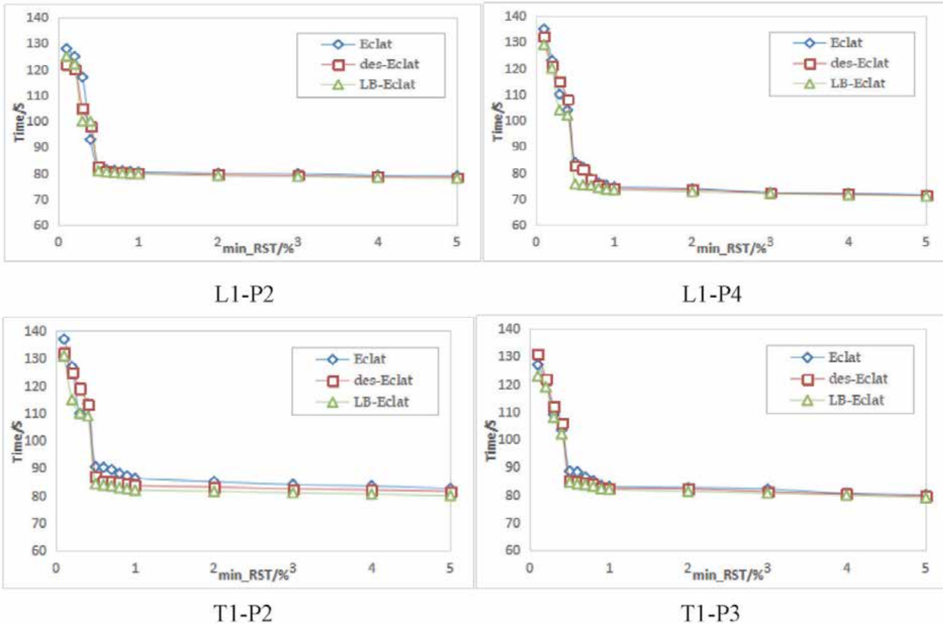

Figure 5.
Comparison of memory space of three algorithms on sparse density datasets.

The comparative results of memory space of the three algorithms are shown in **Figures 5–7**. No matter what the density of data set, the three algorithms occupy the same memory space distribution, the value change trend is the same, LB-Eclat algorithm is slightly smaller than other algorithms, the larger the data set density,

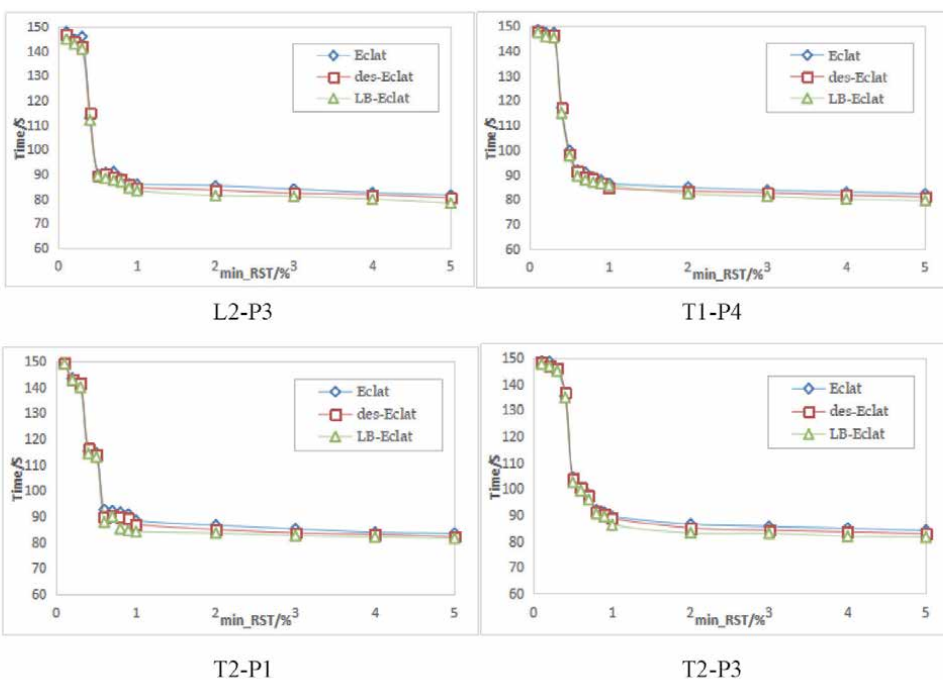

Figure 6.
Comparison of memory space of three algorithms on moderate density datasets.

compared with the traditional Eclat algorithm and des-Eclat algorithm, the smaller the space complexity, that improve the utilization of memory.

The comparison results of probabilistic frequent itemsets mined by the algorithms are shown in **Figures 8–10**. With different $\min\_RST$, the number of

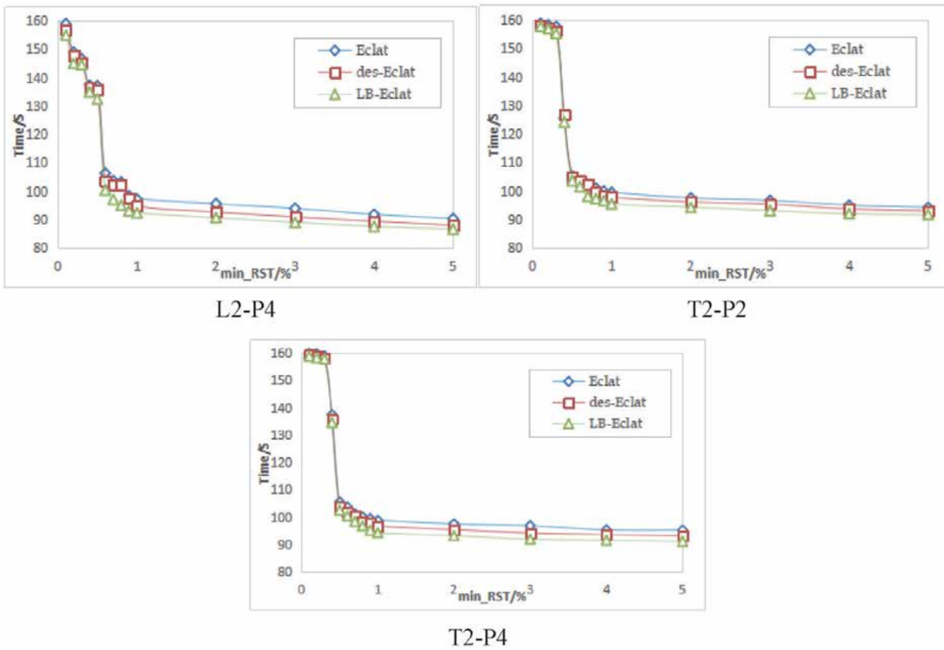

Figure 7.
Comparison of memory space of three algorithms on dense density datasets.

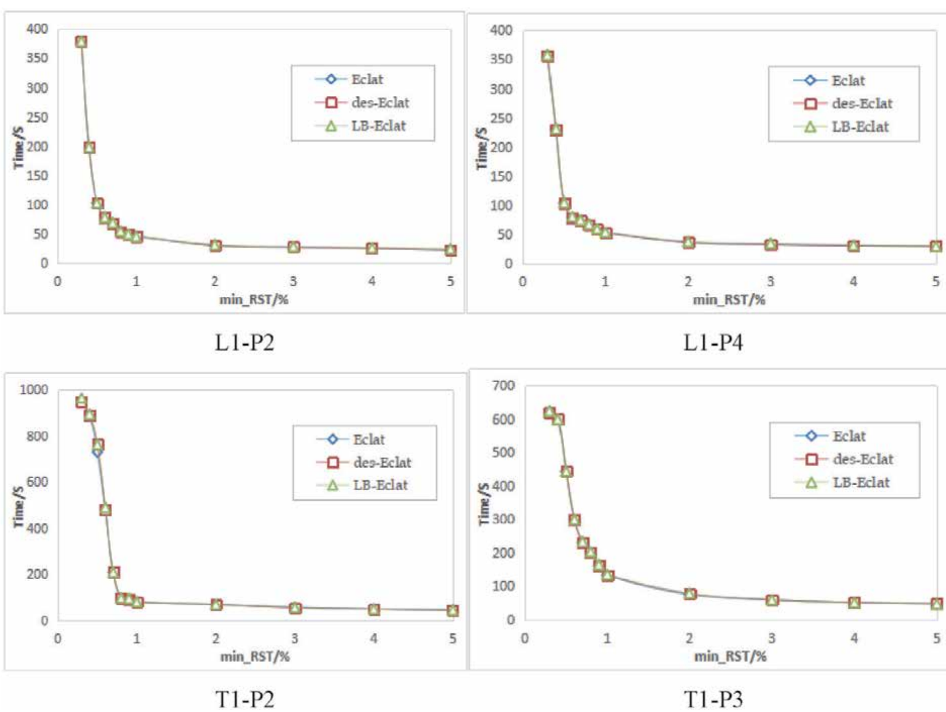

Figure 8.
Comparison of probabilistic frequent Itemsets of three algorithms on sparse density datasets.

probabilistic frequent itemsets depends on the items of learning behaviors and the density of transactions. Although the running time and memory space of the three algorithms are different on the same dataset, the number of probabilistic frequent

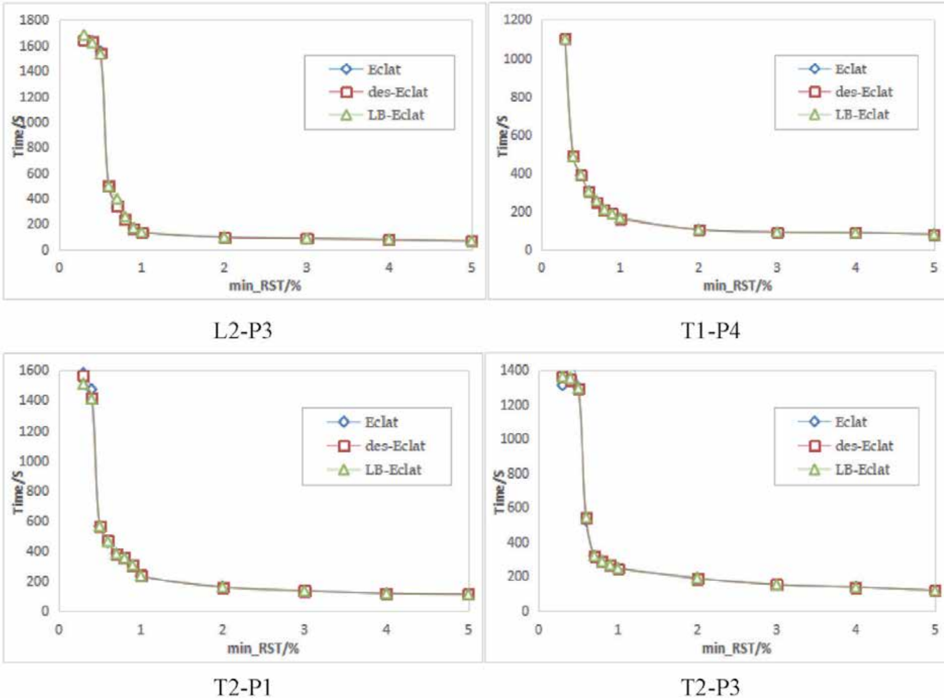

Figure 9.
Comparison of probabilistic frequent Itemsets of three algorithms on moderate density datasets.

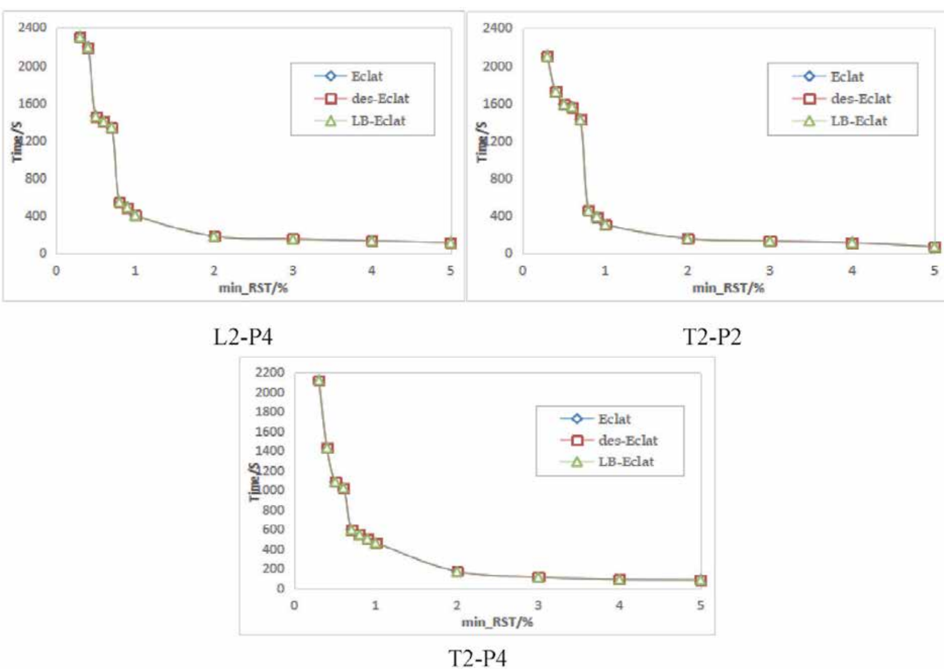

Figure 10.
Comparison of probabilistic frequent Itemsets of three algorithms on dense density datasets.

itemsets obtained is basically the same. With the increase of $\min\_RST$, the fewer the number, the smaller the value, The larger the number, the more transactions and items need to be analyzed and calculated, which will inevitably increase the time complexity and space complexity.

The experimental results show that the LB-Eclat algorithm is effective in the study of uncertain learning behavior probabilistic frequent itemsets. About the running time and memory space, LB-Eclat is better than the other two approximate algorithms in mining and analyzing the probabilistic frequent itemsets of sparse density data sets, moderate density data sets and dense density data sets. Since there are 11 learning behavior data sets, the data are all from the real learning processes, and the comparison test process is fully complete. The indicators show that LB-Eclat algorithm are robust and realistic.

6. Probabilistic frequent itemsets analysis of learning behaviors

Based on LB-Eclat algorithm, the probabilistic frequent itemsets of 11 data sets of learning behaviors are mined, and the itemsets with high probability are found. On the basis of "Support" (>0.3) and "Conference" (>0.7), the probability frequent itemsets of each dataset are mined, and then the association degree of rules generated by itemsets is verified by "Lift". If "Lift" > 1, the association degree of relevant rules is high. In the mining results of probabilistic frequent itemsets, 2-itemsets are the most, as shown in **Tables 6**–**8**, the other 3-itemsets and 4-itemsets are mainly based on the intersection and combination of 2-itemsets. The higher the density of data sets, the more frequent itemsets are mined. Based on the constraints of "Support" and "Confidence", some data sets are limited to 2-itemsets, such as L1-p2 and L1-p4.

From the distribution of frequent 2-itemsets in **Tables 6**–**8**, they have the following characteristics:

1. There is a strong correlation between the components of learning behaviors, and even has a more obvious impact on the components of learning results. In the data set of approximate density, the frequent itemsets of Technology courses are significantly more than that of Literature courses. It shows that the learning behavior components of Technology courses have a strong diversity, and there is a continuous and serial interaction between the components, which makes learners form the approximate frequency participation. Compared with Literature courses, the components of Technology courses are more conducive to the formation of frequent itemsets of learning behaviors.

L1-P2	T1-P2		T1-P3
forumng, homepage	forumng, homepage	content, url	forumng, homepage
forumng, content	homepage, content	wiki, url	forumng, wiki
content, final_result	homepage, wiki	subpage, url	forumng, url
forumng,final_result	homepage, subpage	homepage, final_result	homepage, content
L1-P4	homepage, url	content, final_result	homepage, wiki
	content, wiki	wiki, final_result	homepage, url
content, subpage	content, quiz	url, final_result	content, wiki
content,final_result			
T1-P3	content, url	homepage, final_result	wiki, final_result
	wiki, url	content, final_result	url, final_result

Table 6.
Probabilistic frequent 2-itemsets of sparse density data sets.

L2-P3	T1-P4	T2-P1	
forumng, homepage forumng, subpage forumng, url homepage, quiz homepage, subpage homepage, url quiz, subpage resource, subpage subpage, url homepage, final_result page, final_result quiz, final_result resource, final_result subpage, final_result	forumng, homepage forumng, wiki forumng, url homepage, content homepage, wiki homepage, url content, wiki wiki, url forumng,final_result homepage,final_result content, final_result wiki, final_result quiz, final_result subpage,final_result url, final_result	dataplus, content dataplus,questionnaire dataplus, url dualpane, content dualpane,questionnaire dualpane, subpage dualpane, url forumng, homepage homepage, content homepage, questionnaire homepage, subpage homepage, url content, page content, questionnaire content, quiz content, resource content, subpage	content, url wiki, subpage page, questionnaire page, subpage page, url questionnaire,subpage questionnaire, url quiz, subpage resource, subpage subpage, url dataplus, final_result dualpane, final_result forumng, final_result homepage, final_result content, final_result page,final_result questionnaire, final_result
quiz, final_result resource, final_result	subpage, final_result url, final_result		
T2-P3			
dataplus, content dataplus, questionnaire dataplus, url dataplus, subpage folder, quiz folder, subpage	forumng, homepage forumng, subpage homepage, content homepage, wiki homepage, questionnaire homepage, subpage homepage, url content, wiki content, questionnaire	content, subpage content, url wiki, questionnaire wiki, subpage wiki, url questionnaire, subpage questionnaire, url quiz, subpage subpage, url	dataplus, final_result folder, final_result forumng, final_result homepage, final_result content, final_result questionnaire, final_result quiz, final_result subpage, final_result url, final_result

Table 7.
Mining results of probabilistic frequent 2-itemsets of moderate density data sets.

2. For sparse density data sets, "forumng", "homepage" and "content" are beneficial to form frequent 2-itemsets with other components, which is obviously reflected in different data sets of Literature and Technology courses. "wiki" also has frequent interaction with other components in Technology courses; For moderate density and dense density data sets, frequent 2-itemsets are similar, "forumng", "homepage", "content", "url", "quiz" and "subpage" all have strong component correlation. For Technology courses, frequent itemsets formed by "dataplus", "dualpane", "wiki" and "questionnaire" are used widely and frequently.

For the frequent itemset association rules of learning behavior components, three indicators are used to measure, which are "Support", "Confidence" and "Lift". "Support" determines the correlation between the components. "Lift" > 1 indicates that there is association and has positive correlation. The higher "Lift" is, the more valuable the association rules are; if "Lift" < 1 and smaller, there is negative correlation; if Lift = 1, the components are independent and have no correlation. The association rules with "Lift" > 1 and high confidence are listed and shown in **Table 9**, these association rules are the basis for tracking, adjusting and optimizing learning behaviors.

On the whole, the association rules corresponding to the probabilistic frequent itemsets of sparse density data sets are less, and the association rules of Literature courses are less in the same density data sets [22]. For the moderate density and dense density data sets of Technology courses, rules are formed among the

L2-P4	**T2-P2**		
forumng, homepage	dataplus, questionnaire	content, wiki	subpage, url
homepage, subpage	dataplus, dualpane	content, page	dataplus, final_result
quiz, subpage	dataplus, content	content, questionnaire	dualpane, final_result
forumng, final_result	dataplus, page	content, quiz	folder, final_result
homepage, final_result	dataplus, url	content, subpage	forumng, final_result
page, final_result	dualpane, content	content, url	content, final_result
quiz, final_result	dualpane, page	wiki, questionnaire	homepage, final_result
subpage, final_result	dualpane, questionnaire	wiki, subpage	content, final_result
	dualpane, subpage	wiki, url	wiki, final_result
	dualpane, url	page, questionnaire	page, final_result
	folder, subpage	page, subpage	questionnaire, final_result
	forumng, homepage	page, url	quiz, final_result
	homepage, content	questionnaire, subpage	subpage, final_result
	homepage, wiki	questionnaire,	url, final_result
	homepage, subpage	urlquiz, subpage	
	homepage, url		
T2-P4			
dataplus, dualpane	dualpane, questionnaire	content, subpage	page, subpage
dataplus, content	homepage, content	content, url	page, url
dataplus, wiki	homepage, subpage	wiki, page	questionnaire, subpage
dataplus, page	homepage, url	wiki, questionnaire	questionnaire, url
dataplus, questionnaire	content, wiki	wiki, subpage	quiz, subpage
dataplus, subpage	content, page	wiki, url	resource, subpage
dataplus, url	content, questionnaire	page, questionnaire	subpage, url
dualpane, page			

Table 8.
Probabilistic frequent 2-itemsets of dense density data sets.

	Support	**Conference**	**Lift**	**Rules**
L1-P2	0.2301	0.8127	1.2832	{homepage, content} → {forumng}
L1-P4			None	
T1-P2	0.2152	0.7836	1.5241	{homepage} → {forumng}
T1-P3	0.2701	0.7435	1.7195	{content, wiki, subpage, url} → {homepage}
	0.2558	0.8281	1.6399	{content, wiki, subpage} → {url}
L2-P3	0.3291	0.8536	1.8408	{homepage, subpage, url} → {forumng}
	0.2453	0.7166	1.6807	{quiz, subpage, url} → {homepage}
	0.2132	0.5369	1.3577	{subpage, quiz} → {final_result}
T1-P4	0.1731	0.8467	1.7063	{homepage, wiki, url} → {forumng}
	0.2229	0.8757	1.7530	{content, wiki, url} → {homepage}
	0.3681	0.5355	1.2122	{content, wiki} → {final_result}
T2-P1	0.3522	0.7739	1.4773	{content,questionnaire,url} → {dataplus}
	0.4119	0.7049	1.6980	{content, questionnaire, subpage, url} → {datapane}
	0.3859	0.7978	1.5795	{homepage} → {forumng}
	0.4619	0.7953	2.0856	{content, questionnaire, subpage, url} → {homepage}
	0.4207	0.8682	1.7532	{page, questionnaire, quiz, resource, subpage, url} → {content}
	0.3361	0.7452	1.6985	{questionnaire, subpage, url} → {page}
	0.4747	0.7210	1.4747	{subpage, url} → {questionnaire}

	Support	Conference	Lift	Rules
	0.5151	0.8386	2.0553	{resource, url} → {subpage}
	0.3361	0.5548	1.2858	{content, subpage, quiz} → {final_result}
T2-P3	0.2023	0.7734	1.6246	{content, questionnaire, url, subpage} → {dataplus}
	0.1285	0.8243	1.6447	{homepage, subpage} → {forumng}
	0.2704	0.8609	1.7790	{content, wiki, questionnaire, subpage, url} → {homepage}
	0.3022	0.8631	1.7404	{wiki, questionnaire, subpage, url} → {content}
	0.3253	0.8098	1.5003	{url} → {subpage}
	0.2521	0.5250	1.5236	{folder, content, quiz, subpage} → {final_result}
L2-P4	0.1781	0.8473	1.4871	{homepage} → {forumng}
	0.3934	0.5563	1.0403	{subpage} → {final_result}
T2-P2	0.1989	0.7732	1.6777	{questionnaire, dualpane, content, page, url} → {dataplus}
	0.2486	0.7531	1.6984	{content, page, questionnaire, subpage, url} → {dualpane}
	0.2019	0.8072	1.5534	{homepage} → {forumng}
	0.3947	0.7515	1.7227	{content, wiki, subpage, url} → {homepage}
	0.3025	0.8761	1.7971	{wiki, page, questionnaire, quiz, subpage, url} → {content}
	0.3342	0.7527	1.6687	{questionnaire, subpage, url} → {page}
	0.2624	0.7085	1.2884	{subpage, url} → {quiz}
	0.3128	0.8552	1.6777	{url} → {subpage}
	0.3760	0.5452	1.4449	{folder, content, quiz, subpage} → {final_result}
T2-P4	0.2763	0.8002	1.7168	{dualpane, content, wiki, page, questionnaire, subpage, url} → {dataplus}
	0.2262	0.7934	1.7061	{content, subpage, url} → {homepage}
	0.2756	0.8858	1.7399	{wiki, page, questionnaire, subpage, url} → {content}
	0.3966	0.7606	1.7510	{questionnaire, subpage, url} → {page}
	0.3149	0.8222	1.9056	{url} → {subpage}

Table 9.
Association rules generated by probabilistic frequent Itemsets.

components of learning behaviors, and some of the components can produce rules with high credibility and strong relevance with the final assessment results.

It can be seen from **Table 9** that there are common association rules of components among different data sets, which indicates that these rules have strong generality; for Literature courses or Technology courses, there are some similarities in association rules, but there are also obvious differences; For the same course, in different periods, the results show that the association rules of probabilistic frequent itemsets have both intersection and differences. About {content, questionnaire, subpage, url} → {homepage}, {resource, url} → {subpage} and {resource, url} → {subpage}, the "Lift" values are higher, indicating that the association degree is very high. From the table, it is easy to form strong association rules around "questionnaire", "quiz", "forumng", "homepage", "resource", "subpage", "url" and so on. "dataplus", "dualpane", "folder", "wiki" and so on have strong relevance in Technology courses. Some of components have an obvious impact on the learning results. The extraction of these association rules can greatly simplify the categories of components in **Tables 1**–4.

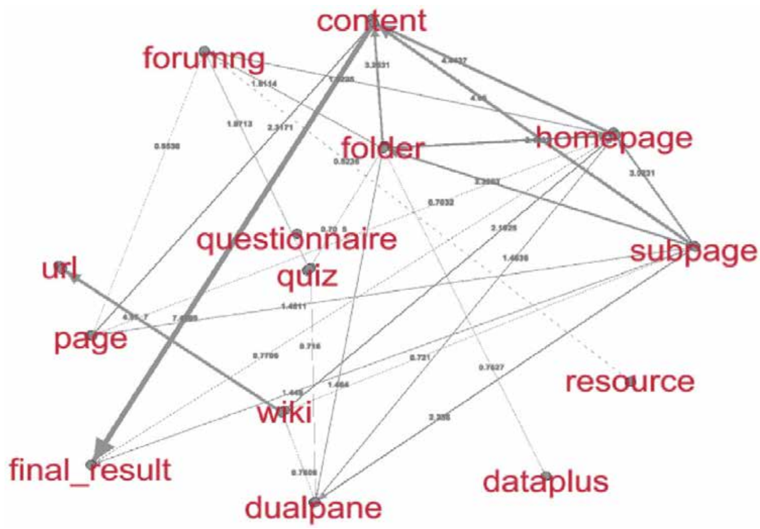

Figure 11.
The key topology of learning behaviors based on probabilistic frequent Itemsets and association rules.

The mining of probabilistic frequent itemsets and the learning of association rules are conducive to the evaluation and recommendation of components in the construction of learning behaviors [22–24]. At the same time, the formation process of learning behaviors can realize the aggregation of effective components according to these association rules. For the components related to association rules, we can build elastic proximity relationships or timely guidance strategies and recommendation mechanisms. This can effectively guide the learning processes, on the other hand, according to the needs of learning objectives, we can design association rules of probabilistic frequent itemsets according to the historical data, which is conducive to analyze and predict feasible participation components.

Based on the data in **Tables 6–9**, the nodes and edges of component interaction processes are constructed, and the key constituent units of learning behavior data sets are generated by Gephi. **Figure 11** shows the topological structure and relationship weight of probabilistic frequent itemsets. There are 14 participation components involved and the weight of each relationship (edge) is calculated automatically. The thickness of the line indicates the strength of the relationship, and the dotted lines represent the potential relationships. The construction and extraction of the key topology of learning behaviors supported by probabilistic frequent itemsets are completed, which is a referential result of data-driven learning behavior prediction and decision making.

7. Decision-making scheme for improving learning behaviors

Studying learning behavior through big data can promote learners to improve their learning processes and learning effects [25]. Aiming at the mining and association analysis of probability frequent itemsets, we realize 11 data subsets of learning behaviors with components as the basic structure characteristics. On the basis of Eclat framework, the vertical data format is adopted to design and improve the data structure and analysis algorithm for learning behavior components. Through the indicator comparison of approximate algorithms, the improved algorithm is effective and feasible for the analysis processes of data subsets, especially in the application of moderate density and dense density data set. Based on the data analysis results, "Support", "Confidence" and "Lift" are the measurement indicators, and the corresponding thresholds are set. The probabilistic frequent itemsets and association rules are mined, and the key topology of learning behaviors supported by the probabilistic frequent itemsets are constructed. The whole processes of mining and analyzing probabilistic frequent itemsets are based on the vertical data format, which ensures the depth and breadth of data research results for decision prediction.

The research of learning behaviors is a specific branch of big data. It is different from other types of data characteristics. Because of the periodicity, continuity, collectivity and individuality of learning behaviors, there may be greater instability and discreteness between the generated data and the expected data. It is very difficult in data analysis and decision making, so it is necessary to design appropriate data structures and algorithms [26, 27] to carry out multi-dimensional empirical study on learning behaviors. Through a series of work and research results of probabilistic frequent itemsets analysis, the following decision schemes are obtained.

7.1 Learning content will affect the frequent itemsets of learning behaviors

Learning content determines learners' tendency. The data of learning behaviors focuses on two Literature courses and two Technology courses, which correspond to multiple learning periods respectively. On the whole, the learning process of Technology courses more complicated, the learning behavior components are more diverse, and the online learning process description is also quite complete and comprehensive, that forms larger scale datasets. Learning content will affect the data density, components and the actual learning processes of learners, which determines the frequent itemsets mining results. For example, from the probabilistic frequent itemsets of the two learning periods of L1 course, the online learning processes corresponding to the learning contents do not have advantages, there is no effective correlation between the components and the learning assessment results, and the advantages of online learning mode are not obvious, which may be more suitable for the teaching mode.

Therefore, the construction of learning behaviors depends on the learning content. According to the mining results of frequent itemsets of historical data and the analysis of association rules, the learning mode of the course is optimized in the new learning period. Based on the learning content, we guide or expand the components of learning behaviors, so as to enhance the learning interest.

7.2 Teaching goals will affect the frequent itemsets of learning behaviors

The same learning content in different learning period, can produce different learning behavior data density, so as to get different frequent itemsets. In different learning periods, the frequent itemsets and association rules obtained by the algorithm are similar, but there are also obvious differences. The components are not the same, and some data sets are quite different. Learners in different periods have different teaching needs, and then correspond to different teaching objectives; On the other hand, the participation and traction in the learning process make the different participation components, and the stickiness of different components are different, which determines the frequent items, and thus produces different association rules, it even affects learners' assessment methods and learning results.

Therefore, the construction of learning behaviors should consider the learning periods and the actual learners, flexibly construct teaching objectives, and design adaptive learning behavior components. In the learning processes, we should also timely analyze the learning behaviors, mine the existing problems and learners' preferences, adjust the components in time, and optimize the learning methods appropriately. We should build a real-time and effective data tracking and analysis mechanisms.

7.3 The frequent itemsets of learning behavior have the characteristics of explicit and implicit association

There are differences in interaction mode of learning behavior components in different platforms, but the demands of serving learning behaviors are the same, that is to realize the continuity of learning behaviors and achieve the learning effects through the interaction of components. Through the mining of probabilistic frequent itemsets and the analysis of association rules, the components of frequent itemsets have explicit association features, and different frequent itemsets may also have implicit association features. It has a strong recommendation value for the prediction and feedback of latent learning behaviors. The key topological relationships of learning behaviors are shown in **Figure 11**, that can provide references for the follow-up learning processes of similar or the same courses, and expand learning methods.

Therefore, the construction of learning behaviors should not only consider the learning content and teaching objectives, but also refer to the historical effective learning behaviors, and also need to carry out effective learning process reform and learning strategy change based on data analysis, gradually promote learners to develop effective learning habits and methods, and construct new learning behavior components. According to the learning situation, stage learning feedback, potential behavior recommendation and implicit interest mining are achieved in order to improve the learning quality.

7.4 Learning behavior needs the adaptive support of specific algorithm and data structure

The generation of learning behaviors is a multi-dimensional process. The research strength of these data determines the cognitive strength of learning behaviors. There are different perspectives on the composition of learning behaviors, which determines different research methods. How to carry out relatively sufficient modeling description and business processing of learning behaviors presents challenges to learning analytics. Some existing software tools and analysis methods can not guarantee the appropriate quantification, standardization and initialization, the analysis process and experimental conclusion may not be thorough and comprehensive. Compared with the statistics and test of learning behaviors carried out by sampling, the effective and comprehensive analysis of learning behaviors is more convincing.

Therefore, the empirical analysis of learning behaviors should be the comprehensive application process of data-driven technologies and methods. Combined with the data characteristics, the technical requirements are demonstrated, and the structures and algorithms suitable for data attributes and process characteristics are designed. This aspect has huge research space and prospect in the field of education big data, which poses challenges for researchers. Learning analytics of educational big data is essentially data analysis, and it is a comprehensive application of computer science and technology, statistics, engineering, etc., and the design and development of general tools in this respect still need time [28]. For a specific data set, it is feasible and more realistic to design suitable data structures and algorithms for decision making.

8. Conclusion

The learning analysis of learning behaviors is a complex process. The data structure, attribute characteristics and relationship categories bring more difficulties. Moreover, the data has strong uncertainty and instability, so it is difficult to achieve technical unity and generality [29]. The development of online learning model gives new definitions and norms to learning behaviors, and also requires new data structure, attribute characteristics, relationship categories, etc. many technologies and methods that can be used in the research of learning behaviors may be inefficient for new data, or do nothing for the new research branches. This research is about the design and application of intelligent data mining technology on a big data set of learning behaviors. Based on Eclat framework, the data structure and algorithms are improved. Starting from the vertical data format, mining probabilistic frequent itemsets, analyzing association rules, and realizing data-driven decision making. In the subsequent research of learning behaviors, for uncertain data, we continue to conduct in-depth research and demonstration of methods and technologies, improve the quality of data analysis and relationship perspective, and provide more valuable conclusions for decision making and prediction feedback of learning behaviors.

Compliance with ethical standards

The authors certify that there is no conflict of interest with any individual/organization for the present work.

A list of acronyms

FP	Frequent Pattern
PFC	Frequent Pattern Calculation
LB-Eclat	Learning Behavior Eclat
Descending Eclat	Descending "Support"

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Chapter 9

The Application of Simple Additive Bayesian Allocation Network Process in System Obsolescence

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Abstract

In designing a system, multi-dimensional obsolescence design criteria such as Scheduling; Reliability, Availability, Maintainability; Performance and Functionality; and Costs affect its overall lifespan. This work examines the impacts of these factors on systems during the design phase using a new application called the Simple Additive Bayesian Allocation Network Process (SABANP). The application uses a combination of Multi-Criteria Decision Making (MCDM) methodology and a Bayesian Belief Network to address the impact of obsolescence on a system. Unlike the requirement of weights that are prevalent in the analysis of MCDM, this application does not require weights. Moreover, this application accounts for functional dependencies of criteria, which is not possible with the MCDM methodologies. A case study was conducted using military and civilian experts. Data were collected on systems' obsolescence criteria and analyzed using the application to make trade-off decisions. The results show that the application can address complex obsolescence decisions that are both quantitative and qualitative. Expert validation showed that SABANP successfully identified the best system for mitigating obsolescence.

Keywords: Obsolescence, Multi-Criteria Decision Making, Bayesian Belief Network, Simple Additive Bayesian Allocation Network Process, Diminishing Manufacturing Sources and Material Shortages (DMSMS)

1. Introduction

Obsolescence is an event bound to happen. It occurs when a component or system (hardware and software) cannot carry out required functions or continue to be useful. Reasons include the component not being available for purchase in its original form from the original manufacturer or producer; not being maintainable, affordable to repair, or reliable; technology evolution; and anything else that causes a component or system to no longer be viable [1–3]. Obsolescence also encompasses discontinuance. However, Pecht and Das [4] made a distinction between the "obsolescence" and "discontinuance" concepts. Discontinuance takes place when the manufacturer stops the production of a component, which occurs at a part-number or manufacturer-specific level, while obsolescence occurs at a technology level [4, 5]. Obsolescence can happen to products, systems, processes, software, policy, standards and organizations.

Many solutions have been proposed for managing obsolescence. However, over the past decade, it is estimated that over $9 billion has been wasted on this problem [6]. The problem is often a result of the rate of technological advancement in systems rendering them obsolete. Managing obsolescence has traditionally been done with a reactive approach. This means that the action taken to resolve the issue occurs after the obsolescence is found. Today, with the rapid growth of digital technology, digital systems and software are reaching their end-of-life sooner rather than later.

Moreover, the contractual agreement between Original Equipment Manufacturer (OEM) and the government is often limited in scope and reactive in nature. This chapter proposes a new application model — a proactive approach that takes into account obsolescence factors that affect systems during the design phase.

The proposed model uses a combination of a Bayesian Belief Network and an MCDM for identifying systems that are more susceptible to obsolescence, which can provide an alert to the system owners to take action before the obsolescence occurs. The combined application of Bayesian Belief Network and MCDM to manage obsolescence in this work serves as the addition to the body of knowledge. This chapter refers to the extension of this methodology as the Simple Additive Bayesian Allocation Network Process (SABANP). The SABANP enables the analyst to define the complex model by connecting a particular Bayesian Believe Network process to the system components (i.e., the leaf nodes), whereby obsolescence characteristics are modeled as an event. When modeling the dynamic characteristics as events, the following set of processes is developed to model the variety of obsolescence criteria:

1. The time when the event occurs or the time to obsolescence,

2. The order by which the events will likely occur, and

3. The event occurrence dependence on time and costs.

The costs that include procurement are required because of their ramifications on the obsolescence problem. The end result of obsolescence in a system is the significant costs it incurs for the organization. The DoD estimated costs upward of $750 M annually for managing obsolescence [7]. Obsolescence is time-dependent; therefore, the model assumed a 95% confidence that systems would be obsolete within two years.

2. Background

In managing system obsolescence, three approaches are used: reactive, proactive and strategic. The reactive approach addresses the obsolescence after the component or part is obsolete, while the proactive one addresses the obsolescence before it occurs [8]. The strategic approach often uses a combination of reactive and proactive approaches to manage the risk of obsolescence; however, the decision models that address obsolescence are underdeveloped [6]. The most agreed upon approach to managing obsolescence is the proactive strategy since it ensures that systems with long life spans are continuously and effectively maintained [9, 10].

Originally, the work began from the need to find better and more effective ways to deal with obsolescence in a proactive manner. To do so, the following obsolescence criteria were chosen from the literature [2, 11, 12]:

(1) Performance and Functionality (P&F); (2) Cost, which includes Acquisition, Licensing and Support; (3) Personnel Training (PT); (4) Reliability, Availability, and Maintainability (RAM); (5) Procurement (PR), which includes Vendor Assembly and Installation Support; (6) Configuration Management (CM); (7) Data Rights and Technical Documentation (DR&TD); and (8) Open Architecture and Standards (OA&S). We also added (9) Technology Readiness Level (TRL), which was adapted from the DoD Technology Readiness Assessment Guidance [13], and (10) Obsolescence Schedule Risk (O&SR).

Each criterion was assessed as either "higher is better" (HG) in the case of a criterion that has a benefit to the stakeholder, or "lower is better" (LW) in the case of non-benefit to the stakeholder to determine the criterion's weight factor. For example, Cost is defined as LW because high ownership and acquisition costs are a non-benefit to the stakeholder. The same can be said of O&SR. This convention is accounted for within the model construct as shown in **Table 1**.

Experts were asked to assess each system's P&F; Costs; required level of PT; RAM; whether they are easily Procurable (PR); installation support and vendor assembly in the design phase. These systems run on software programs, and experts were also asked via a survey to assess each system's CM, the availability of DR&TD, the OA&S, and the TRL by assigning grades on a scale ranging from 0 to 9. These criteria were agreed upon by the experts and are based on the literature review.

Experts rated the O&SR on a scale of 1–5, where 5 represents the highest score and 1 the lowest score. While the rest of the criteria scales are from 0–9, a scale of 1–5 was used for the O&SR because a risk matrix that goes from 1–5 is easily conceptualized by expert practitioners.

2.1 Criteria weights

Weights (w_j) were required to sum to one, and all criteria weights met this requirement. The ratings represent the weights of the ten criteria as provided by the decision maker based on experience and expertise. The weight data served as the inputs to the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) model. This decision making method, that is, TOPSIS was used to validate the Simple Additive Bayesian Allocation Network Process. **Table 2** shows the decision maker-weighted values for each criterion, which total to 1 or 100%.

Criteria (x_j)	**(1) P&F**	**(2) Cost**	**(3) PT**	**(4) RAM**	**(5) PR**	**(6) CM**	**(7) DR&TD**	**(8) OA&S**	**(9) TRL**	**(10) O&SR**
Weight Factors	HG	LW	HG	HG	HG	HG	HG	HG	HG	LW

Table 1.
Criteria benefit and non-benefit weight factors.

Criteria (x_j)	**(1) P&F**	**(2) Cost**	**(3) PT**	**(4) RAM**	**(5) PR**	**(6) CM**	**(7) DR&TD**	**(8) OA&S**	**(9) TRL**	**(10) O&SR**
Weights (w_j)	0.19	0.12	0.06	0.15	0.11	0.07	0.09	0.07	0.06	0.08

Table 2.
Decision maker-assigned weight values.

2.2 The time-discrete Bayesian belief network modeling

The Bayesian Networks are composed of nodes and arcs [14, 15]. Bayesian Networks have the capability to perform diagnostic analysis because of its rich graphical and embedded mathematical capability of modeling and analyzing dynamic behavior of systems [16]. Nodes, in this case, represent Random Variables and arcs between nodes represent the dependencies between the random variables [14]. It uniquely defines joint probability distribution of the random variables. Once the joint probability distribution is known, any random variable query can be solved. Furthermore, random variables can be either infinite (continuous random variable) or finite (discrete random variable) [14]. This chapter only considers discrete random variable since the data that are gathered are from experts and the distribution is discrete. There are three types of nodes: root nodes, sequential root nodes, and leaf nodes. Root nodes are nodes without incoming arcs or without parents, and sequential root nodes are nodes that have incoming arcs and outgoing arcs or are both parents and children. Leaf nodes are nodes without outgoing arcs or without children. Root nodes will have marginal prior probability tables that are associated with them, and sequential root nodes and leaf nodes have conditional probability tables that are associated with them [14]. A conditional probability table provides the probability of each random variable state conditional on the values of its parent nodes. To determine the joint probability distribution, the Chain Rule is used and assumes that the conditional independence is encoded in the designed Bayesian Believe Network structure between the variables.

The joint probability distribution of the variables set $\{X_1, X_2, \dots, X_M\}$ is given as follows [4]:

$$P\left[X_1, X_2, \dots, X_m\right] = \prod_{i=1}^{m} P[X_i | parents(X_i)], i = 1, 2, 3 \dots, m \qquad (1)$$

Recent research works have resulted in better and more efficient algorithms for computing and inferring probabilities in Bayesian Networks. The inference has become easier to the point that algorithms can utilize the independence assumptions between variables and its powerful computations make the command execution quicker for the user. Bayesian Networks have been used extensively in areas such as medical diagnosis, troubleshooting systems, manufacturing control, etc. Nevertheless, it has not been used to mitigate or predict obsolescence in systems with Subject Matter Experts' (SMEs) input or qualitative analysis.

To develop the model, a discrete-time Bayesian Believe Network is formulated to model the system obsolescence. The leaf node or random variable represents the system component. The system component herein is categorized as a component, sub-system or system that interacts between collections of components. These leaf nodes that are used in the experiment are the Integrated Bridge System that are found on Naval Vessels, as described in Section 2.4.

By using this model, one can analyze the interactions among the criteria and find the critical criteria that could have the most adverse effects on a system's operations. This model is used to develop simulation test scenarios, such as what if the costs were not a significant factor in the tradeoff analysis or what if the configuration management does not have any effect on the system's lifecycle. This analysis can also gather information on which obsolescence-related attributes should be prioritized with respect to the design, development, testing, and maintenance.

2.3 Expert judgment

The expert judgments were used to gather the required input data for this experiment. The expert-assigned scores were documented and aggregated for each leaf node based on the agreed upon obsolescence criteria, after normalization of the scores. Though the systems that were employed for the experiment were fielded on Navy ships, the experts were asked to initiate a scenario in which system development was being planned on a new ship class in order to determine the best system against obsolescence through which it can be mitigated.

The system of reference Integrated Bridge System was established after iterative discussions with experts. The research participants were recruited by e-mail with nineteen obsolescence experts completing and returning responses. The minimum requirement for expert judgment participation was set at fifteen returned surveys. Therefore, this number of responses is acceptable for expert judgment. The demographic data also reflected the experts' diverse experiences. All participants had at least four years of experience in managing obsolescence and DMSMSs with some exceeding 35 years of experience. Approximately 10% had a Ph.D., 58% had a master's degree, and 32% had a bachelor's degree. The analysis also revealed that 70% were employed by organizations with 500 or more employees, and these organization sizes ranged from 500 to 100,000 employees.

Participants were asked to complete the study that consisted of approximately 90 data fields. The survey data responses were documented, and the ranking of each alternative on each criterion across the experts was aggregated, normalized and transposed into the model. Exceptions were made for the Cost criterion data scale where the actual cost range data were used. The criteria agreed upon by the experts were used to formulate the survey questions.

2.4 An integrated bridge system (IBS)

An IBS serves as the context of the survey instrument. The IBS on the Naval vessels of the USS Arleigh (DDG-51), the USS Ticonderoga (CG-47) and the USS Nimitz (CVN-68) were examined in this work. The IBS serves as the system-under-test. An IBS is designed to assist the vessel navigator in selecting information that is relevant to the operational context by collecting, processing, and presenting relevant data without cluttering displays with other information that may not be needed at that point. It takes a systems approach to the automated collection, processing, control, and display of ship-control and vital navigational sensor data to maximize the bridge watch efficiency and safety. An IBS is based on human-machine interaction, which integrates all navigational functions and provides accurate navigational information to operators or users with no human error. Its capabilities include multifunction workstations, multiple layers of redundancy, Commercial Off-the-Shelf (COTS) hardware, ease of maintenance, and open system design (i.e., intersystem links to other systems). These systems fall under the purview of being mission essential. Mission essential systems are systems that can have an adverse impact on the mission if they are not operational due to obsolescence.

2.5 Research process

The following steps were used in the research process. One must first determine the current deterministic MCDM methods that are applicable for use in nonlinear (multidimensional) decision analysis. Then, currently available mission-ready systems that serve as points of reference for the study was identified. Finally, an analysis was conducted using the Simple Additive Bayesian Allocation Network Process model with expert judgments in the analysis of alternatives in order to select the best system against obsolescence.

3. Methodology

Simple Additive Bayesian Allocation Network Process (SABANP) utilized the components of the Simple Additive Weighing (SAW) method as the input variables to the Bayesian Belief Network. SAW is an MCDM. To better understand SABANP, it is necessary to provide details of what SAW is and how it is used in the model. The SAW model, which is also known as the WSM or the "weighted average," is a common approach used for multicriteria analysis [17].

One must first calculate the normalized decision matrix for the benefit criteria (higher is better), where n_{ij} is the normalized score of the i^{th} alternative with respect to j^{th} criterion, and r_{ij} are the values in the decision matrix provided by the experts [17, 18]:

$$n_{ij} = {}^{r_{ij}}/_{r_{ij}^{max}}, i = 1, 2, 3, \ldots m, j = 1, 2, 3 \ldots, n \quad (2)$$

r_{ij}^{max} is the maximum value of the i^{th} alternative with respect to each j^{th} criterion in the decision matrix.

For the non-benefit criteria (lower is better), r_{ij}^{min} is the minimum value of the i^{th} alternative with respect to each j^{th} criterion in the decision matrix [6]:

$$n_{ij} = {}^{r_{ij}^{min}}/_{r_{ij}}, i = 1, 2, 3, \ldots m, j = 1, 2, 3 \ldots, n \quad (3)$$

The normalized Matrix for IBS is found in **Table 3**.

The best alternative is the one that maximizes A_i in Eq. (4) below. The weights (w_j) are the weighted criteria values, and they sum to 1 as shown in **Table 2**.

Criteria	IBS DDG-51 Class	IBS CG-47 Class	IBS CVN-68 Class
(1) P&F	1	0.920	1
(2) Cost	0.984	1	0.815
(3) PT	0.9717	0.937	1
(4) RAM	1	0.889	0.959
(5) PR	1	0.896	0.976
(6) CM	1	0.896	0.976
(7) DR&TD	0.947	0.895	1
(8) OA&S	0.987	1	0.939
(9) TRL	1	1	0.979
(10) O&SR	1	0.938	0.978

The time for the system to reach obsolescence was modeled with a 95% confidence interval, i.e., the software and hardware would be obsolete within two years.

Table 3.
SAW normalized matrix.

$$A_i = \sum_{j=1}^{n} w_j n_{ij}, i = 1, 2, 3 \dots, m \tag{4}$$

The SAW model is governed by additive utility theory [19]. As shown in the equation above, each alternative aggregate value is equivalent to the summation of its multiplication. In a one-dimensional case in which the units are similar—for example, seconds, feet, and dollars—the WSM is easy to use [17, 20]. The approach becomes difficult when applied to decision-making problems that are multidimensional [21]. The weights were assessed during the data collection using the direct weighting method. The direct weighting method allows the decision maker to rank the criteria and provide subjective values to the criteria weights based on the defined rank. However, the weights were not needed in the SABANP model to calculate the best alternative. Eqs. (2) and (3) were used since SABANP requires only the normalization of the experts' inputs. The normalized scores ranging from 0 to 1, as shown in **Table 3**, were transposed into the SABANP model for the analysis.

3.1 Simple additive Bayesian allocation network process (SABANP)

The SABANP process begins by populating the survey's raw data into the decision matrix. As shown in **Table 4**, the score of criterion C_j with regard to alternative A_i is r_{ij} and the weight of the C_j *is* W_j. The weights are not required for the analysis.
The following steps are required to conduct SABANP analysis:

1. The normalized decision matrix is first determined (Eqs. (2) and (3)). The normalized score (r_{ij}) is computed to turn the different attribute dimensions r_{ij} into nondimensional attributes, allowing for comparison throughout the attributes.

2. After the normalized decision matrix is determined, the true and false functions are utilized to establish the initial probabilities:

$$\text{The true function is given as } T(n_{ij}), \text{where } T(n_{ij}) = n_{ij}; \tag{5}$$

And the false function is given as $F(n_{ij})$, where $F(n_{ij}) = 1 - T(n_{ij}) = n_{ij}^*$

	C1	***C2***	**...**	***Cn***
A 1	r_{11}	r_{12}	...	r_{1n}
A 2	r_{21}	r_{22}	...	r_{2n}
A 3	r_{31}	r_{32}	...	r_{3n}
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
Am	r_{m1}	r_{m2}	...	r_{mn}
	W_1	W_2	...	W_n

Table 4.
Raw data decision matrix.

	C1	C2	...	Cn			C1	C2	...	Cn
A 1	X_{11}	X_{12}	...	X_{1n}	⇒	A 1	n_{11}, n_{11}^*	...	...	n_{1n}, n_{1n}^*
A 2	X_{21}	X_{22}	...	X_{2n}		A 2	n_{21}, n_{21}^*	...	...	n_{2n}, n_{2n}^*
A 3	X_{31}	X_{32}	...	X_{3n}	⇒	A 3	n_{31}, n_{31}^*	...	...	n_{3n}, n_{3n}^*
.	.	.	.	.		.	.	.	.	.
.	.	.	.	.		.	.	.	.	.
.	.	.	.	.	⇒	.	.	.	.	.
Am	X_{m1}	X_{m2}	...	X_{in}		Am	n_{m1}, n_{31}^*	...	...	n_{in}, n_{in}^*

Table 5.
Data decision matrix.

3. Initial probabilities, n_{ij} and n_{ij}^* are assigned to each variable set {X_{ij}} in the joint distribution function (Eq. (6)) as shown in **Table 5**.

The joint probability distribution (JPD) of the variables set {X_{11}, X_{21}, … , X_{mn}} is given as follows:

$$P[X_{11}, X_{21}, \dots, X_{mn}] = \prod_{i=1}^{m} \prod_{j=1}^{n} P\left[X_{ij} \middle| parents\left(X_{ij}\right)\right], i = 1, 2, 3 \dots, m; j = 1, 2, 3 \dots, n \tag{6}$$

In modeling the system, the IBS system data collected from experts with respect to the systems alternatives and criteria were analyzed using the SABANP. NETICA™ software was used to develop the model. NETICA™ is a powerful, easy-to-use, complete program for developing belief networks and influence diagrams. It provides an interface for drawing networks, and creating relationships between variables which can be probabilities, equations, or data files.

The systems were modeled using RAM, P&F, PR, CM, DR&TD availability, OA&S, TRL, PT, and O&SR as inherent factors that affect the system's design with effects on the costs and time to obsolescence. The NETICAL™ software model shows the captured image when the model was simulated twice or when N = 2 as displayed in **Figure 1**, where N represents the number of times the model and simulation were run. A graphical representation of it is shown in **Figure 2** for the IBS 1 on DDG-51. **Figures 3** and **4** show the graphical representations of the SABANP models of the IBSs (2 and 3) on CG-47 and CVN-68, respectively.

The research question was centered on the following: Does using the newly derived methodology (SABANP) to evaluate multiple obsolescence characteristics in a System enable one to predict which system is less susceptible to obsolescence?

The null hypothesis is that SABANP cannot predict which System is less susceptible to obsolescence, and the alternative hypothesis is that SABANP can predict which system is less susceptible to obsolescence. Additionally, statistical analysis was not conducted. Rather, the model was ran one hundred times (100x,) and the results were aggregated for accepting or rejecting the null hypothesis. A sensitivity analysis was also performed on the results.

Three questions were used within the survey to validate the SME inputs. These questions were used to cross-examine the survey data received from the experts. The data were analyzed to check for inconsistencies. Individual responses to system rankings and criteria weights were plotted to ensure that there were no outliers, and that the data are attributed to a credible sample of expert practitioners.

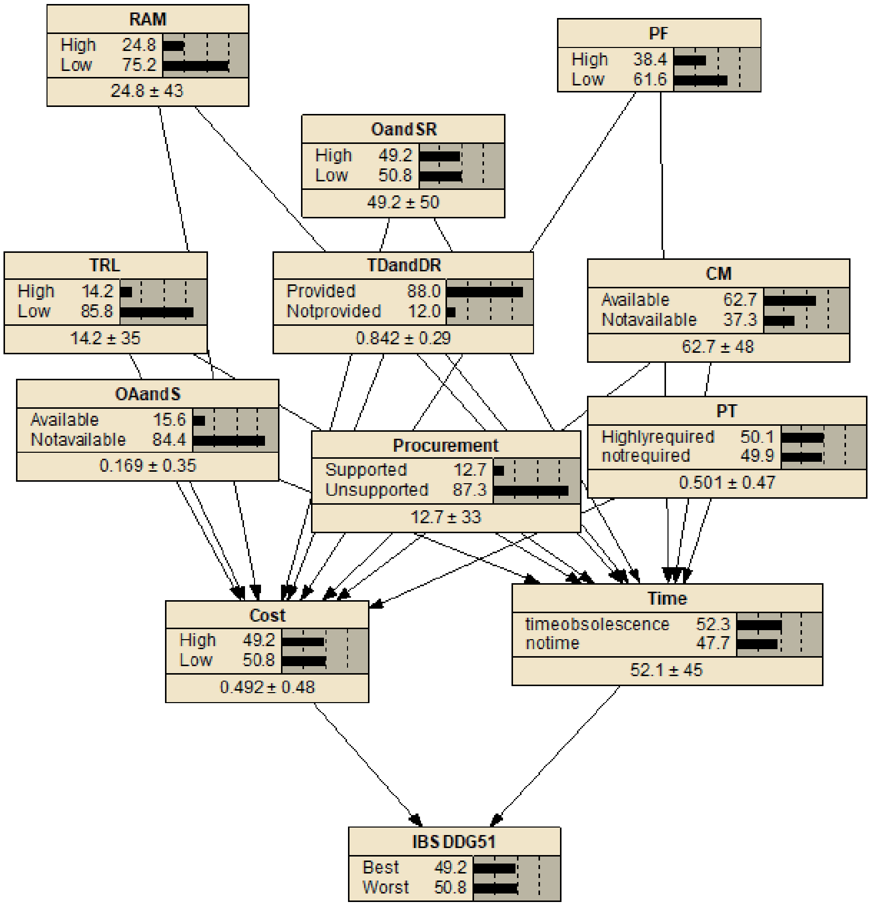

Figure 1.
System design characteristics of the SABANP model (N = 2) with netica software.

Each criterion was modeled on two functions. The function was based on a true or false table. To construct the table, the true table was given an arbitrary phrase like high, provided, available, supported, highly required, time to obsolescence and best. For example, for RAM, the true table states the following: what is the probability that the system has a high RAM? For P&F, the true table states the following: what is the probability that the system's P&F is high? This logic of the true table for these examples is applied to the remaining criteria.

The same logic was applied to the false table. To construct the false table, an arbitrary phrase like low, not provided, not available, unsupported, not required, no time and worst was used. For example, for PT, the false table states the following: what is the probability that Personnel Training is not required for the system? In addition, for time, what is the probability that the system will not be obsolete in two (2) years? **Table 6** represents the true and false table probabilities. The true table probabilities are the normalized values of the expert judgments that are displayed in **Table 3**. The false table is the difference between the probability of each event as described in Eq. (5). The criteria are modeled as events. For example, when one event's true table value is 0.9, the false table value is 0.1. The JPD of the model is given as Eq. (6) and modeled using NETICA™ respectively for IBS 1, IBS 2 and IBS 3 system. Each system is modeled based on the probabilities of each criterion (RAM; P&F; PR; CM; DR&TD availability; OA&S; TRL; PT; and O&SR) given Cost and Time to obsolescence.

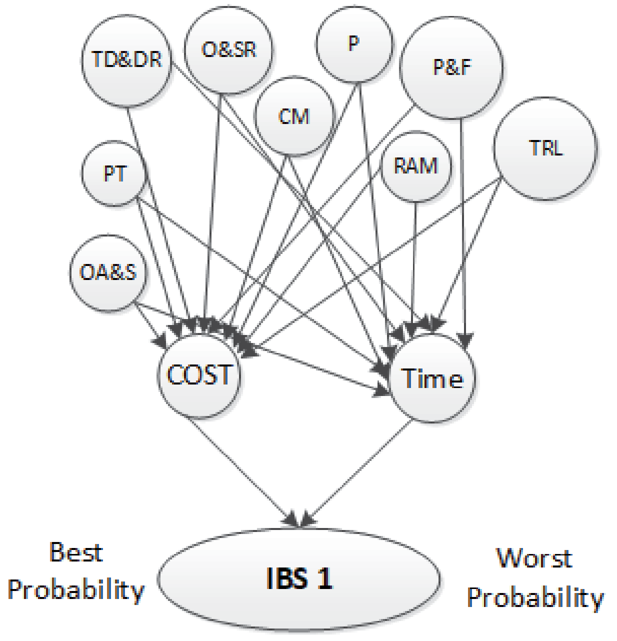

Figure 2.
The IBS for DDG-51 and its equivalent SABANP model.

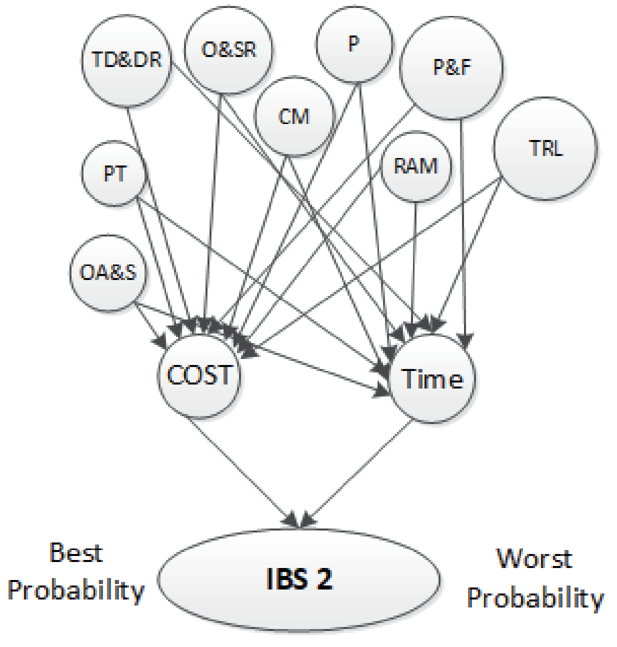

Figure 3.
The IBS for CG-47 and its equivalent SABANP model.

3.2 Multi criteria decision making (MCDM)

What is MCDM? MCDM methods provide a way to combine qualitative data (such as expert opinions) and quantitative data in order to analyze various

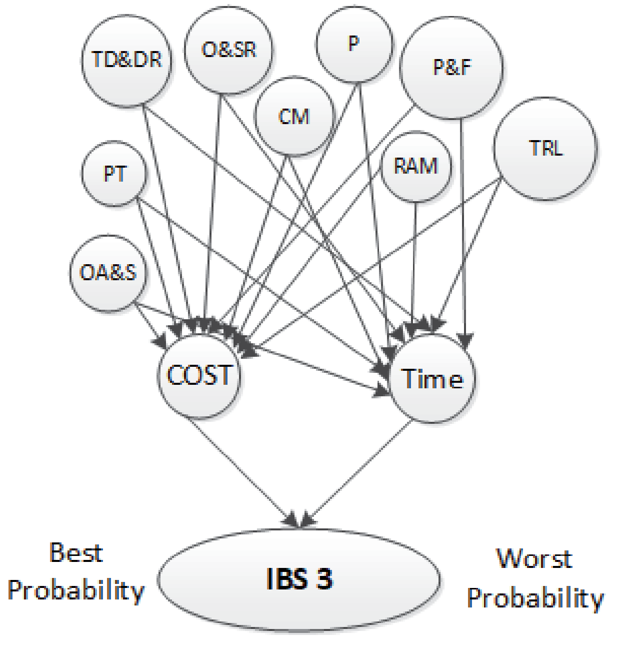

Figure 4.
The IBS for CVN-68 and its equivalent SABANP model.

Criteria	TRUE IBS DDG-51 Class	FALSE IBS DDG-51 Class	TRUE IBS CG-47 Class	FALSE IBS CG-47 Class	TRUE IBS CVN-68 Class	FALSE IBS CVN-68 Class
(1) P&F	1	0	0.920	0.08	1	0
(2) Cost	0.984	0.016	1	0	0.815	0.185
(3) PT	0.9717	0.028	0.937	0.063	1	0
(4) RAM	1	0	0.889	0.111	0.959	0.041
(5) PR	1	0	0.896	0.104	0.976	0.024
(6) CM	1	0	0.896	0.104	0.976	0.024
(7) DR&TD	0.947	0.053	0.895	0.105	1	0
(8) OA&S	0.987	0.013	1	0	0.939	0.061
(9) TRL	1	0	1	0	0.979	0.021
(10) O&SR	1	0	0.938	0.062	0.978	0.022

Table 6.
True and false table.

alternatives [17]. When nonlinear factors are present, MCDM techniques are beneficial for discriminating among alternatives. Nonlinear factors are cases where the units of measurement (e.g., feet, seconds, Fahrenheit, and miles/hr.) are not the same. In the case of linear factors, the units of measurement are the same across the attributes or criteria. MCDM techniques can be categorized as fuzzy, stochastic or deterministic [20]. Additionally, a popular MCDM was examined for validation and or comparison to the SABANP result. The MCDM is TOPSIS. TOPSIS was chosen because of its popular usage in the literature and because it is capable of providing a deterministic data approach that accounts for the expert judgment participation, the dimensional criteria space, the methodical representation, and the explanation.

Four steps are required in any decision-making approach that relies on numerical analyses of alternatives to assess system factors' nonlinearity when selecting an MCDM methodology:

1. establish the relevant alternatives and criteria,

2. allocate numerical values to the criteria weights and the alternatives' impacts on the criteria,

3. assess the nonlinearity related to the system in consideration when choosing an MCDM method, and.

4. process numerical values to rank each alternative [17, 21].

There are several methods used to determine criteria weights, such as weight-assessment models [22, 23]. Certain authors have stated that standards are not available for defining which technique yields the most accurate criteria weight because whether the technique is biased is uncertain [24]. Others have suggested pairwise assessment matrices to calculate the significance or weights of criteria [18, 25]. A weighting method can be categorized as subjective or objective, algebraic or statistical, decomposed or holistic, and indirect or direct [17, 26]. In this study, the direct weighting method is selected because this method allows the decision maker to rank the criteria and provide subjective values to the criteria weight based on the defined rank. The direct weighting method was utilized in the analysis of TOPSIS, however, SABANP requires no weight inputs. Often weights are difficult to quantify when there are many experts. The benefit of having no weights is that it simplifies the decision matrix and provides for optimal decision making.

3.2.1 TOPSIS analysis

Established by Yoon [27] and Hwang & Yoon [28], the basic principle underlying TOPSIS is that the selected alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution [29]. **Figure 5**, which is adapted from Adetunji's [6] graphic, depicts an assumption

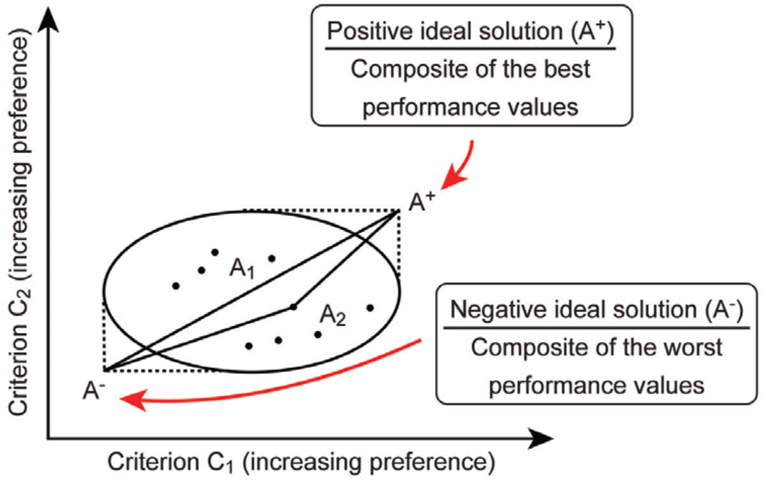

Figure 5.
Technique for order of preference by similarity to ideal Sslution (TOPIS) graphical representation.

for two criteria, where (A^{-}) is the negative ideal solution and (A^{+}) is the positive ideal solution [17, 28]. The negative ideal solution is made up of the worst performance value of all the alternatives. The positive ideal solution is made up of the best performance value of all the alternatives.

Justifying the selection of A_1 is difficult [17, 29] as shown in the visual example in **Figure 5**; therefore, the proximity (relative closeness) to each of these performance poles (A^{-}) and (A^{+}) is measured in the Euclidean sense [17, 28, 30], for which the square root of the sum of the squared distances along each axis is in the 'attribute space' [30].

The following steps are required to conduct a TOPSIS analysis:

1. The normalized decision matrix is first determined using Eq. (7). The normalized score (r_{ij}) is calculated to transform the various attribute dimensions X_{ij} from the raw data into non-dimensional attributes, thus allowing for comparisons among the attributes [17, 28, 29]:

$$r_{ij} = {}^{X_{ij}}\!/\!\sqrt{\sum_{i=1}^{m} X_{ij}^2}, \textit{where } i = 1, 2, 3, 4 \dots, m; j = 1, 2, 3, 4 \dots, n \tag{7}$$

Table 7 shows the normalized decision matrix.

2. Calculate the weighted normalized values (v_{ij}) by multiplying r_{ij} by the criterion weights (w_j) [17, 28, 29] (see **Table 8** and Eq. (8)):

$$\boldsymbol{v_{ij}} = w_j r_{ij}, \textit{where } j = 1, 2, 3, 4 \dots, n; i = 1, 2, 3, 4 \dots, m \tag{8}$$

The weighted normalized values are shown in the weight normalized matrix in **Table 8**.

3. Evaluate the positive (A^{+}) and negative (A^{-}) ideal solution using Eq. (9) [17, 28, 29]:

Criteria	IBS DDG-51 Class:	IBS CG-47 Class:	IBS CVN-68 Class:
(1) P&F	0.386	0.355	0.386
(2) Cost	0.332	0.327	0.401
(3) PT	0.362	0.355	0.392
(4) RAM	0.377	0.364	0.388
(5) PR	0.399	0.354	0.382
(6) CM	0.397	0.356	0.387
(7) DR&TD	0.371	0.351	0.392
(8) OA&S	0.382	0.387	0.363
(9) TRL	0.373	0.373	0.366
(10) O&SR	0.374	0.398	0.382

Table 7.
TOPSIS normalized decision matrix for IBS.

Criteria	IBS DDG-51 Class:	IBS CG-47 Class:	IBS CVN-68 Class:
(1) P&F	0.073	0.067	0.073
(2) Cost	0.040	0.039	0.048
(3) PT	0.022	0.021	0.024
(4) RAM	0.057	0.055	0.058
(5) PR	0.044	0.039	0.042
(6) CM	0.028	0.025	0.027
(7) DR&TD	0.033	0.032	0.035
(8) OA&S	0.027	0.027	0.025
(9) TRL	0.022	0.022	0.022
(10) O&SR	0.030	0.032	0.031

Table 8.
TOPSIS weighted normalized decision matrix for IBS.

$$A^+ = \left\{ \left(\max_i v_{ij} \,|\, j \in J \right), \left(\min_i v_{ij} | \, j \in J^+ \right) | \, where\ i = 1, 2, 3, 4 \dots, m \right\} \tag{9}$$

$$= \left\{ v_1^+, v_2^+, v_3^+ \dots, v_j^+, \dots, v_n^+ \right\},$$

$$A^- = \left\{ \left(\min_i v_{ij} \,|\, j \in J \right), \left(\max_i v_{ij} | \, j \in J^- \right) | \, where\ i = 1, 2, 3, 4 \dots, m. \right\}$$

$$= \left\{ v_1^-, v_2^-, v_3^- \dots, v_j^-, \dots, v_n^- \right\},$$

$$\mathrm{J}^+ = \{\mathrm{j} = 1, 2, 3, 4 \dots, \mathrm{n} |\ \mathrm{j\ relates\ to\ the\ benefit\ criteria}\}.$$

$$J^- = \{\ j = 1, 2, 3, 4 \dots, n |\ j\ relates\ to\ the\ non - benefit\ criteria\}$$

The A^+ and A^- solutions are shown in **Tables 9** and **10** respectively.

V1-V10	Positive Ideal
V1+ =	0.073
V2+ =	0.039
V3+ =	0.024
V4+ =	0.058
V5+ =	0.044
V6+ =	0.028
V7+ =	0.035
V8+ =	0.027
V9+ =	0.022
V10+ =	0.030

Table 9.
TOPSIS positive ideal solutions for IBS.

V1-V10	Negative Ideal
V1- =	0.067
V2- =	0.048
V3- =	0.021
V4- =	0.055
V5- =	0.039
V6- =	0.025
V7- =	0.032
V8- =	0.025
V9- =	0.022
V10- =	0.032

Table 10.
TOPSIS negative ideal solutions for IBS.

4. Calculate each alternative separation from the positive (s_i^+) and negative (s_i^-) ideal solutions (use the n-dimensional Euclidean distance) using Eq. (10) [17, 28, 29]:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v^+{}_j)^2 \; where \; i = 1, 2, 3, 4 \dots m,} \tag{10}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v^-{}_j)^2 \; where \; i = 1, 2, 3, 4 \dots m}$$

Tables 11 and **12** show the separation measures between the positive and negative ideal solutions.

5. Calculate the relative closeness of each alternative to the ideal solution (c_i^*) [17, 28, 29] using Eq. (11):

S1-S3	Positive Ideal
S1+ =	0.003
S2+ =	0.010
S3+ =	0.009

Table 11.
TOPSIS separation Mmasures to positive ideal solutions for IBS.

S1-S3	Negative Ideal
S1- =	0.012
S2- =	0.009
S3- =	0.009

Table 12.
TOPSIS separation measures to negative ideal solutions for IBS.

Position(s)	Organization(s)	Years of Experience
(1) Principal Logistics Specialist	DoD (NSWC Philadelphia)	+25
(2) Principal Logistics Specialist	DoD (NSWC Philadelphia)	+25
(3) DMSMS/Obsolescence Engineer	DoD (NSWC Philadelphia)	6
(4) Logistics Manager	DoD Contractor (ICI Services)	+35
(5) DMSMS/Obsolescence Analyst	NAVSEA SEA 21	+7
(6) ILS/Configuration Manager	DoD Contractor (ICI Services)	+35
(7) DMSMS/Obsolescence Team Lead	DoD (NSWC Port Hueneme)	+10
(8) ILS Program Manager	DoD (NSWC Port Hueneme)	+15
(9) ILS/Systems Engineer	DoD Contractor (LCE Inc.)	+30
(l0) DMSMS/Obsolescence Manager	DoD (NSWC Philadelphia)	+20
(11) Obsolescence Engineer	DoD Contractor (Alion Science)	+30
(12) ILS Engineer	DoD Contractor (NDI Engineering)	+15
(13) Operations Engineer	DoD (NSWC Philadelphia)	+10
(14) ILS Program Manager	DoD (NSWC Philadelphia)	+15
(15) DMSMS/ILS Engineer	DoD (NSWC Port Hueneme)	4
(16) DMSMS/Obsolescence Engineer	DoD (NSWC Philadelphia)	+5
(17) DMSMS/Obsolescence Technical Rep.	DoD (NSWC Philadelphia)	+5
(18) DMSMS/Obsolescence Analyst	DoD (NSWC Philadelphia)	+4
(19) Systems Engineer	DoD Contractor (DDLOMNI Engineering)	+20

Table 13.
Experts' demographics.

$$c_i^* = S_i^- / (S_i^- + S_i^+), \; 0 < c_i^* < 1, i = 1, 2, 3, 4 \ldots, m \tag{11}$$

$$A_i \; equals \; (A^+) \; if \; c_i^* equals \; 1; A_i \; equals \; (A^-) \; if \; c_i^* \; equals \; 0$$

6. Sort the order of preference alternatives by the descending order of c_i*: The nearer c_i* is to one indicates a higher importance of the alternative [17, 28, 29].

3.3 Delivery mechanism

Before administering the research survey, each research participant was provided an information sheet and consent form to complete and instructions on how to complete the survey. Once retrieved, the survey files were password protected and saved. The experts' participation in the study was voluntary and anonymous. The breakdown of the experts' demographics is shown in **Table 13**.

4. Results

100 runs of data that were collected from the SABANP model using the IBSs on DDG-51, CG-47 and CVN-68 were aggregated. The results revealed that the DDG-51 IBS has a 52% probability of being the best system among the systems examined

in the trade-off analysis as shown in **Table 14**. The CG-47 IBS is the second best with a 51.78% probability, shown in **Table 15** and the CVN-68 IBS is the third best with a 51.56% probability as shown in **Table 16**. The sensitivity analysis conducted on the result over ten thousand times shows that the DDG-51 IBS is less susceptible to obsolescence than its counterparts.

The results of the SABANP model also revealed that in the 100 runs with respect to the best system, Procurement (PR), which includes Vendor Assembly and Installation support, at 79.1% is a critical criterion path that could have the most adverse effect on a system's lifecycle operations, and it should be prioritized with respect to the design, development, testing, maintenance. This is followed by the TRL at 76.1%, O&SR at 75%, and DR&TD at 72.1%. The least adverse effect is the availability of OA&S at 16.5%. **Table 17** show the breakdown of the likelihood of an impact for each obsolescence criterion across the systems that were selected.

Runs	Worst	Best
1	62.2	37.8
2	50.8	49.2
3	48.5	51.5
4	32.3	67.7
5	67.5	32.5
•	•	•
•	•	•
•	•	•
99	72.9	27.1
100	49.6	50.4
Aggregated Values:	**47.99**	**52.01**

Table 14.
SABANP runs DDG-51 IBS.

RUNS	Worst	Best
1	63.7	36.3
2	49.2	50.8
3	48.5	51.5
4	32.3	67.7
5	67.5	32.5
•	•	•
•	•	•
•	•	•
99	35.1	64.9
100	57.7	42.3
Aggregated Values:	**48.22**	**51.78**

Table 15.
SABANP runs CG-47 IBS runs.

RUNS	Worst	Best
1	66.5	33.5
2	49.2	50.8
3	48.5	51.5
4	32.3	67.7
5	67.5	32.5
•	•	•
•	•	•
•	•	•
99	35.7	64.9
100	57.7	42.3
Aggregated Values:	**48.44**	**51.56**

Table 16.
SABANP runs CVN-68 IBS runs.

		Rank (1)	**Rank (2)**	**Rank (3)**
Criteria	Measure	IBS DDG-51 Class	IBS CG-47	IBS CVN-68
(1) P&F	HIGH	43.40%	79.90%	22.1%
	LOW	56.60%	20.10%	77.9%
(2) Cost	HIGH	51.40%	49%	50.2%
	LOW	48.60%	51%	49.8%
(3) PT	NOT HIGHLY REQUIRED	49%	74.8%	61.7%
	HIGH REQUIRED	51%	25.2%	38.3%
(4) RAM	HIGH	28.60%	17.8%	92.4%
	LOW	71.40%	82.2%	7.62%
(5) PR	SUPPORTED	79.10%	72.8%	34.4%
	UNSUPPORTED	20.90%	27.2%	65.6%
(6) CM	NOT AVAILABLE	55.10%	58.2%	59.9%
	AVAILABLE	44.90%	41.8%	40.1%
(7) DR&TD	NOT PROVIDED	72.10%	61.3%	62.4%
	PROVIDED	27.90%	38.7%	37.6%
(8) OA&S	NOT AVAILABLE	16.50%	42.2%	75.4%
	AVAILABLE	83.50%	57.8%	24.6%
(9) TRL	HIGH	76.10%	67.4%	37.2%
	LOW	23.90%	32.6%	62.8%
(10) O&SR	HIGH	75%	42.2%	75.4%
	LOW	25%	57.8%	24.6%
Aggregated Result	**Worst Case Probability**	47.99%	48.22%	48.44%
	Best Case Probability	52.01%	51.78%	51.56%

Table 17.
Likelihood of impact for each obsolescence criterion across the selected systems (N = 100).

Systems	TOPSIS "S"	TOPSIS "R"
DDG-51 =	0.795	1
CG-47 =	0.473	3
CVN-68 =	0.494	2

Table 18.
IBS ranking of the result (TOPSIS) solutions. "S" score and "R" ranking.

4.1 Validation

To validate the results, comparative analyses were done using TOPSIS. Whereas for SABANP, the weight data were not required since normalization was the only required parameter. The result shows that TOPSIS ranked the DDG-51 IBS as the best system, which follows the results provided by the SABANP model. The results of the ranking and comparisons to TOPSIS is found in the **Table 18**.

5. Conclusions

The use of SABANP for obsolescence management and as a method for selecting the system or technology that could potentially mitigate obsolescence early in the design stage of a system was successfully demonstrated. The results also indicate that systems should be designed with a proactive obsolescence approach in mind. MCDM that is deterministic (TOPSIS) model was also applied and demonstrated similar results in identifying the best systems among alternatives that mitigate obsolescence. The proposed model is shown to successfully combine quantitative and qualitative expert judgment data that incorporate attributes such as risk and training criteria using SABANP in order to efficiently propagate the evidence of obsolescence.

The analysis conducted in this chapter can serve to provide a holistic analysis of obsolescence in systems. The results of the data analysis were presented to the experts, and concluded that the IBS on DDG-51 was the best system for mitigating obsolescence. Future research should be focused on conducting systems engineering trade studies with the use of SABANP in decision making. This allows for the documentation of early decisions in a program and reducing long-term waste. Notwithstanding, it is recommended that all identified criteria in this work be prioritized equally in the design, development, testing, and maintenance.

This chapter recommends the use of SABANP in obsolescence management in order to conduct trade studies for systems during the design stage. The chapter does not intend to be an authoritative decision mechanism nor provide a recommendation for the best MCDM to use for the normalization technique. Rather, it serves as a new tool, approach, or guidance in obsolescence decision management. Additionally, future research can evaluate the normalization of other MCDM techniques in comparison to the SAW that was utilized in the SABANP model.

Author statement

This chapter is an extension of the author's original published research article. The views that are conveyed in this article are those of the author and do not represent the official policy or position of NSWC Philadelphia, the DoD, and its contractors, or the U.S. Government.

Acronyms

BBN	Bayesian Belief Network
CG-47	USS Ticonderoga
CM	Configuration Management
COTS	Commercial Off-the-Shelf
CVN-68	USS Nimitz
DDG-51	USS Arleigh
DMSMS	Diminishing Manufacturing Sources and Material Shortages
DR&TD	Data Rights and Technical Documentation
IBS	Integrated Bridge System
MCDM	Multi-Criteria Decision Making
NETICAL	NETICAL Software Tool for modeling system criteria dependence
RAM	Reliability, Availability, and Maintainability
SABANP	Simple Additive Bayesian Allocation Network Process
SAW	Simple Additive Weighing
SME	Subject Matter Expert
OA&S	Open Architecture and Standards
O&SR	Obsolescence Schedule Risk
P&F	Performance and Functionality
PR	Procurement
PT	Personnel Training
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
TRL	Technology Readiness Level

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Chapter 10

Political Leadership and Financial Emoluments: A Case of Developing Countries

Daniels Aide Okun and Osama Ose Iyawe

Abstract

The theoretical concept of political leadership would have to be the most elusive and fluid concept of leadership. It has within its authority dominated policies, influenced security- intelligence, shaped intellectual-cultures, inspired citizens-aspirations and has directed the trajectory of nation-states and sovereignties within international governance and global affairs. The political behaviors of developing nations through foreign policies, national interests and diplomacy have been a reflection of the authority of their political leadership; regime after regime. There are no best-kept secret to the fundamental strengths and weaknesses of political Leadership other than the influential impact of the political leader's self-empowerment, self-leadership and self-legacy. Political Leadership is fundamentally controlled by the polices of choices where decisions meet actions and authoritarian powers redefines humanity. The elusive extent, and fluid depth of political influence through the impact of governance does not measure -up to the assurance of humanity in most developing countries around the world. The political consciousness and idiosyncrasies of most individuals over the years have contributed none or fewer interests to the study, the justification, and the analytical reasoning of the influence of political leadership. This new study and the assertive findings on this chapter are aimed to pragmatically educate, inspire, and reignite the zealousness of visionary leadership, through the consciousness of humanity. The intellectual assertions in this chapter are envisioned to create, expand and illuminate the distinctive reality between of our profound empirical knowledge, theoretical beliefs and interpretive researches on the conceptual understanding of political leadership. The topics in this chapter are aimed to create an endless stream to the consciousness of political leadership and financial gains to the betterment of humanity. It expands the understanding of political leadership through psychological lens beyond the titles, offices and political display of power. Political leadership in developing countries can improve and offer better outcomes in todays world, when humanity meets the consciousness of political leadership in financial prosperity. The societal divisions of ethnicity, wealth and the polarization of political ideologies into sets of beliefs, questions the influential impact of political leadership. As political leaders govern and navigate through their leadership goals, aspirations and visions more often than not, the traits of their ethnic identity, individuality and beliefs constantly create struggles with their understanding and acceptance of humanity as a whole.

Keywords: individuality, nationality, opportunity, corruptibility, profitability, political consciousness, loyalty, humanity, service, legacy

1. Introduction

The theoretical concepts of political leadership creates an in-depth understanding of the societal consciousness of the political processes and the outcomes of the quality of leadership; retrospectively classical writers like; Niccolo Machiavelli, Robert Michels and Max Weber explored theoretical ideas, arguments, and definitions of the authority of political leadership. Political leadership has always had a great influence and an impact on the empowerment of the nation-building process of countries. The never-ending challenges and struggles that political leaders are faced with is the economic reality of their nations which have always been the question that dictates the achievements of the leadership quality of a political leader.

Political Leadership is the patriotic state of consciousness that ignites the spirit of nationalism, and the pride of citizenship that unifies ethnic diversity.

Political Leadership is the act of governance that distinguishes: leadership from politics, integrity from loyalty, and humanity from prosperity.

Political Leadership centers on the duties of social responsibilities, nation-building, cultural capital, and the welfare-betterment of humanity.

Political Leadership does not symbolize nor define left wing - right wing political competition against ideologies, positions, and party dominance on the political spectrum. It represents, justifies and validates the essence and advancement of togetherness through communal systems in the presence and acceptance of diversity.

The accountability demands, credibility measures and aspirational heights of political leadership ought to be grounded in their profound values and beliefs on humanity, capacity development, life and security. Conversely more often than not; these measures of expectations are solely directed to economics, financial gains, wealth creation and individual wealth appropriation which clearly never answers the deeper questions to the efficiency of political leadership.

Political Leadership avails a fundamental social responsibility for the unification of social cohesion in the presence of diversity, divides and conflicts in order to achieve a collective human-capital force that assures economic growth, prosperity, survival and protection. Pragmatically, these assertions do not resonate with the political realities of most developing countries; it is conversely on the opposite, state of affairs were political leadership disregards, excludes humanity from governance through the tactics of politics which hardly represents the ideals of leadership but utilizes the rustiness of power through authority.

The theoretical understanding of Political Leadership is not as elusive and fluid as presented overtime it is the trust-given responsible to serve, lead and advance the betterment of humanity harmoniously through prosperity, humanity capacity development and cooperation.

There a question in the developing countries that everyone dares and struggles to get an answer to which is:

"Why are the offices of political appointees, and leaders synonymous to the bank of wealth? ".

I believe pensively, that this question may never be answered as it references and represents a norm, a culture and a tradition that is systematically instituted to picture a reality. The inhibitions of political Leadership is found in the sensitivity and in the powerful pieces of decision making process and the execution of action that are constantly motivated by visionary leadership and inspired by the enthusiasm and compassion for humanity.

Political leaders are faced with the battle of consciousness between "Efficiency and Effectiveness". Confidently ensuring that their tasks and responsibilities are executed perfectly right apt enough to better welfare and ensuring that they are standing, endorsing and motivating the right actions that will justify the path of humanity towards peace, betterment and prosperity.

Political Leadership is not the absence of the quality, compassion and ideals of the other forms of leadership. But rather; it is indeed the collective accumulation of all the other forms of leadership aimed for a collective and mutual betterment and good for humanity. The stereotypical negative connotations of political leadership been associated and linked to corruption and wealth embezzlement has indeed created a social construct, a message of deceit and a norm which has hindered leadership accountability, credibility, selfless responsibilities, and expectations from the political leader.

Political Leadership is the given-responsibilities and authority by trust, belief, and assurance to an individual with the identification of patriotic loyalty, recognition of leadership, and compassion for humanity. Political leadership is not a game of politics, a display of wealth nor is it a competitive showcase of power and authority, it is the real business of putting humanity, first and above, policies, interests, ideological bents, beliefs and traditions. Political leadership is the combination of power, intelligence, security, wealth and authority into a force for enthusiasm and compassion for humanity.

Political leadership owes the people no greater speech, no greater promise, no greater policies, no greater agenda, no greater army, no greater bridges, no greater roads than the effective and efficient building of better, stronger and greater tomorrow that ensures and insures the harmonious -collective - consciousness of purpose, dedication to duty and the validation of the worthiness of humanity.

There will be no greater oath of office, affirmation of a strong-will dedication to office, than the one that specifically centers on the core fundamental values, principles and compassion for the greater good, advancement and prosperity of humanity in its worthiness and validation.

The swearing in to office of any appointed political leadership opportunity ought to be the-one-and-only social consciousness to duty that should exhilarate, justify and empower the interests, ambition and intentions to govern with political authority a leader can have.

The fear, anxiety and bravery to serve humanity through political leadership should be an oath of sacrifice, an allegiance to dedication of self and a pledge to better humanity with all the resources there is within or outside the sovereignty of nation states.

Political leadership creates the means and justifies the means to govern humanity towards the path of betterment by the people for the people and with the people. This does not make it a complicated mission to accomplish, it rather eliminates the space for self-interests, personal gains, personal agendas and competition of self-greatness. It reaffirms the truth bearing of faith and allegiance to serve humanity for a greater, better and a more harmonious life of creation that humanity is worthy of and validated for.

Political leadership is an authoritative responsibility that creates more for the people than it takes from the people. It is an office that benefits all, an opportunity that creates sustainable growth, progressive advancements and a harmonious culture for productivity. There is an endless path to the progressive advancement of political leadership in developing countries that ought to journeyed on, that path can only be traveled through with the human- capacity- development- investment- and- advancement as the only policies of change that should be demanded and gotten.

The theoretical concept of Political leadership is asserted to be an authority symbolic to parenthood. It carries on, upon it the responsibilities, the never ending

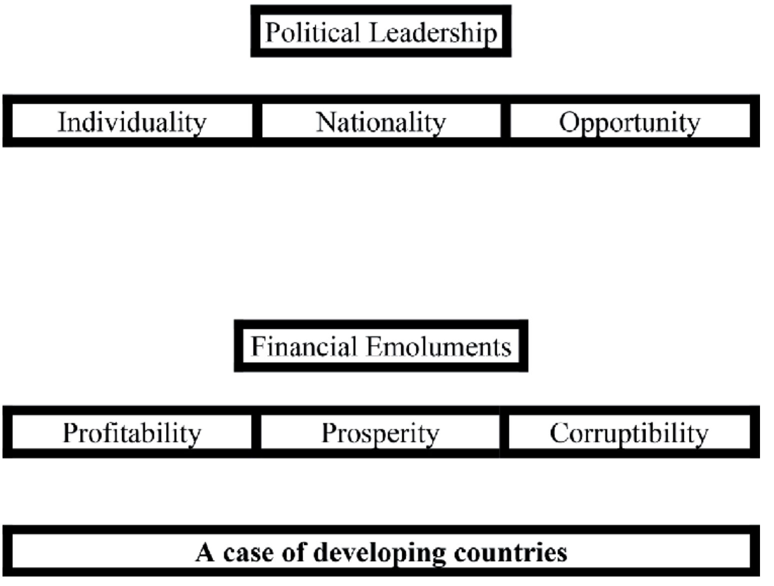


Figure 1.
Schematic Presentation of the title's core Components. Authors Compilation (2020).

duty of ensuring and insuring the betterment of humanity with which all the other means and agendas of prosperity is assured.

Political leadership in developing countries owes its humanity more than just the legal obligations of citizenry by means of identity but to the embracing of what it truly means, symbolizes, represents deeply, compassionately and emotionally to be a citizen of a country regardless of its political, socio-economic and moral status. Until the betterment of humanity as the only capital source of wealth is assured it is impossible to enrich or discover the wealth in any nation in the absence of slavery and exploitation.

Political Leadership is patriotically the social-political consciousness of the authority to utilize power to the ultimate advantage of the betterment of its humanity regardless of political realities, international regimes or competitive economic markets.

It is in the authenticity and intentions of purpose and the protection of citizenry that nation's competitive advantages are born. No nation could hardly excel productively, economically and intellectually without its citizenry. It is the putting first and above of its citizenry by political Leadership that puts a nation above other nations on the global map of relevance and power. No nation could journey without a strong-willed political Leadership that assures and insures the existence of its citizenry in a proud state of humanity (**Figure 1**).

1.1 Worthy of notice

The consciousness of individuality, the awareness of self worth, the embracing of nationality and the privileges of leadership opportunities are fundamental to the understanding and recognition of the influential authority of political leadership.

2. The S-E-L-F approach to political leadership

The theoretical practice of political leadership is structured in systematic processes and alignments that have become institutionalized norms, cultures,

The S-E-L-F Approach

S: Selflessness in the service of humanity

- The selflessness of service to humanity through political leadership defines and justifies the core values, driven-purpose, visionary inclinations, missions, goals and aim of office.
- A political leader truly assumes the affirmation of duty to serve when they are fully prepared to lay-off selfishness of interests, inhibitions, gains and agendas.
- Political leadership becomes the finest and most powerful form of leadership when it is without an iota of selfishness.

E: Enthusiastically apt enough to empower humanity

- Political leadership through authority, power, justice, institutions, structures and systems can invest in the humanity capacity development, advancement and betterment of its citizenry.
- Profoundly, it is through these investments, that individual are empowered, strengthened to create opportunities, hope, prosperity of peace and wealth in the country.
- Political leadership owes its citizenry the protection, security and assurance of wealth creation through human empowerment and capacity development. Political leadership ought to invest in the human capacity development of its citizenry.

L: Loyalty to the labor for humanity

- Political leadership has a meaningful purpose and an impactful mission when it is in alignment with humanity with the strongest feeling of support and allegiance to its betterment.
- This is when the harmony of purpose, collective consciousness, and oneness in purpose, the rule of law and a state of equality justifies the commonality of political leadership, authority and influence of power in the society.

F: Fundamental policies of Followership through humanity

- Political Leadership is the formulation of the fundamental values and polices on followership through humanity which broadens and deepens the duty of service through political leadership.
- The theoretical concept of followership is functional when political leadership is invested in the collective collaboration and strengthened relationship between political leaders and citizenry.
- The strength of followership is a political tool for collective consciousness, progressive prosperity and intelligence security. Followership on both sides; the citizenry to political leaders and political leaders to citizenry.

Figure 2.
Schematic Presentation of the concept of SELF. Authors Compilation (2020).

social constructs and beliefs that have either advanced or hindered the progress of political leadership.

Political Leadership is broader than an office or a position it is a functional duty, a political responsibility, a social responsibility, a patriotic duty, an oath of office and an allegiance to service. The huge shoulders of these responsibilities are sensitively influenced, motivated, controlled and manipulated by a holistic range of factors that directs the pace, the choices, the decisions and the impacts of political leadership duration the cause of time [1].

The situational reality of political leadership and the call to serve in developing countries is a unique case study one that involves a wider and deeper understanding of how individuality plays a huge role and creates a deep impact in social constructs and definition of political leadership (**Figure 2**).

3. The S-E-L-F approach

The S-E-L-F approach to political leadership is a psychological framework and a guiding-tool to the state of consciousness for political leadership. It serves as a leadership mantra for the formulation of political policies, fundamental structures and the institutionalization of systems that justifies and validates the efficiency and effectiveness of political leadership. Political Leadership therefore, becomes more effective and efficient when it serves humanity through its policies, interests, institutions, foreign policies, diplomacy, structures and systems.

4. The influential impact of individuality on political leadership

Political leaders are influenced by their personality traits, which creates an intellectual opening for them on how they view, see and assert the roles of political leadership. A visionary outlook on life's struggles, strives, successes and strengths is created from the persona of an individual. The mindset of an individual creates a map of imagination, dreams and visions which controls the levels expectations and ambitions that an individual can experience and birth. While it is important to define political leadership on the standards and principles of what it should be, what it is expected to accomplish and how it's expected to achieve much through humanity for humanity and by humanity; it is also fundamentally crucial to assert the influential impact of individuality on political leadership. The political tools needed to function effectively in office by a political leader is hugely influenced by the leader's character traits, behavioral strength, self-knowledge, and personality which builds and forms a mental strength that develops the leader's political skills, political intelligence, political strategy, and political approach to duties [2].

The understanding of the influential impact of individuality on the effectiveness of political leadership creates a broadened knowledge on how far a nation can journey and strive progressively under the regimes, policies and adopted systems of governance. The individuality of political leaders comes first in the direction and utilization of their political will and governing authority. What saves a political system from the collapse of individualistic anarchism is the consciousness of selfishness in humanity.

Pragmatically, the idiosyncrasies of most political leaders is clearly seen in the extent of how far they bring their own; ideologies, needs, wants, desires, responsibilities, goals, and targets to the political arenas during their regime; this then becomes fundamentally crucial to the state of success and advancement of their leadership role. While the Individuality of political leadership disregards and ignores the humanity of citizenry, it embezzles and plans to exploit excesses for selfishness through corruption and political isolation [3].

The executive actions of a political leader does not pose much an important question. The reason "why" the executive actions were carried out appears to be more crucial and worthy of understanding. Political leadership is crafted on the visionary path, mission and betterment of humanity, it is a selfless agenda aimed at ensuring the collective prosperity and advancement of humanity is assured. Compassionately, when individualism and collectivism compromises interests, needs and values for the purpose of advancement collective humanity, it brings alive the strengths and greatness of political leadership [4].

There is a greater possibility for political leadership to utilize profound individualism for compassionate collectivism for the betterment of humanity. Political leadership in the sovereign space of individuality where the rationality of self-interest prevails, show there is a recognition of true individualism. It is one that is associated and identifiable with compassion, consciousness and empathy for humanity.

Compassionate collectivism makes it possible for individualism in political leadership to collaborate interests, needs, desires and agendas into a submerged goal for the greater, mutual and collective good of humanity. This is indeed the greatest challenge of conflicting ideologies of interests that is socio-consciously reconcilable and achievable. Collectivism becomes an intellectual tool for security, prosperity and harmony, when individualism through political leadership perpetuates and creates systems that are powerfully apt enough to see humanity as the collective consciousness and influence of the individual [5].

The pursuits and interests of individuality can be birth in collectivism when it recognizes and validates the presence of humanity. Political Leadership strives stronger and greater through the influential impact of individuality, when its individuality is submerged in the security of collectivism for humanity. Political leadership through the impacts of individualism, collectivism and humanism makes it possible for effective and efficient governance to succeed in a struggling world. The psychological presence of individuality makes it possible for dreams to be envisioned and for inspiration to illuminate aspirations [6].

As individuality is key to self-leadership, so is it fundamentally present in political leadership. The recognition of the self-centered fulfillment of individualism in political leadership and the unresolved conflicts of division and the widened gap of poverty, makes is consciously sensitive for political leadership to find the strengths of individuality in collectivism for the betterment, advancement and prosperity of humanity [7].

5. The financial emolument of political leadership

Political Leadership has its payoffs, incentives as well as rewards just like every other endeavor and aspiration. All leaders in every sphere of influence, deserve to be honored respected and remunerated for work done and inputs made as a result of responsibilities tied to such leadership roles. From a political perspective, the benefits and returns for leadership responsibility varies. They include emotional, monetary, territorial, economic, physical and even legal. Motivations for leaders vary also, depending on personal traits, inclination and situation. The bottom-line is every political leader has a motivating factor that is tied to a reward whether it is positively or negatively aligned. Prolonged observation and evaluation has shown especially in developing climes that the monetary gain seems to be the highest motivating factor.

It must be understood at every point in time that every leader especially a political one, is just as human as any other individual. They have needs and desires just like everyone and have their emotions active accordingly. Their fundamental senses are at work just like all healthy humans. The preceding statement is vital, so as not to have overbearing expectations political leaders, even though more is required of them by virtue of the leadership positions they now occupy.

But then again, it behooves on us to assess political leaders on their true motive for taking up political positions and offering themselves for service. Evaluations of political leadership from developing countries in continents like Africa, have shown that more often than not, monetary benefits and self-aggrandizement are their primary focus.

Let us take into consideration a country like Nigeria for instance. Judging from her statistics and natural endowments, she ought to be the innovative driver for Africa. Is this the scenario at play currently? Apparently, it is not. A country richly endowed with natural resources and high quality human capital, but it is yet to find its rightful place among the comity of nations. A major reason that has been responsible for her socioeconomic stagnation is the element of corruption. Corruption rarely thrives were monetary benefits are not the major incentives attached to deliverables and accomplishments tied to job roles or positions.

6. What is financial emolument?

Emolument is the term used to describe payment for an office or employment; compensation for a job, which is usually monetary. It could also be in form of tangible items such as automobiles or houses but the emphasis in this work is on monetary payments.

7. Financial emoluments and the political leadership motivation

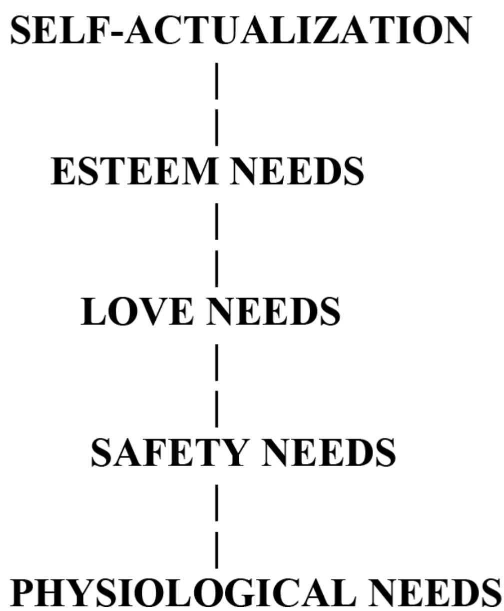
Over the years, money has been the major tool for individual and corporate transactions. It signifies empowerment, economic protection and supremacy. With such paradigm, financial hardship creates scenarios were individuals fall into the despondency from lacking the preceding attributes stated earlier and therefore will see themselves losing out economically, socially as well as territorially- the inability to dominate their sphere of influence. Hence, Political leadership seems to be the quickest route to achieving these aspirations and goals as it affords the political leader the opportunity to wield so much influence and control over vast financial resources by virtue of the scope of his position. One of the few institutional devices obtainable to regulate the action of politicians apart from elections is their remuneration structure [8].

Presently, the quest for political positions for the sake of financial gains, is highest in developing and underdeveloped countries. It is not so difficult to know why this is so. Such countries, have the weakest economies and inefficient institutions. Based on the foregoing, individuals in these nations see political leadership- because of the influence attached to it, as the fastest route to self-aggrandizement and acquisition of wealth. The emoluments attached to political positions in these countries are so humongous, that within months of being in office, the life and economic status of the office holders usually experience tremendous economic transformation. Critical evaluations shows that such benefits now make the contest for such positions a very intense one even to the risk of the lives of the participants.

Apparently, the nature of political leadership in such countries affects who vies for such offices and also who finally gets in.

8. The Maslow's hierarchy angle

The Maslow's hierarchy of needs is a motivational theory in psychology comprising a five- tier model of human needs, often depicted as hierarchical levels within a pyramid. Needs further south in the hierarchy must be satisfied before individuals can sort out needs northwards. From bottom-up, the needs are: physiological, safety, love and belonging, esteem and self-actualization.



Maslow [9] using the above hierarchy of human need, stated that people are motivated to achieve certain needs and that some needs take precedence over others. From the list, he postulated that our most basic need is that of physical survival and this will be the first factor that motivates our behavior. Articulating that money is key to solving our physical needs, it therefore means that man gravitates quickly to wherever he can acquire funds with ease. Understanding the preceding fact, whatever positions have great monetary benefits attached usually will attract vehement but detrimental interest. Political Leadership is usually not an exception. The monetary emoluments attached to political positions; particularly in developing countries is enormous. As a result, the race to political offices are highly contested to critical levels such that it usually becomes a very risky affair. The acute poverty level in such countries ironically, is connected to the political leaders abysmal performance, creates an intense pursuit for political positions as an easy route to economic hardship.

9. Comparative analysis of emoluments in developing countries

To state that the pay packages of political office holders completely dwarfs that of civil servants/workers in developing countries is not an overstatement. From critical analysis and information sourcing, the civil servants remuneration is match for the average political leader in most countries in Africa. Citing scenarios from Nigeria, according to information captured from online tabloid-Pulse, the average Nigerian Senator earns a minimum of N32million monthly as pay package. And this is to represent a poverty-stricken people of whom most live on less than $1 a day. If we compare this with the earnings of the highest level researcher from the knowledge setup- a Professor, you will see the clear imbalance. The highest earning Professor in a country like Nigeria, with all emoluments put together earns nothing above the realms of N8million annually. Considering that they are the hope for the dissemination of new knowledge and discoveries as well as inventions, such pay in comparison with their political counterparts is appalling. This type of pay disparity will not encourage the youths and upcoming professionals to develop interest in other areas as much as politics. This what will bring all sorts on individuals into the political terrain. Rather than come for service, they will come in for wealth gain which never makes for productive leadership.

10. The profitability and corruptibility of political leadership

Political leadership represents the hope of the citizenry for societal progress and advancement. When political leadership is gotten right, no one misses out of the benefits. This calls for using crucial and well thought out processes to selecting such leaders. When the process is right, we can readily get the right political leaders in position. So also, when the process is flawed, we get to tolerate and endure flawed leadership. Political Leadership must be laced with the right leadership ingredients so as to get profitable outcomes for the citizens, location notwithstanding. Ingredients such as empathy, vision, uprightness, accountability, hard work, charisma, integrity honesty, mentorship, inter-relationship skills, conflict resolution capacity and so on.

There must be stringent laws, ethics and ordinances to guide all political office holders not to fall below the minimum expectation when it comes political positions. The outcomes of their political leadership must be made serious by way of regular accountability and consequences by law enforcement agencies for erring parties. This is crucial, as were the laws concerning political office becomes weak the political leader is at liberty to go overboard with his excesses. In the words of William Pitt "*Unlimited power is apt to corrupt the minds of those who posses it; and this I know, my lords: that where laws end, tyranny begins*". This preceding act has been the bane of unprofitable leadership in developing countries.

To make laws weak or impotent, is to indirectly empower corruption. The weakness of laws and the justice system of any nation is what empowers corruption. Once corruption can thrive within a political leadership space, the productivity of such leadership begins to erode. Consequently, when the political leadership class of a country espouses corruption, it becomes difficult for it to act positively to the benefit of the state and its citizens [10].

11. Case analysis on the corruption effect

As defined simply by Lewis [11] the phenomenon of corruption is referred to as "an impairment of virtue and moral principles".

Because the scenario as obtained in developing countries has painted a picture were political leadership is the path to easy wealth accumulation, corruption has become a systemic and institutional issue in most of these countries. Take for instance the continent of Africa where you have a large proportion of developing countries, a detailed investigation analysis will reveal that most of its leaders (rulers) have occupied those positions for an average of not less than fifteen (15) years. Were the period is less than this, it is possible to have a leader who has lead sometime in the past but has again returned to power. More often than not, this insatiate disposition stems from the quest to acquire possessions inordinately using such office. They forget that they were voted in or appointed to be good custodians of the nation's resources. As regards the above scenario, the case of Zimbabwe comes to mind. There, you had a man who had ruled a nation for 30 years and counting, but was unwilling to relinquish power. What could make a man so stuck on a political position after three decades, if not corrupt practices. This does not totally exempt the developed nations of corrupt political leadership, but we can deduce that it is not to the degree found in developing and underdeveloped nations.

A country like Nigeria who at present, ought to be the economic and industrial giant of Africa, has failed to assume this position for no other reason than highly institutionalized and syndicated corruption. Right from the pre-colonial (before 1960) era till now, the phenomenon has kept rearing its ugly head unchecked. From laws that give immunity coverage to political office holders to skewed election outcomes in favor of those with large treasure chest and in control of the treasury, the spate of corruption in high places has gone on unabated. A survey on the level of corruption in Nigeria carried out in 2003 by the Institute of Development Research of the Ahmadu Bello University, Zaria ranked political parties in the country third in the list of thirty most corrupt public institutions in Nigeria [12].

It therefore means that if there is be any meaningful change in the political leadership outcomes of developing nations, there must be a head on approach to corruption; financial corruption as a matter of fact.

12. The 21 pensible principles of political leadership

Political Leadership transcends through humanity the very powerful capital that influences and justifies the pathways, actions, policies and decisions of governance.

While in the absence and disregard of humanity political leadership assumes a different position and duty in regimes of most developing countries.

When it is not in the interests of political leaders to serve humanity through progressive policies of actions and in their political willingness to better the humanity of their citizenry; political leadership becomes exploitation, suppression and oppression.

The 21 pensible principles of political leadership represents the fundamental truths to the consciousness that ought to provide, protect and govern humanity in a striving world of survivals:

1. Political Leadership ought to serve humanity selflessly.

2. Political Leadership ought to inspire the creation of prosperity for its citizenry.

3. Political Leadership ought to collaborate and partner with its citizenry.

4. Political Leadership ought to be accountable for the welfare and betterment of its citizenry.

5. Political Leadership ought to have the credibility and integrity of office.

6. Political Leadership ought to be symbolic to parenthood.

7. Political Leadership ought to assure, and ensure the prosperity of humanity in the insurance of wealth and health.

8. Political Leadership ought to have compassionate knowledge on "what to do for" humanity.

9. Political Leadership ought to have the leadership structural skills on "how to serve" humanity.

10. Political Leadership ought to have the visionary inclinations and intellectual capacity to achieve a desirable future for its citizenry.

11. Political Leadership ought to have the mental intelligence to lead humanity.

12. Political Leadership ought to have the emotional intelligence to defend humanity.

13. Political Leadership ought to have a high-level of spiritual intelligence apt enough to illuminate humanity.

14. Political Leadership ought to have the cultural intelligence to unity the diversity in humanity.

15. Political Leadership ought to have the political willingness and bravery to protect and secure humanity.

16. Political Leadership ought to have protection, provisions, and an advancement for humanity to heights of excellence and security.

17. Political Leadership ought to formulate policies that protects the advancement of human capital, economic capital, social capital and natural capital.

18. Political Leadership ought to have the consciousness of empathy, sympathy and compassion for humanity.

19. Political Leadership ought to give more and take less from humanity.

20. Political Leadership ought to invest, collaborate, educate, enlighten and build humanity.

21. Political Leadership ought to lead through the social-cultural dynamics and diversity of humanity harmoniously and compassionately.

These pensible principles of political leadership are trusted enough to ensure that political leadership can strive for more and excel effectively and efficiently in governance through the consciousness of these principles and compassion for humanity.

13. Conclusion

From the foregoing, it is obvious that Political Leadership must be inspired by acts and expectations beyond financial emoluments. Work has its rewards no doubt but because leadership is about people; particularly political leadership, the incentives attached to political positions as well as public office must not be so enticing. This is so as not to create a scenario, were the responsibilties done, are taken as a means to an end. Political Leadership is first for service to humanity and societal development before anything else. This chapter clarifies in summary that if the structures placed for political offices are not ones that call for service and sacrifice, then the true motive for it will never be achieved. This is most critical in developing countries, were there is so much lack and deprivation.

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Chapter 11

New Technologies and Decision-Making for the Military

Gérard de Boisboissel

"One should act as a man of thought and think as a man of action".
Henri Bergson

Abstract

This chapter aims at reviewing the concept of decision-making on the battlefield for military leaders. Thus, it intends to address the changes implied by the use of new technologies (such as Robots, AI) that will gradually invade the battlefield. The leader of tomorrow will have to quickly manage remote information and keep control of high performance automated systems integrating a certain form of autonomy, including lethal autonomous weapon systems. He must ensure that a global meaning is given to the military action taking place on the battlefield. He has to be able to command to achieve his goals.

Keywords: military, leader, decision-making, decision aid, technology, autonomy, AI

1. Introduction

If the qualities required of a leader to be a good commander and a good decision maker remain constant in human history in the face of the complexity of the battle, the leader of tomorrow will have to adapt to the uses of new technologies. This will allow him to be better informed, and consequently to be more reactive in order to keep the initiative in the manoeuvre, but also to carry his action further and delegate certain tasks to the machines he will have at his disposal. Such adaptations are not trivial, because they reconsider the existing military doctrines, and can call into question the very principle of the hierarchy that makes the strength of armies. It is therefore necessary for the military to know how to use these new technologies through training, but also to know how to keep control of the use of new systems integrating a certain form of autonomy. Above all, it is important for the military leader to preserve the very essence of his very identity: to give meaning to military action and command to achieve his goals.

2. Commandment

Primarily, a military leader must command, which implies legitimate decision-making authority and a responsibility towards the soldiers entrusted to him for the mission which he must ensure.

The command is the very expression of the personality of the leader. It depends on the tactical situation which includes the risk and the obligations of the mission to be carried out.

To be a good military leader implies several additional qualities: to be demanding, to be competent, to have a high moral strength in the face of the difficulties of war, to have confidence in his own abilities and in those put at disposal, to be in responsibility to assume his decisions and for that to put in responsibility his subordinates, and finally to be able to decide in complete freedom.

He is the one who decides and commands. He is the one to whom all eyes turn in difficulty [1], but the exercise of his command requires a demanding discernment between reflection and action.

3. Decision

The military world is very demanding and dangerous. Having to take into account the danger for his soldiers, the danger for himself and the responsibility of the mission he has been given, the military leader should:

- discern in complexity (deploy true situational intelligence);
- decide in uncertainty (have the strength of character to accept calculated risks);
- act in adversity (to unite energies, encourage collective action and make conscious decisions);

This forms the basis of the educational project of the Saint-Cyr Coëtquidan military academy, and perfectly synthesises the objectives of a training system adapted to the officers of the 21st century. However, this initial training must take into account the technological evolutions allowing military decision-makers of today and tomorrow to reduce the fog of war.

3.1 Military leader is accountable for the decision

What is decision-making for a military officer? It consists of choosing between different possibilities and opting for a conclusion among the different possible solutions, while having analysed all effects that this decision implies.

In order to decide, the leader must master the various areas listed below: a perfect knowledge of the mission entrusted to him, of the means at his disposal and of his troops. Nothing is worse than indecision when the lives of soldiers are in danger. His decision must call for moral and intellectual courage.

"The unknown is the governing factor in war" said Marshal Foch. However, the role of the leader is above all to be able to adapt and modify his analysis and the behaviour of his troop in order to respond to unforeseen situations. This ability to adapt is essential to maintain the freedom of action that allows for initiative on the battlefield, and to be able to innovate according to the constraints.

The leader must show discernment in action, to appreciate facts according to their nature and their fair value. This implies being cautious in his choices and the scope of his choices.

Finally, the leader must be lucid, and control his stress, pressure and emotions. These to preserve his "esprit d'initiative".

3.2 Information, the key to victory

To meet all these requirements, information is one of the major foundations for the exercise of the command of the chief. It is the keystone of all military action, to keep the initiative and maintain supremacy on the ground [2].

In fact, information allows the chief to plan the military action, taking into account the means at his disposal, ensuring the transport logistics, and confronting the possible friendly and enemy modes of action in order to determine the manoeuvre that he will conduct.

The management of the information received is reflected "en conduite[1]" by the regular rhythm of reports and situation updates to higher or subordinate levels, in order to anticipate threats and maintain a capacity to react as quickly and efficiently as possible in the face of adversity or any obstacle hindering the manoeuvre.

For the decision-making process to run smoothly, the information must be updated regularly because the situation can change very quickly and the leader will have to adapt his analysis accordingly.

Thus, there is no single decision of the military commander in operation, but a continuum of decisions, some of which are almost routine or implicit, while others require extensive analysis. Some decisions are ultimately critical, as they can result in a favourable or tragic outcome to a given situation.

4. What is fundamentally changing

This chapter addresses the change in the art of decision-making for a military officer, implied by the use of some technologies that will gradually invade the battlefield.

Indeed, some technologies will allow the leader to be better informed, but also to be more reactive in order to keep the initiative. Their management requires a mastery of new data management processes resulting from the digitisation of the battlefield, in particular the possible influx of operational data from the field and their synthesis for the military leader.

4.1 A more accurate and faster remote information acquisition

The one who sees further and before the others is the one who dominates the military manoeuvre. This is what enables him to gain a tactical advantage because the one who acts first with determination is most often the one who wins. Moreover, the ability to see further and more accurately thanks to remote sensors or cameras brings an undeniable advantage to the military leader, enabling him to react faster than his enemy.

Today, spaces are getting tighter, and information can be transmitted in a few milliseconds to any point on the planet, provided that the sensor capturing the information is available. This is done through cyberspace which must be secured for military forces so that they can be sure of the veracity of the data they use. This immediacy of information is a new parameter in the art of command. It forces the leader to make a quick analysis and to be reactive in his response.

It also raises the question of his capacity to process the information, if there is too much data to process. In this case, it will be necessary to process automatically the data as soon as it is received by the systems, to extract only the relevant

[1] "en conduite" is a French expression literally translated by " while driving " which means to decide while the military action is taking place.

information. And if these systems are unable to do this, the leader will have to be assisted in the analysis and decision-making by a third party, which may also be a machine. This raises the question of the control of these decision aids provided and which he must rely on.

4.2 Act remotely to remove the danger and increase the area of action

One of the major military revolutions that began at the start of the 21st century in the Iraq and Afghanistan wars is the robotisation of the battlefield. It is unavoidable and will gradually be introduced into the battlefield because the use of unmanned robots (UAV, USV, UUS and UGV) offers many advantages to the armies that will use them on the ground.

Firstly, it avoids exposing our own combatants, which is all the more important in our modern armies where the latter are a scarce and expensive resources to train.

Secondly, it extends the area of perception and action of a military unit. In a sense, they are the "5 deported senses" of the fighter, i.e. his eyes (camera), his ears (reception), his mouth (transmission), his touch (actuator arm) and even his sense of smell and taste (detection of CBRN products).

As tools placed at the disposal of the combatant, robots will allow him to control the battlefield by deporting effectors or sensors allowing a control of the various dimensions and spaces of the battlefield, on land, in the air, at sea and even electromagnetically. These will thus progressively move the combatant behind the contact zone, in order to move him away from the dangerous area and reduce the risks, or allow him to dive in with the maximum of means at his disposal, thus significantly reducing the vulnerability of the combatants [3].

Finally, the ability to act remotely while preserving the lives of his men will allow the leader to act even the enemy can even deploy his forces for his manoeuvre.

Robotic systems will thus become new tactical pawns that the military leader will now use to prepare his action, to facilitate his progress, allowing him new effects on the enemy, the terrain, the occupation of space and on the rhythm of the action. Especially since these machines will eventually be more efficient, more precise and faster for specific tasks than a human being can be. This is currently evident in industrial manufacturing and assembly plants.

4.3 The disruption of autonomy

This military revolution of deporting action with robotic systems is accompanied by another, no less disruptive, that of the autonomy of these systems. Autonomy will allow for omnipresence of action in the area, 24 hours a day, subject to energy sufficiency. It will allow the machines to adapt to the terrain and its unforeseen events in order to carry on the mission entrusted to them by the military leaders. Autonomous systems will allow them to react to complex situations by adapting their positioning strategy, and even adapting the effects it produces on the battlefield. For example, it may be an automatic reorganisation of the swarm formation adopted by a group of robots to follow an advancing enemy, followed by the decision to block an axis of progression with smoke or obstacles to hinder enemy progression.

However, autonomy is not fundamentally new for a leader. A section or a platoon leader has combat groups under his command, whose group leader who receives a mission has full autonomy to carry it out. The new fact is that if robots are tactical pawns at the disposal of the combatant, and if they can have a certain form of autonomy in the execution of their action, they do not have and will never have the awareness of their action and the capacity of discernment which are characteristics of the human being. This opens up a number of ethical questions regarding the opening of fire that will not be addressed in this chapter (See [3]).

5. The contribution of new technologies to military decision-making

These upheavals are based on technologies that create new opportunities in military decision-making processes.

5.1 All deployed systems are interconnected

The digitisation of the battlefield stems from the constant trend towards the integration of electronic components in all future military equipment, which, coupled with a means of transmission, allow for their interconnection and the dissemination of the information collected. It affects all systems deployed in the field (from weapons systems to military vehicles), right down to the disembarked combatant who, just like any civilian with a smartphone, will be connected to the great digital web of the battlefield and therefore traceable and reachable. Just like every individual in the civil society, every actor on the battlefield is traceable and able to communicate.

5.2 Enriched information

As explained above, technology will enable a faster detection of threats on the battlefield. The Law of Moore has sometimes been used to describe the increase in the capabilities of digital cameras, according to a ratio of "twice as far" or "twice as cheap" or "twice as small" every 3 years. In fact, each innovation allows to see further for a smaller footprint. The digital zoom allows high magnifications but at the cost of algorithmic processing of the image which causes lesser definition quality. It is often paired with the optical zoom, which consists of adapting the focal length to the target you want to look at. Cameras can now merge data from multiple sensors of different types. In particular, thermal imaging allowing you to see a large fraction of the spectrum and to view and measure the thermal energy emitted by an equipment or a human. To which one can add light intensification processes to amplify the existing residual light to recreate an image usable by the human eye, in low light conditions.

All of this fused data can enrich the field of vision of the combatant by superimposing additional data that completes his knowledge of the tactical situation. This is the principle of augmented reality.

5.3 The immediacy of information processing

If data acquisition and transmission is possible, the information should nevertheless be processed. However processing it requires easily accessible hardware and software resources offering the necessary computing capacity to react as quickly as possible, particularly in order to be extremely reactive in situations where the analysis time is too short for a human to do it by himself. Embedded computer software can provide such capacity at the core of deployed systems, but this capability can also be moved to a secure cloud, which can be both a tactical cloud, i.e. a cloud deployed on the battlefield in support of the manoeuvre, or to a further away, highly sovereign and secure cloud.

5.4 To the detriment of human decision-making

This immediacy of information processing allows a hyper-reactivity of systems, foreshadowing the concept of "hyperwar" formulated by General John Allen & Amir Hussain Allen in 2019, which puts forward the idea that the advent of hyperwar is the next fundamentally transformative change in warfare.

"What makes this new form of warfare unique is the unparalleled speed enabled by automating decision-making and the concurrency of action that become possible by leveraging artificial intelligence and machine cognition... In military terms, hyperwar may be redefined as a type of conflict where human decision-making is almost entirely absent from the observe-orient-decide-act (OODA) loop. Consequently, the time associated with an OODA cycle will be reduced to near-instantaneous responses. The implications of these developments are many and game changing[2]".

5.5 A support for information processing

For information processing, the volume of data produced increases exponentially and the accuracy and granularity of the data produced by sensors grows. This trend will become more and more pronounced over time [4].

Military experts usually process observation data retrieved from the battlefield by satellites, reconnaissance aircraft, drones or sensors abandoned on the ground. However, as human resources are scarce and the volume of data is constantly increasing, it will be necessary to delegate the processing of this amount of data to AI algorithms in support of the human being, at the risk of not being able to process all of them without this technology.

On the ground, the deployed combatant will be increasingly charged cognitively by the complexity of the systems to operate and the amount of information to process. It will be vital to automate the processing of certain information in order to unload it, so that only what is really necessary will be presented. This needs to be done in an extremely ergonomic way. This requires defining which data can be subjected to artificial processing, and up to what hierarchical level their processing can be automated.

5.6 The contribution of artificial intelligence

Automated management of routine, repetitive and time-consuming procedures could emerge. In a headquarters, for example, reports management and automatic production of summaries adapted to the level of command would immediately make the chain of command more fluid. The AI could take the form of a dashboard to stimulate the reflection of the commander and his advisers by dynamically delivering relevant information and updated statements [5].

During operational preparation, depending on the tactical situation, the leader must confront the possible modes of action he envisages with the reference enemy situation and the possible enemy modes of action. Very often he does not have the material time to confront his action with several enemy modes of action, and he only anticipates certain non-compliant cases that he considers probable. Artificial intelligence could be more exhaustive in confronting more possible modes of action of the enemy, and thus present a more complete analysis of possible options to the military leader who could then decide accordingly.

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[2] https://www.fifthdomain.com/dod/2017/08/07/emerging-hyperwar-signals-ai-fueled-machine-waged-future-of-conflict/

The field is wide, and even more infinite. A new question then arises: for new technologies, is a new way of command needed?

6. Reduction of the OODA decision cycle

The technologies listed above have a direct effect on the OODA decision cycle, which will be profoundly impacted by the new technologies.

This concept was defined in 1960 by an American military pilot by the name of John Boyd to formalise the decision cycle in air combat. It has since been used to schematise any decision cycle. The author will use it here in the light of the potential offered by the technologies detailed above (**Figure 1**).

6.1 Observe: a better detection

"Seeing without being seen" is essential in military operations, and remains a common adage. Technology is helping, with the extended distances made possible by long-range cameras and their deportation to robotic systems. It can now also help to overcome several natural detection constraints such as night, fog or walls.

Moreover, digitised systems can operate 24 hours a day with great consistency, where humans are subject to fatigue and inattention, avoiding the risk of missing information.

For surveillance or patrol missions, where human resources are often lacking, the leader can delegate to systems the analysis of images of the area for the detection of movements and the potential presence of enemies. It should be noted that this detection should filter out false alarms as much as possible, such as the movement of leaves in the trees when the wind picks up.

6.2 Orient: a better analysis

Remotely seeing will make it possible to identify a potential target from afar, to discriminate it (is the target a combatant) and to characterise its behaviour (is it hostile or not). If these criteria are met, the target becomes a potential target that can easily be geolocated, this information will then be transmitted to the

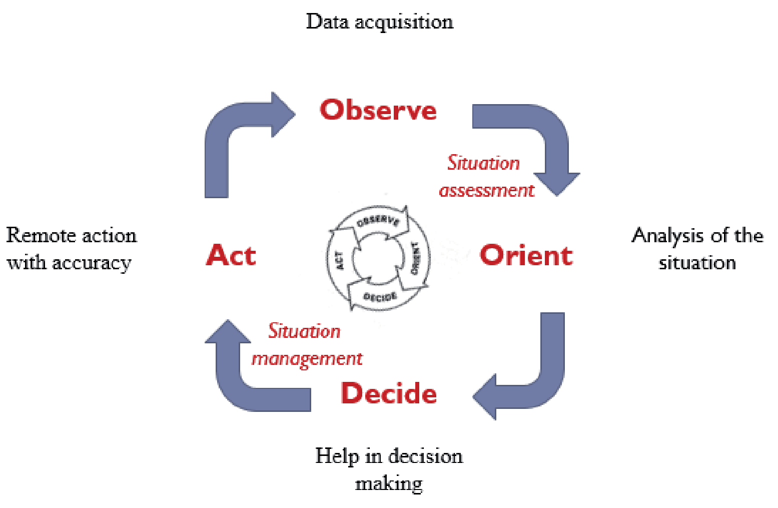

Figure 1.
OODA cycle time reduction: A better reactivity.

decision-making levels. The gain here is that of anticipating the analysis for better decision-making.

The leader will also be able to rely on the automatic processing of data acquired within the digital environment of the battlefield. Faced with the potential 'infobesity' of the battlefield, artificial intelligence will enable massive data processing, subject to the availability of a computing capacity directly embedded in remote robotic platforms, or by remote processing of information via long-distance communications. It will allow constant monitoring of the analysis of captured images or sounds, a task that the best human experts can only supervise because they are subject to fatigue and inattention. This is particularly the case with satellite images or images captured by surveillance drones, which can monitor an area 24 hours a day. Finally, it will also enable the detection of weak signals that would be invisible to humans, by correlation between several distinct events, or by cross-checking.

There are still two essential components to the analysis of the situation that a machine can never integrate. Firstly, instinct and intuition, which a machine cannot have and which are the fruit of a life-long learning of human experience, and secondly, the transcendence of military action which only a metaphysical dimension in the literal sense can provide.

6.3 Decide: a better reaction

The military commander is the decision-maker for military action. It is therefore up to him to take the decision according to the information at his disposal. He can of course rely on a deputy or on operational advisers who help him analyse the situation, if time permits.

For example, France is intervening in Mali and the Sahara as part of the *Barkhane* military operation to combat Salafist jihadist armed groups infiltrating the entire Sahel region. Launched on 1 August 2014, this operation replaces operations *Serval* and *Épervier*. The following scenario is fictitious: an armed Reaper drone of the French army flies over a region of the Malian desert at night and its cameras (incorporating AI for automatic motion detection processing of the captured images) detect a suspicious movement. The sensor operator of the drone is alerted and zooms in on the area to detect a jihadist 4x4 occupied by armed personnel via its Infrared camera. This vehicle is moving towards a village 20 kilometres away. Setting up an operation with Special Forces is not possible because they are not in the area, and there is a great risk that the occupants of the 4x4 will disperse once they reach the village. The legal advisor on duty quickly confirms the possibility of the drones firing on the target because no collateral damage is possible in this desert area. The head of the operation decides to give the order to fire the drone.

This example clearly shows the drastic reduction in the OODA decision cycle offered by the new technologies: the chief detects and is informed as soon as possible by an automatic detection of a suspicious movement of an enemy vehicle. He confirms with his image operator the Positive identification (PID) of the target as an enemy. He then reports it to his hierarchy and receives the order to open fire. He can thus, in compliance with IHL, open fire from a distance. The enemy has not even spotted him.

There are still situations where time is critical and the leader will not have time to make a decision due to the rapidity of the attack. The automation of response processes then becomes a possible option, i.e. he can delegate to a machine the possibility of giving an appropriate response to a situation by itself. This is already the case with missiles or ballistic threats, which require armies to use automatic systems to counter them. This requires automatic systems that are faster and more precise than human beings (e.g. coupling weapons and radar). Tomorrow, faced with future systems that will develop unpredictable trajectory strategies (enemy missiles with AI), faced with saturating threats that risk overwhelming our defences, faced with swarms of offensive robots, our systems will have to adapt in real time to counter the threat. Only a certain autonomy of the defensive systems will make it possible to face them, an autonomy which will have to remain under the control of the leader having these systems at his disposal.

6.4 Act: a quicker and more accurate reaction

A quicker reaction: A man reacts in a few seconds, the machine in a few milliseconds or less. Where a human thinks in a few seconds for the best, the machine will analyse parameters in a few milliseconds and propose a response in near real time.

A more accurate action: A human shooter who moves, breathes and shakes is less accurate than a machine that does not move, breathe or shake because it is not subject to emotion. Precision in action will therefore increasingly be the prerogative of the machine.

The outcome of a fight or a counter-measure may depend on these factors 10 or 100 seconds to a thousand seconds.

7. Technology as a decision aid for the leader

Military decision-making is centred on the military leader, because he is at the heart of the command situation. He takes responsibility for military action, a mission given to him by the legitimately elected political power.

The leader must therefore control the decisions taken within the framework of military action because he is the guarantor and he assumes the consequences.

What lessons can one learn from the opportunities offered by new technologies for military decision-making and the possible resulting changes in the art of command?

7.1 To reduce the "fog of war"

The leader must rely on technology to reduce the uncertainty and fog of war. It will allow him to be more aware of his tactical situation by searching for intelligence. Furthermore, it will enable him to delegate to machines the management of repetitive tasks that do not require constant situational intelligence.

Depending on the circumstances and if he has time to reflect, the digitisation of battlefield information will also allow the leader to replay certain possible scenarios before taking a decision. Finally, it will give him the possibility to select the information he has received that he deems important, to view it several times (especially if the information is imprecise) before making a decision.

7.2 For decision support

A digital aid will be welcome to synthesise the multiplication of digital actors on the ground with whom he is in contact, or whom he must command or coordinate as a leader.

One of the consequences of the digitization of the battlefield is that it may lead to information overload for the leader who is already very busy and focused on his tasks of commanding and managing. It is already accepted in the military community that a leader can manage a maximum of seven different information sources at the same time, and even less when under fire.

Delegating is one way to avoid cognitive overload. Thus, one possible solution is to create a "digital assistant" who can support the leader in the information processing steps.

His digital deputy can be a digital assistant, an autonomous machine that will assist the leader in filtering and processing information, which will help the leader in the decision-making process.

Nevertheless, the leader will have to fight against the easy way out, take a step back, allow himself time to reflect, and reason with a critical sense when faced with machines that will think for him. This process will help him fight against a possible inhibition of human reasoning. Artificial intelligence does not mean artificial ignorance if it is used as an intellectual stimulant, although it can have this flaw.

7.3 For an optimization of its resources

The chief will be able to entrust machines with the execution of certain time-consuming and tedious tasks, such as patrols or the surveillance of sectors, and thus conserve his human resources for missions where they will have a higher added value.

The same applies to missions that require reactivity and precision, especially if there is a need to be extremely quick to adapt to the situation. For example, it will be useful in the case of saturating threats, where targeted destruction or multi-faceted and omnipresent threats such as swarms of drones must be dealt with.

8. But technology as a decision aid subject to control and confidence

Delegation of tasks to increasingly autonomous machines raises the question of the place of humans who interface with these systems and should stay in control.

8.1 The leader must always control execution of an autonomous system

At first, the military will not use equipment or tools that they do not control, regardless of the army in the world. Every military leader must be in control of the military action, and for this purpose, must be able to control the units and the means at his disposal. He places his confidence in them to carry out the mission, which is the basis of the principle of subsidiarity.

For this reason, it is not in his interest to have a robotic system that governs itself with its own rules and objectives. Moreover, this system could be disobedient or break out of the framework that has been set for it. Thus, machines with a certain degree of autonomy must be subordinate to the chain of command, and subject to orders, counter orders, and reporting [6].

8.2 Operators must have confidence when delegating tasks to an autonomous system

The military will never use equipment or tools that they do not trust. This is the reason why a leader must have confidence in the way a machine behaves or could behave. For that, military engineers should develop autonomous systems capable of explaining their decisions.

Automatic systems are predictable, thus, one can easily anticipate how it will perform the task entrusted to it. However, this becomes more complex with autonomous systems, especially self-learning systems where one may well know the objective of the task to be performed by the machine, but has no idea how it will operate. This raises a serious question of trust in this system. As an example, when I ask an autonomous mowing robot to mow my lawn, I know my lawn will be mowed, but I do not know exactly how the robot will proceed.

The best example to focus on are the expectations of the soldier about Artificial Intelligence embedded in autonomous systems.

AI should be trustable. This means that adaptive and self-learning systems must be able to explain their reasoning and decisions to human operators in a transparent and understandable manner;

AI should be explainable and predictable: one must understand the different steps of reasoning carried out by a machine that delivers a solution to a problem or an answer to a complex question. For this, a human-machine interface (HMI) that explains its decision-making mechanism is needed.

One must therefore focus on more transparent and personalised human-machine interfaces for the operator and the leader [6].

9. The risks inherent in the use of new technologies for military decision-making

9.1 Tunnel effect

Easy access to information or possible information overload both favour a possible tunnel effect. This effect, due to a sudden rise in adrenaline, causes a failure in the analysis of signals and data received by a brain that is no longer able to step back and analyse the situation. For the military, this tunnel effect is clearly the enemy of the soldier who has to concentrate on a screen, on a precise task, forgetting to look at the enemy threat around him and thus exposing himself seriously. It is also the enemy of the leader who, because he focuses on a piece of information that he finds crucial, becomes unable to step back and fulfil his role as a leader, which is to take into account the globality of the military action, and not one of its particular aspects highlighted by this information. Too much information should not prevent the commander from stepping back and reflecting.

The question of the gender of the soldier operator may be an avenue of exploration here, as women may have the capacity to manage several tasks simultaneously better than men.

9.2 Inhibit the action

Easy access to information encourages another possible flaw in decision-making. That of not deciding anything until one has all the information at his disposal. This flaw can probably become a major concern in the future. With the responsibility of the soldier at stake, he may hesitate until the last moment to take a decision because he lacks information that he can hope to recover by technological means. This is the death of daring, of manoeuvre by surprise, which often ensures a victory for the leaders who dare to practice them.

9.3 AI will influence the decision of the leader

Stress is an inherent component of taking responsibility. It is common for a military leader to have the feeling of being overwhelmed in a complex (military) situation. In such contexts, the leader will most often be inclined to trust an artificial intelligence because it will appear to him, provided he has confidence in it, as a serious decision-making aid not influenced by any stress, having superior processing capabilities, and able to test multiple combinations for a particular effect.

9.4 Too much predictability in operational decision-making patterns

The modelling of human intelligence by duly validated but very fixed algorithmic processes can lead to the inhibition of human intelligence. In particular, there will be a risk that military thinking will be locked into decision-triggering software. In other words, the formatting of military thought into controlled and controllable decision-making processes, developed by the need to respect the rules of engagement and international rules, particularly those of the decision to open fire. The processes will certainly be validated, but once activated, these processes may become completely rigid technological gems, admirably designed, but incorporating doctrinal biases that cannot be challenged in the face of unpredictable enemy behaviour [7]. By the time, these systems and their uses are adapted, it will be too late and the battle will be lost.

Another major risk is the predictability of the behaviour of these systems by the enemy. As these systems are known, their vulnerability will also be known. It will therefore be easy for the enemy to circumvent them by manoeuvres combining cunning and opportunity, with victory only reflecting the inability of these highly technical systems to adapt to an unpredictable or simply illegal conflict.

The leader must therefore anticipate these pitfalls and use the means at his disposal with intelligence. On these aspects, the French army has developed the concept of "major effect" to be achieved. This major effect conceptualises the way in which the leader intends to seize the initiative in the execution of his mission and which makes it possible to adapt the means and methods of execution to the final effect sought [8].

9.5 A principle of subsidiarity undermined

As a corollary to the extraordinary potential of the digitisation of the battlefield, namely to allow all levels of the hierarchy to access information in real time and simultaneously, there is also a new risk at every level of the military hierarchy: that of the leader having the possibility of directly accessing 'target information', thus breaking the principle of subsidiarity, which requires him to delegate to his subordinates the responsibility for and the use of the means made available to him. The temptation to interfere in the decisions of subordinates and to decide in their place will be great, given his experience and his position. In order to avoid this possible risk, it will be necessary to define precisely the right level of information to be communicated for the right strategic level, in order to respect the freedom of action of each level and to avoid a general and systematic dissemination of information without intermediate processing and filtering.

10. Conclusion

"The philosophy of war does not change. It will not change as long as it is men who make war" said General Charles de Gaulle.

In spite of everything, new technologies bring new equipment to the forces in operation. They are transforming the art of waging war through the opportunities they offer and by the new uses they bring to the battlefield.

With these new means at his disposal, the leader must continue to ensure the delicate balance between reflection and action. Without real and concrete commitment, there can be no good understanding of the situation, and without hindsight, there can be no good decisions [9].

This balance can only be achieved through advanced training. Firstly, human learning, to know how to command his men and respect the opponent. Secondly, intellectual learning, because he must understand the technologies he will use on the battlefield. Military training, because war is an art that leaves no room for the unexpected and requires skills and qualities that are acquired through effort, courage and performance training.

It is this leader of tomorrow that the French Military Academy of Saint-Cyr Coëtquidan is training in Brittany, in the western part of France.

Glossary

AI	Artificial Intelligence
CBRN	Chemical, Biological, Radiological and Nuclear
HMI	Human-Machine Interface
OODA	Observe-Orient-Decide-Act
PID	Positive Identification
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
USV	Unmanned Surface Vehicle
UUS	Unmanned Underwater Vehicle

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This book presents a comprehensive overview of the principles and practices of decision-making. It highlights the interface between engineering/technology and the organizational, administrative, and planning abilities of decision-making. The chapters address decision-making using real-world case studies. They also discuss decision-making theory as well as relevant analysis techniques. The book blends computational techniques, dynamic analysis, probabilistic methods, and mathematical optimization techniques to support the analysis of multi-criteria decision-making problems with defined constraints and requirements.

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