Understanding of ISO 9000 Standards through Recursive Object Modeling (ROM)

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Abstract

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Rodica V. Pop

The use of a quality management system (QMS) is one of the key factors for business success. The implementation of a QMS includes understanding the quality requirements entailed by the undertaking, improvement and the control of the quality. A good quality management system can be realized through well-defined methodologies such as ISO 9000, TQM, Six-Sigma, etc. The ISO 9000 standard is one of the most widely recognized generic international standards for quality management systems, providing guidelines that increase business efficiency and customer satisfaction. The successful implementation of ISO standards requires a clear and accurate understanding of the purpose, objectives, and requirements of these standards. Such an implementation leads to the comprehension of the various possibilities of using the ISO system as an effective tool or as a system foundation for organizational development. On the contrary, misunderstanding quality standards may cause serious failures in the quality systems implementation. In this context, the present thesis proposes a new method to effectively understand ISO standards by applying a recursive object model (ROM), that is, a graphical representation of linguistic information. Using this methodology, a new approach is provided in the present thesis for better understanding ISO standards by illustrating and identifying the concepts, definitions, and requirements as well as the relationships between them. The approach proposed can effectively aid to analyze the context of technical documents and extract the main content and structure in a limited time.

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1 Introduction

1.1 Background and Motivation

In today's highly competitive market, business success depends on the ability to effectively understand, manage, and continuously improve the product development process in order to satisfy customer requirements. Among the national and international standards developed to help organizations produce high quality products and meet customer satisfaction, the ISO 9000 family of standards is the most important generic international standard related to quality management systems, providing guidelines to increase business efficiency and customer satisfaction. The successful implementation of ISO standards requires a clear understanding of the purpose, objectives, and requirements of the standards. In order to perform a quality implementation, companies are looking to various approaches. One possible approach is to use a model developed to implement ISO standards; other approaches includes management-related training courses as a way to understand ISO standards [1]. The International Organization for Standardization (ISO) has developed quality standards regulations for almost all industries; however, failures in the implementation of quality systems are often reported in industrial practices [1, 2]. Failures in quality systems implementation can be attributed to several causes beginning with the belief that the implementation of a strategic quality system is costly, complex and time-consuming [3], or that it is an inadequate or outdated implementation plan [4]. Another difficulty in implementing ISO standards is associated with the lack of top management support (attitude and commitment), and with difficulties in understanding and interpreting the quality standards [5, 6]. Such problems exist in businesses in various countries. Here are a few examples:

(a). In Turkey, a comprehensive survey was made of 101 companies, in order to document the current state of ISO 9000 implementation. Various obstacles were faced by the companies, of which the most commonly identified problem during the certification process was the lack of understanding of ISO standards among all departments and difficulties in understanding the ISO 9000 requirements [7]. The results are shown in Table 1.

(b). In Malaysia, a survey of 100 companies that obtained ISO 9000 certification was conducted, and one of the most frequently mentioned problems was the lack of understanding of ISO 9000 standards and the failure to understand the concepts and philosophies behind ISO standards. The survey shows, "there are misconceptions that compliance with the standards creates unnecessary paperwork" [8]. Also, training plays an important role in the implementation and is an integral part of the quality program. The lack of training acts as a barrier to the implementation program in companies [8]. The results are shown in Table 2.

Table 1: Obstacle faced during the ISO 9000 certification process [7]

Obstacles	No. of companies
Lack of understanding of its importance by all departments	35
Unwillingness to change from the existing system	22
Difficulty in understanding the ISO9000 requirements	22
Documentation control	18
Time and/or cost	6
Others	7

Note: Many responses overlap

(c). In Sweden, 114 companies certified ISO 9001 or 9002, were asked for their reasons for ISO system implementation during the exploratory phase of the study, regarding different aspects of changes that take place because of the implementation of a quality management system. Their final conclusion was that the comprehension and interpretation of the standard were difficult. That difficulty was perceived as one of the main reasons for the complications in achieving a quality system [9]. The results are shown in Table 3.

Table 2: Implementation problems [8].

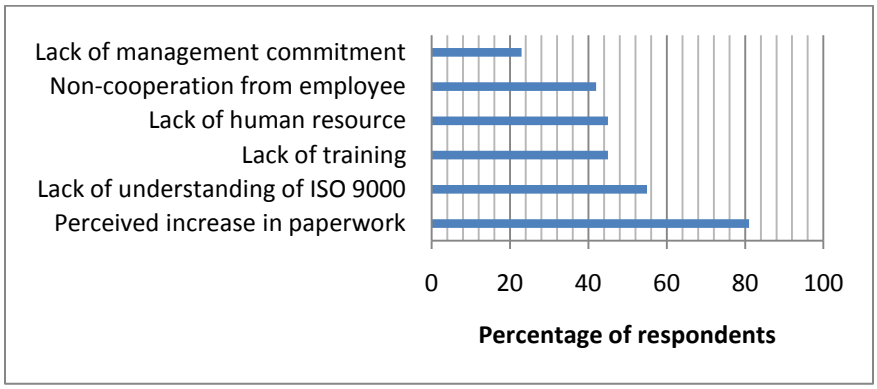


Table 3: Difficulties experienced in implementing ISO 9000 [9]

Stated reasons for difficulties	Mean	SD
Time and resource-consuming	3.32	0.98
Difficulties in interpreting the standard	2.94	1.01
Cumbersome and bureaucratic documentation	2.82	0.93
Initial difficulties in making the quality system understood and accepted	2.64	1.06
Difficulties in choosing a suitable level for documentation	2.61	1.02
Difficulties in setting relevant quality goals	2.57	0.77
Difficulties in communicating the message	2.51	0.77
Difficulties in securing employee commitment	2.48	0.90
The accountants lack knowledge of our line of business	1.93	0.99
Unclear guidelines from the certifying body	1.92	0.95

Note: Mean and standard deviation in 96 ISO certified companies; scale 1= no problem, 2= minor problems, 3= some problems, 4= great problems, 5= extremely great problems.

(d). A survey of Greek companies reported several reasons as barriers in the certification process such as: misinterpretation of ISO 9000 standards; over-development of the quality system; excessive documentation and control; and underestimation of efforts and resources needed in certification. However, the conclusion was that understanding ISO 9000's standards and requirements were the major barrier in the certification process [10].

(e). In the UK a survey of companies that had obtained registration, reported that understanding the purpose of the ISO 9000 standards and quality management system is a very important preliminary step in the implementation process [3, 5, 6].

(f). Another study that explores and discusses issues in the implementation of ISO 9000 at the employee's level was conducted in Malaysia (Selangor) for 50 local manufacturing companies. The study reported that "Negative employee factors" did not favour the successful certification of ISO 9000 standards [1]. The results are shown in Table 4.

(g) Finally, a survey was conducted in the Hong Kong electronics manufacturing industry, in order to investigate the factors that have impacted the effective use of ISO 9000 standards within the manufacturing environment. The survey revealed that the factors regarding the ineffectiveness of enhancing organizational performance was due to senior management's attitude, commitment, and confidence in understanding ISO 9000 and quality management system relationships in the development of QMS as well as the purpose of the standards [6].

Table 4: Negative employee factors [1]

No	Negative factors	No of responses
1	Resistance / unwillingness to change or stubbornness or arrogance	17
2	Inadequate / no commitment	9
3	Negative / wrong perception	7
4	Not following / bypass / cut short procedures	7
5	Complacency / ignorance / bad attitude	7
6	Inadequate / no co-operation or coordination	6
7	Inadequate / no training	6
8	Inadequate / no knowledge or understanding	6
9	No teamwork	4
10	Inadequate sense of responsibility/ownership	4
11	Unwillingness to learn / lazy / unmotivated	4
12	No communication or poor dissemination of information	4

Based on the surveys conducted in different countries, understanding is identified as a major barrier in the implementation of ISO 9000 as listed below:

- ✓ Lack of understanding of ISO 9000
- ✓ Difficulties in understanding ISO 9000 requirements
- ✓ Difficulties in interpreting the standards
- ✓ Difficulties in understanding (or misunderstanding) the purpose of ISO 9000 and of the quality management system
- ✓ Difficulties in understanding quality issues
- ✓ Difficulties in understanding the concepts and philosophies behind ISO standards
- ✓ Difficulties in understanding the relationship between the ISO 9000 and the quality management in the development of a QMS

1.2 Objectives

The present thesis focuses on the effective understanding of ISO 9000 standards through the use of a Recursive Object Model (ROM). The effective understanding of ISO documents is a preliminary step in the implementation process as well as one of the key elements for a successful implementation of the standard. Also, the effective understanding leads to the comprehension of the various possibilities of using the ISO system as an effective tool or as a system foundation for organizational development. Moreover, well-established and defined guidelines are important elements in any quality program development. However, the ISO standards do not give any instructions about the steps that should be followed or applied.

In our work, to effectively understand ISO standards we use ROM, a graphical representation of linguistic information. By using this method we provide a new way, a different approach in understanding ISO standards by understanding the concepts, definitions, and requirements as well as the relationships between them, also by highlighting important concepts and ideas in the text, and by identifying commonalities and differences between texts. In short, the objective of the present thesis is to demonstrate a different approach to enable people to understand ISO standards in organizations.

1.3 Research Contributions

To improve the application of quality standards using a new methodology developed by Zeng [11], which is a graphic language called Recursive Object Model (ROM), the present thesis has arrived at two major contributions:

(1) Understanding ISO standards by showing keywords of a concept

(2) Understanding ISO standards by showing the hidden connections between concepts that are not directly defined.

(3) A systematic method to understanding ISO standards. This method can be used during training sessions as well as during quality system implementation.

1.4 Organization

The remainder of this thesis is organized as follows:

- Chapter 2: provides information regarding the definition of quality management systems. We also present a brief description of ISO 9000 standards and different approaches to implementing ISO standard.
- Chapter 3: introduces a brief presentation of the concepts related to text, information, and interpretation-aided mechanisms.
- Chapter 4: presents the methodology.
- Chapter 5: gives details about the extraction of meaning from ISO standards.
- Chapter 6: describes the main research results of the present thesis, and develops a direction for future research in this area.

2 Context

2.1 Quality Management System

2.1.1 Quality

Quality plays an important role in the highly competitive business environment. The word “quality” is a general term, applicable to various traits or characteristics, whether individual or generic, and has been defined by various experts under different aspects to assign different meanings to this term. Juran defines quality as “Customer satisfaction and loyalty” or “Fitness for use”[12], whereas Crosby defines quality as “Conformance to specification”[12]; Taguchi defines quality as “Loss to society”[12] and Deming defines quality as the “Predictable degree of uniformity”[12]. In ISO 9000:2005(E) standards, quality is defined as the “degree to which a set of inherent characteristics fulfills requirements” [12, 13]. Therefore, requirements are defined by contract in a contractual situation and transformed into product features and characteristics with specified criteria whereas the implied needs are identified and defined by the company.

2.1.2 Quality System

A quality system is defined as the assembly of organizational activities, procedures, processes, resources, responsibilities, and the infrastructure required in order to formulate and implement a quality management [14]. ISO 9000 standards focus on implementing quality in every aspect of a business with an incorporated quality management system, involving all the processes in the lifecycle of a product that affects quality.

2.1.3 Quality Management

ISO standards defines quality management as the "coordinated activities to direct and control an organization with regard to quality" [13], including the quality policy, quality objectives, quality planning, quality control, quality assurance, and quality improvement. Therefore, quality management should be an integral part of an organization's overall management function that defines and implements the quality policy [14].

2.1.4 Quality Management System

Quality Management System (QMS) is defined as "a set of coordinated activities to direct and control an organization in order to continually improve the effectiveness and efficiency of its performances" [15]. A general requirement for any type and any size of organization is to set up, document, implement and maintain a quality management system as well as to continually improve its effectiveness in order to meet the requirements of the standard (ISO 9001:2000 Quality management systems – Requirements) [16].

Therefore, the quality management system that is properly implemented, documented, and maintained within the organization and across its supply chains will guarantee the customer's and organization's requirements satisfaction as well as the achievement of long term goals. A quality management system enables organizations to identify, measure, control, and improves diverse key business processes that in turn will lead to the improvement of business performance. Therefore, the benefit of quality management

system is that it enables an organization to achieve its goals and objectives. In Figure 1 is shown a representation of the benefits of a QMS.

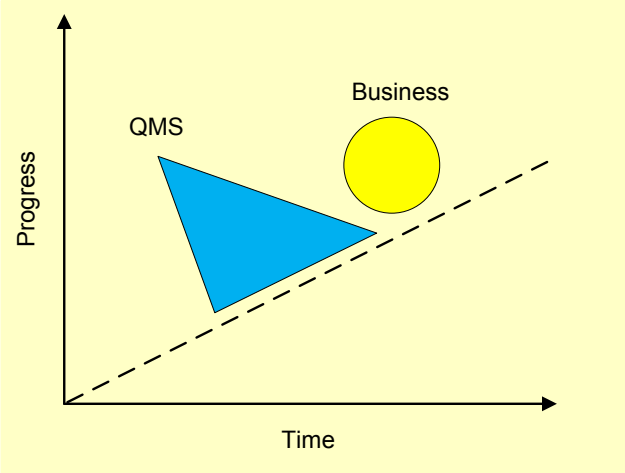


Figure 1: The benefits of a QMS [15]

In this two-dimensional coordinate system (time–progress), a quality management system (QMS) is represented as a triangle and plays an essential role within the business environment, acting as a wedge to help keep business operations effective and to prevent good practises from slipping [15].

2.2 ISO Standards

2.2.1 Definition

The International Standards Organization (ISO) was established in 1947 in Switzerland to develop world-wide standards for business, governments, and societies. The ISO 9000, in particular, is a set of standards for quality management systems, published for the first time by ISO in 1987 and modified in 1994. ISO 9000 in fact derived from BS 5750 created by the British Standards Institution (BSI).

The ISO 9000 family of standards has been developed to help organizations, of all types and sizes, to implement and operate effective quality management systems. Together, the ISO standards form a coherent set of quality management systems standards facilitating a mutual understanding in national and international trade [13]. ISO standards are adopted through the implementation of quality processes. They provide the basis for establishing, documenting, and maintaining a system that ensures the quality of the process. Registration under this series indicates that a firm meets a minimum standard for quality systems and can produce and deliver goods or services from processes that meet expected ISO 9000 registration standards [17].

The reasons for obtaining ISO 9000 certification can come from the requirements of customers or future customers, from image or marketing advantages, from the need to improve the efficiency of the processes within the company, and from international competition [2].

However, the ultimate purpose of ISO standards is to enhance efficiency and to improve the quality of products and services by focusing on the constant identification, evaluation, and improvement of key business processes within an organization. The standards were initially used only for large-sized companies in the manufacturing industry. In the mid-1990s, small and mid-sized companies also began to implement these standards. By the end of 1997, the ISO 9000 had been accepted by more than 100 countries as their national quality assurance standard. The ISO 9000 family of standards relate to quality management systems and are designed to help organizations ensure that they meet the

needs of customers and other stakeholders [2]. Today, the ISO 9000 family of standards are the most important generic international standard related to quality management systems providing guidelines intended to increase business efficiency and customer satisfaction.

The ISO 9000 family of standards is composed of the following standards:

- ISO 9000, which describes the fundamentals of quality management systems and specifies the terminology for quality management systems.
- ISO 9001, which specifies the requirements for a quality management system where an organization needs to demonstrate its ability to provide products that fulfill customer and applicable regulatory requirements and aims to enhance customer satisfaction.
- ISO 9004, which provides guidelines that take into account both the effectiveness and efficiency of the quality management system. The aim of this standard is the improvement of the performance of the organization and satisfaction of customers and other interested parties.
- ISO 19011, which provides guidance on auditing quality and environmental management system.

However, ISO 9000 deals with the fundamentals of quality management systems, including eight management principles on which the family of standards is based [18, 19]. Quality management principles provide a comprehension of and direction for the application of quality management [20]. The following eight quality management

principles represent the opportunity for any organization to become more efficient and profitable and are considered the best management practices:

1. *Customer focus:* organizations should concentrate their efforts on identifying, understanding, and achieving customer requirements and expectations.
2. *Leadership:* management by leadership is based on the belief that an organization, in order to be competitive, must involve employees in achieving the organizational goals and direction set by its leaders.
3. *Involvement of the people:* the involvement and motivation of employees at various levels of the organization, facilitates the use of skills for the benefit of the organization.
4. *Process approach:* the management of resources and activities addressed as a process.
5. *System approach to management:* increased effectiveness and efficiency of an organization is determined by the management of a system of interrelated processes.
6. *Continual improvement:* the permanent objective of an organization.
7. *Factual approach to decision making:* this is based on an objective analysis of data and information in order to take an effective decision.
8. *Mutually beneficial supplier relationships:* this refers to taking into account the permanent existence of interdependence between the organization and its suppliers as well as to enhancing the ability of both parties to create value.

The main purpose of a generic quality management system is to create and maintain an organizational system that provides quality assurance and auditing throughout the organization while optimizing the process of production, including the four elements of a system: the input, the transformation process, the output and the feedback loop [21, 22]. Figure 2 shows a model of the quality management system approach proposed by the ISO 9001:2000 standard. This model includes four key elements that correspond to the four ISO 9001:2000 standards main processes: (1) management responsibilities, (2) resource management, (3) product realization, (4) measurement analysis and improvement [16].

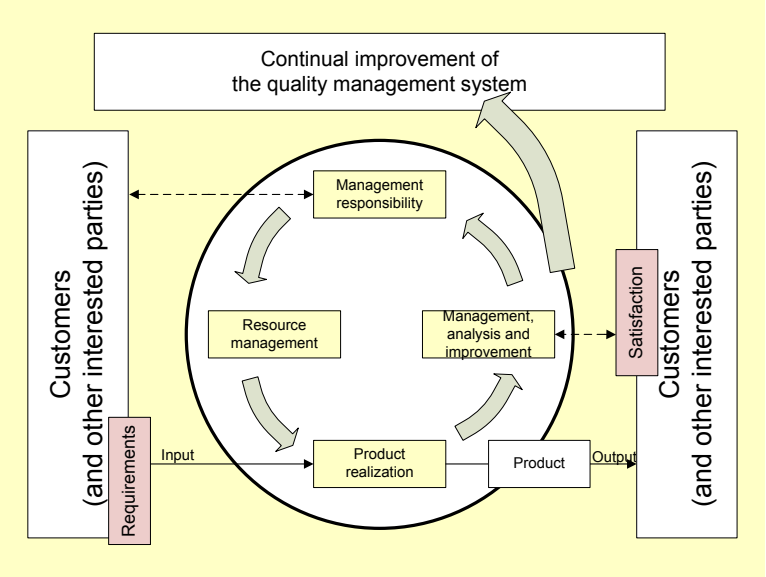


Figure 2: The model of a process-based quality management system [13, 16]

The businesses that achieve quality certification benefit because they can clearly identify and define areas that need to be improved. ISO 9000 standards guarantee a basic quality system within the organization and the capability of providing quality products and services to customers, but ISO does not ensure that a quality or defect-free product or service will be provided [2, 6, 23].

2.2.2 ISO Implementation Approach

ISO standards are considered as a family of standards or guidelines that manage the processing of products or services and help to develop a quality management system. The organizations that want to improve their quality processes are seeking certification, even if the implementation of the quality systems involves major organizational changes. The benefits achieved by organizations through ISO implementation increase due to internal improvements, interdepartmental relationships, internal organizations as well as employee motivation. However, achieving ISO certification is not an easy task, because it is not a standardized package that can be applied in the same way in every organization [24-26].

In order to help organizations implement ISO standards different implementation approaches have been developed. One of these approaches considers that the people involved in the quality system, from the line operator to the top management, are the decisive factor in the successful implementation of ISO 9000 Standards. In Figure 7 there is a model that was developed as a strategy for ISO standard implementation. This model helps to visualize the critical success factors and to provide the basis for developing such a strategy. There are two forces at work: the external forces, represented by customer expectation/satisfaction, and the internal forces, represented by the benefits of the company. Both of these sets of forces that in fact are represented by the market demand and process standardizations, are defined in the present model, providing the impulse for change. The key elements in the strategy for a successful ISO system implementation were identified as the need to improve the understanding, the belief and the

communication channels throughout the company as well as the continuous commitment and involvement of the people involved in the implementation process [27].

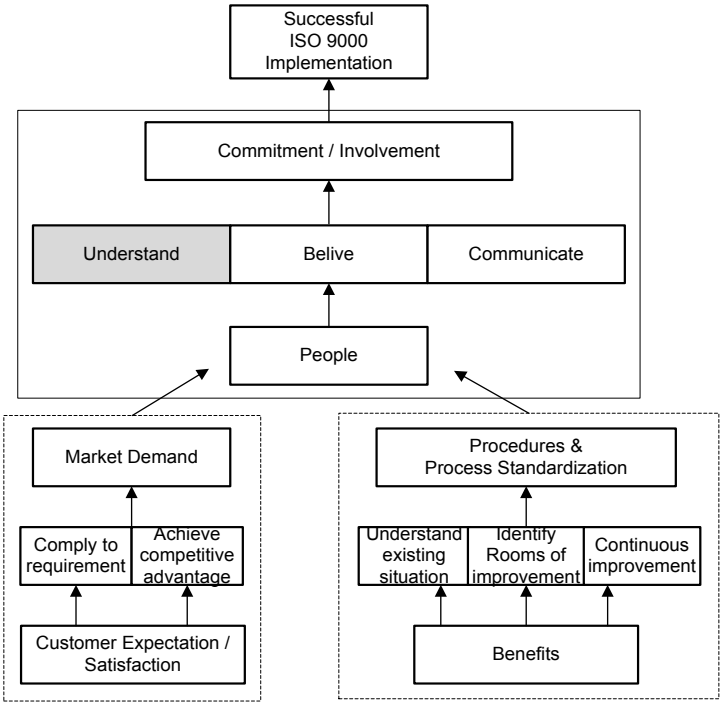


Figure 3: The ISO implementation strategy [27]

Another approach to ISO implementation is to consider ISO 9000 standards as a code or common language used by business to extend market share as well as industrial relationships. However, this code establishes the documentation requirements that must be met by the organizations in order to demonstrate the compliance with a quality system. From the very beginning of the process, this code must be appropriated by the people involved in the implementation process. To complete the codification within the business, the language that is specific to ISO standards must be translated into the business's own language. Familiarity with the interpretation and understanding of ISO standards lead the organizations to move easily between the two codes, that of the ISO and that of the

organization. The people at the end of the process will be able to interiorize the written procedures, and evolution of routines. The successful completion of the codification depends on the interpretation of the standards and on the understanding of the standards, on the commitment of top management as well as the nature of the business [28].

In a thesis entitled "Implementation of ISO Standards through Formalization of Requirements for Process Management" [29], Gonzales proposed an approach to the implementation of ISO standards through the identification and the analysis of the ISO standards requirements that could be achieved by applying Environment Based Design (EBD) methodology. Furthermore, Gonzales developed a Quality Implementation Practical Flowchart (QIPF) for ISO standards implementation. By applying EBD, it was possible to meet the requirements stated in ISO standards while the QIPF served as a model for the implementation of ISO standards.

2.3 Understanding

The effective understanding of ISO standards is crucial and plays an important role starting at the implementation phase. The ROM methodology, which is the only one of its kind in its application to ISO 9000 Standards, will lead to an effective understanding of ISO documents. But, what is understanding? What are difficulties that prevent people from understanding? Is understanding measureable? In this section, we will address these questions.

2.3.1 Definition of Understanding

Understanding is a broad term that professional documents usually avoid discussing. It involves all kinds of intellectual processes across a broad spectrum, from the lowest to the highest level, and is applicable to the most abstract thinking of science or, technical knowledge. The "principles of understanding" should be principles exemplified at every level of intellectual activity [30]. Understanding represents a performance, which some of us are able to do. It is, therefore "one of our talents" [31]. It is, "the basic motion of our existence; is not only a possibility, an ability , but at the same time an impossibility, an inability" [32].

Understanding is to comprehend the meaning of a thing, a situation or an event, the ability to see it in relation to other things; to see how it operates or functions, what kind of consequences derive from it, what causes it, and what uses it can be put to. By contrast, things without meaning are those whose relations are not grasped or understood. The relationship of means-consequence is the key of all understanding [33].

As a concept, understanding is defined as "a mental construct, an abstraction made by the human mind to make sense of many distinct pieces of knowledge" [33]. Hence, understanding is different from knowledge; understanding is to comprehend the meaning of something while to know is the ability to demonstrate, to clearly prove or to support a statement [34]. Also understanding is the capability to transfer our knowledge and skill creatively, flexibly, and fluently to new situations on our own [35]. In other words, understanding is the ability to communicate effectively with people who are

knowledgeable in a given domain; it is also the capacity to apply a principle consistently in a variety of contexts in order to generate a process or procedure so as to always obtain the desired results. Understanding is the ability to make analogies that are considered appropriate by people who are considered knowledgeable in a certain domain [36]. Therefore, knowledge and skills are important elements of our understanding.

In terms of grammar, understanding (as a noun) can be defined as the "mental process of a person who comprehend(s)"; (as a verb used with object) understanding is "to perceive the meaning of" ; and (as a verb used without an object) understanding is "to perceive what is meant" [37]. The question arises about what can we understand? We can understand sentences, purposes, events, intentions, persons, science, nature, and environment.

In summary the concept of understanding is defined as follows:

"*Understanding is bringing things into relation, of building up a network of connections, and interdependencies*" [32].

2.3.2 The Quality of Understanding

Understanding refers also to the kind of statements that we can comprehend. Therefore, we can understand only what has a structure, is complex, is composed, and is capable for analysis. In other words, understanding is basically a "matter of analytical data processing" [31].

But what does the quality of understanding involve?

The quality of understanding is reflected in the level of details and precision, in the depth of critical analysis, in the degree and completeness, and in the different ways of interpretation.

There are four dimensions of understanding: knowledge, methods, purpose, and forms, which represent several aspects of the nature of understanding. Within each dimension there are four levels of understanding: naïve, novice, apprentice and master [38].

A brief description of each dimension is provided as follows [38]:

- The *knowledge* dimension: refers to the ability of people to move consistently and smoothly back and forth between abstractions [38].
- The *methods* dimension: uses a strict methodology that allows the evaluation of peoples' capacity to maintain a degree of doubt about their knowledge or learning as well as their ability to consistently evaluate judgments as valid, ethically defensible, or balanced and beautiful [38].
- The *purposes* dimension: The degree of understanding of peoples is revealed in the degree to which students are able to see the goals and motors behind the creation of new knowledge, to oversee the application of that knowledge to new situations, and to foresee the results of that application [38].
- The *forms* dimension: The degree of understanding that peoples possess is also expressed in the degree to which people can manipulate symbols (visual, mathematical, and bodily kinesthetic) to communicate within long-standing frames of reference - for example, in verbalizing in writing, music, speaking, and even in furnishing mathematical explanations [38].

Each level of understanding is described as follows [38]:

- *Naïve* understanding: The first level is the performance of *naïve* understanding, which is based on intuitive knowledge. People in such performances are not able to make connections between what they learn and their everyday life. In such cases there are no signs of the fact that people are mastering what they know. Moreover, they are "unreflective about the ways that knowledge is expressed or communicated to others" [38].
- *Novice* understanding: The next level is the performance of *novice* understanding, which is based on testing and training methodologies. In this case, people begin to insert disciplinary concepts as well as to make connections between concepts or ideas [38].
- *Apprentice* understanding: The performance of *apprentice* understanding is based on disciplinary knowledge and models of thinking. At this level of performance people demonstrate the flexible use of disciplinary concepts or ideas. Moreover, people are able to see relationships between disciplinary knowledge and everyday life while searching for the possibilities to use this knowledge [38].
- *Master* understanding: Finally, the performance of *master* understanding is absolutely integrative, creative, and critical. At this level, people are able to move flexibly across dimensions, as well as to express and transfer knowledge to others in creative ways [38].

Some dimensions may be more significant than others in specific performances. Deep understanding requires the ability to use knowledge in all dimensions.

2.3.3 The Criteria of Understanding

The criteria of understanding are needed in order to evaluate the degree or level of understanding. Generally speaking, understanding is a complicated concept. Understanding a topic means to be able to deal flexibly with the topic, that is: to explain, to interpret, to find evidence and examples, to generalize, to apply, to analogize, to have perspective, to emphasise, to have self –knowledge, to extrapolate, to relate and to use the topic in ways that go beyond knowledge and routine skill as well as to develop performances of understanding around the topic [35, 39, 40]. The criteria of understanding are summarized below:

- *Can explain*: means to describe a set of phenomena, facts, and data through generalizations or principles; to make insightful connections and to provide clear and helpful examples or illustrations [35]. *Can explain* also means to try to demonstrate how or why something is or will be [41].
- *Can interpret:* refers to providing some materials, such as stories, images, anecdotes, and analogies or models in order to understand the meaning of the text at different levels [35].
- *Can apply:* it is to use knowledge effectively and to adapt it to new situations and diverse contexts [35].
- *Have Perspective:* to see other persons opinions through critical eyes; to see the whole picture [35].
- *Can empathize:* is "to find value in what others might find odd, alien, or implausible; to perceive sensitively on the basis of prior direct experience" [35].

- *Self-Knowledge*: to demonstrate metacognitive awareness; this expression refers to self-knowledge about how we think and why, and the relation between our preferred methods of learning and our understanding. Our understanding is demonstrated by our capacity to precisely self-assess and self-regulate. [35]

The questions characterizing the six factors listed above are listed in Table 5.

Table 5: Criteria of understanding [35]

Criteria of Understanding	**Questions regarding the criteria of understanding**
Explain	Why is that so? What explains such events? How can we prove it? To what is this connected? What is implied?
Interpret	What does it mean? Why does it matter? How does it relate to me?
Apply	How and where can we use this knowledge, skill or process?
Perspective	From whose point of view? What is justified or wanted? It is reasonable? What are the strengths or weaknesses of the idea?
Emphasize	How does it seem to you? What do they see that I don't?
Self-knowledge	What are the limits of my understanding? What am I prone to misunderstand because of prejudice, habit or style?

As shown in Table 5, complete understanding covers all six factors which emphasize the ability to transfer knowledge.

2.3.4 Factors that Affect Understanding

First of all, difficulties in understanding a statement can arise for phonetic, syntactic or semantic reasons. Also, we cannot understand a statement because it is very complex, confused, vague, or does not contain sufficient information, or because we not have enough related knowledge or experience. To highlight these observations we provide the following example, which demonstrates the different meanings attached to the concept "first lady".

The concept "first lady" for most Americans represents "the wife of the president", whereas for Canadians the expression refers to "the wife of the head of the state, while for people in Great Britain the expression can refer to the queen, the Queen Mother, or Margaret Thatcher?" [42]. It is clear that the understanding depends on the circumstances and the richness of the context in which the word/term is used as well as on the level of knowledge accumulated at a time in a given domain and how it is applied.

What do people do when they have difficulties in understanding? The answers are:

- ✓ Ambiguity: When the statement is ambiguous, people will try to clarify what they can or cannot comprehend.
- ✓ Confusion, vague or lack of knowledge: When the statement is confused or people do not have related knowledge, they will search for information, evidence, meaning, interpretations, and connections.
- ✓ High complexity: When the statement is very complex, people will try to analyze it by sections.

Secondly, besides the aforementioned obstacles to understanding there may be other elements that influence the performance of understanding such as: individual's educational and cultural background, field and context. Moreover, individual's performances in different field at different levels may have impacts on understanding. As an example, a mathematical problem is understood differently by a high-school student compared to a graduate student [43].

2.3.5 Methods for Measuring Understanding

As we have mentioned before there are different methods regarding the evaluation of a person's understanding. Only to mention a few: asking the person to explain a statement; to give examples and definitions; to solve an exercise. The evaluation of the degree of understanding can be carried out in the above-mentioned ways, all of which can be tested using standardized tests. However, because of the existence of different levels of performances we distinguish between:

- ✓ Too common performances: the measurement of the degree of understanding can be made by using true-and-false quizzes, or standard exercises [41].
- ✓ High performances: the measurement of the degree of understanding can be made by imposing the writing of a thesis, a dissertation, or an advertisement [41].

The elements that characterize a standardized test can be defined as follows:

1. In all cases it is necessary to define the criteria that distinguish good from poor understanding, and the dimensions that define the quality of understanding.

2. In all cases we define the successive stages of quality ranging from the poorest understanding to the best understanding, taking into account the exact delineation between the current and the next stages.
3. Also the amount of control is used as a measurement of understanding, that is, we know what can and cannot be done and how.

Evaluating a person's understanding means the evaluation of the person's ability to perform based on a set of well-defined rules. The result demonstrates the level of understanding of the tested person [44]. We conclude that, when a person can perform well then that performance means that the person understands.

2.4 ROM (Recursive Object Modeling)

2.4.1 Theoretical Foundation

The theory underlying ROM is the "Axiomatic Theory of Design Modeling", which is a logical tool that can be used to represent and to reason about object structures [45]. The axiomatic theory provides the designer with a logical approach to human thought by defining axioms dealing with objects. The axioms pertaining to objects as defined by the "Axiomatic Theory of Design Modeling" are as follows:

- Axiom 1: Everything in the universe is an object
- Axiom 2: There are relations between objects

2.4.2 ROM

The Recursive Object Model (ROM) was developed by Zeng [11], and is a part of a general design theory: Environment-Based Design (EBD) [45-48]. ROM is is a linguistic

analysis tool that transforms a text into a graphic language, derived from the "Axiomatic Theory of Design Modeling".

ROM can be used to organize, interpret and analyze English language. Moreover, ROM can be considered as an intermediate medium between natural language and structured modeling language. Using ROM each word in a sentence is treated as an object and every object may have relations to other objects. ROM uses only five symbols (elements) to represent objects, compound objects, constrained relationships, predicate relationships, and connection relationships, as presented in Table 6, Table 7, Table 8, and Literature Review.

There are many methods and techniques used to interpret texts. Here are some examples of interpretation-aided mechanisms: Network Text Analysis (NTA), Cognitive Map, Mind Map, Concept Map, Topic Map, and Entity Relationship Model.

In addition, there is a new technique called the Recursive Object Model (ROM) developed by Zeng [11]. In fact, the major purpose of using any of these methods and techniques is to understand and to extract information from texts. In this section of the present thesis, the concepts of text and information are discussed. Also, brief introductions about the interpretation-aided mechanisms are presented, while ROM method has been presented in preceding section (see Section 2.4).

Table 9 provide examples for each element presented in Table 6.

Table 6: The Elements of the Recursive Object Model (ROM) [11]

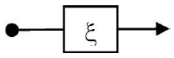
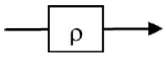
Type		**Graphic Representation**	**Definition**
Object	Object		Everything in the universe is an object.
	Compound Object		It is an object that includes at least two other objects in it.
Relations	Constraint		It is a descriptive, limiting, or particularizing relation of one object to another
	Connection		It is to connect two objects that do not constrain each other.
	Predicate		It describes an act of an object on another or that describes the states of an object

Table 7: Examples of constraint relations

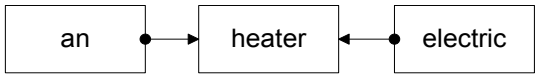
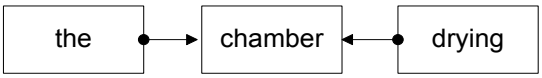
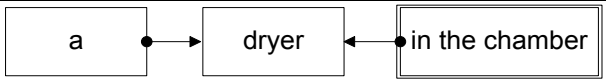
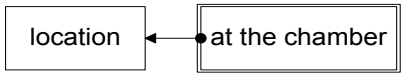
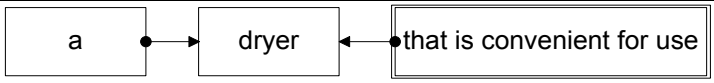
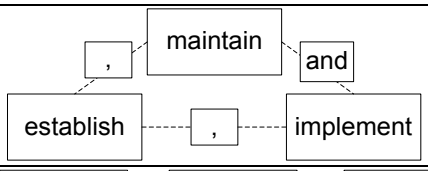
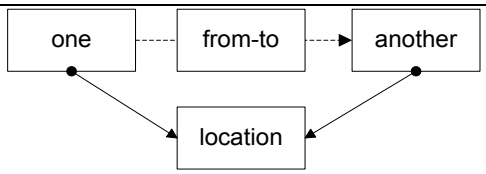
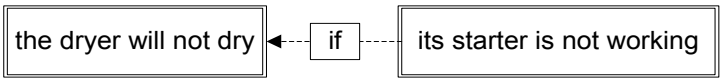
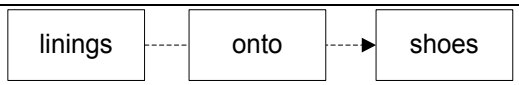
Text	**Graphic language**
an electric heater	
the drying chamber	
a dryer in the chamber	
the cost of the dryer	
location at the chamber	
a dryer that is convenient for use	

Table 8: Examples of connection relations [11]

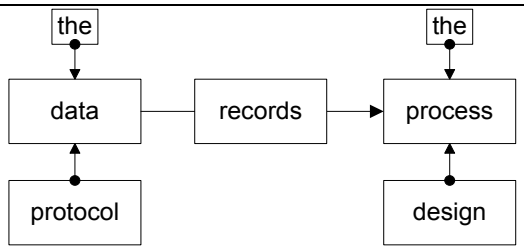
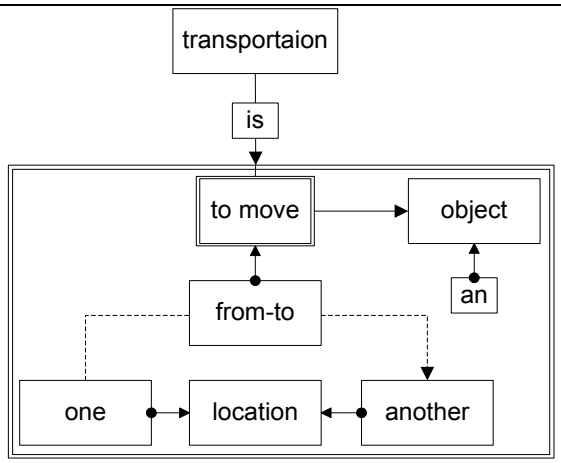
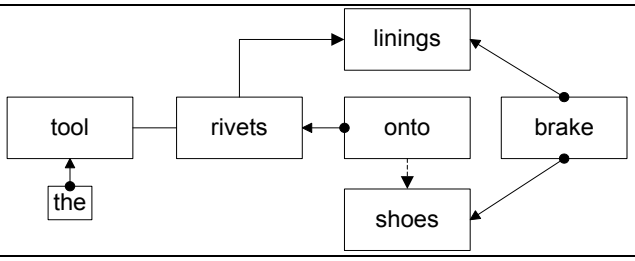
Text	Graphic language
establish, implement and maintain	
from one location to another	
the dryer will not dry if its starter is not working	
linings onto shoes	

3 Literature Review

There are many methods and techniques used to interpret texts. Here are some examples of interpretation-aided mechanisms: Network Text Analysis (NTA), Cognitive Map, Mind Map, Concept Map, Topic Map, and Entity Relationship Model.

In addition, there is a new technique called the Recursive Object Model (ROM) developed by Zeng [11]. In fact, the major purpose of using any of these methods and techniques is to understand and to extract information from texts. In this section of the present thesis, the concepts of text and information are discussed. Also, brief introductions about the interpretation-aided mechanisms are presented, while ROM method has been presented in preceding section (see Section 2.4).

Table 9: Examples of predicate relations [11]

Text	Graphic Language
the protocol data records the design process	
transportation is to move an object from one location to another	
the tool rivets brake linings onto brake tools	

The present literature review is divided into the following sections:

1. Text and its components
2. Information and classification
3. Interpretation-Aided Mechanism

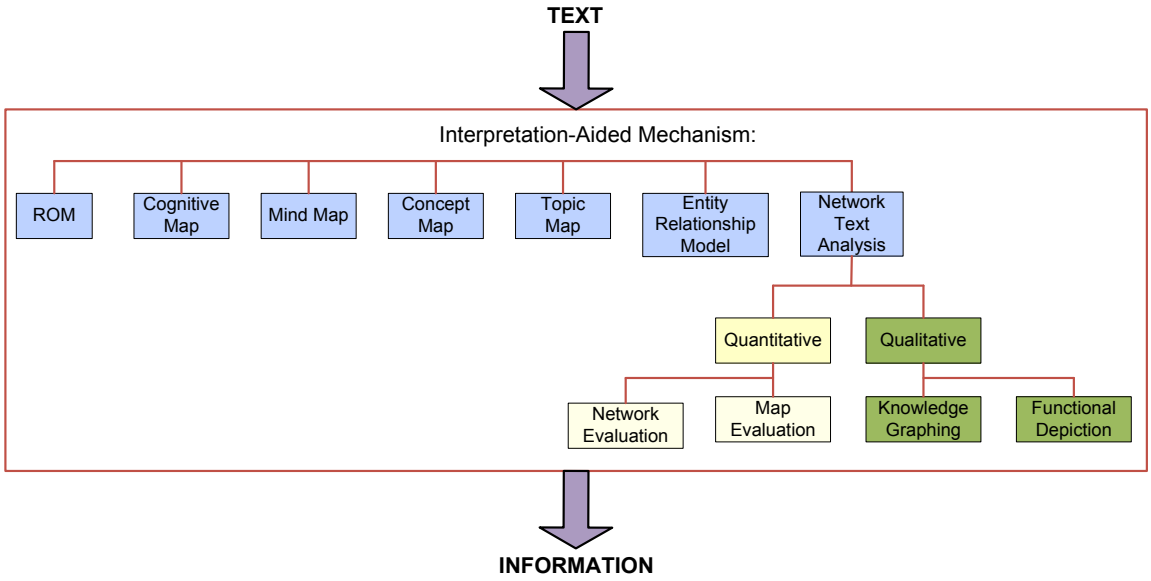


Figure 4: Text Interpretation Mechanisms

3.1 Text

There are various discussions in literature related to the concept of text. Text can be considered as a semantic unit as well as the basic unit of the semantic process in spoken and written forms. Text can be defined as a source of information [49]. Generally speaking, we can identify a text if we are able to see a clear relationship between the words, sentences, phrases and the meanings contained within the text. A text may have one of the following aspects: it may be spoken or written; it may be in dialog, monolog, prose or verse. Besides other features we should mention the set of proprieties of the text that can be used to understand and distinguish the text from a mere set of unrelated sentences.

A text is defined as a semantic unit, a unit of meaning and not of form; however, a text does not have structural integration, unlike sentences. Therefore, a text is not made up of sentences but is realized by sentences or encoded in sentences [50]. A text can be of

whatever length. There is no upper or lower limit for the length of a text. However, as a grammatical unit a text is larger than a sentence. In the following section, we present the component elements of the text.

3.1.1 Texture

Texture is the property of a text which distinguishes it from what is called a non-text. A non-text can be considered as a collection of sentences without link, meaning and form. Texture is what holds the clauses of a text together to make it a unified whole.

Example: Clean and dry your tools. Put them on the shelf. (1.1)

In this example “them” from the second sentence refers back to the “tools” from the first sentence and this reference creates cohesion between these two sentences, so these two sentences constitute a text. These cohesive relations provide the texture. The meaning of the cohesive relation between “them” and “tools” is that they refer to the same thing.

3.1.2 Ties

Ties are referred to cohesive relation between two elements of a text [50]. The concept of tie is used to characterize a text by the number and kind of ties. Cohesive ties are used for analyzing a text, to determine the pattern of the text and to study the relationship between cohesion and organizing a text into paragraph.

Example: Clean and dry your tools. Put them on the shelf. (1.1)

In example (1.1) the relation between “them” and “tools” constitute a tie. This tie is called a reference.

Example: Clean and dry your tools. Put the tools on the shelf. (1.2)

In fact, in this example there are two ties; one is on the reference and the other is the repetition of the word "tools".

Cohesive ties are classified into the following categories based on the cohesive relation between the words and sentences: reference, substitution, ellipsis, conjunction, and lexical cohesion. A brief description about each of the above elements is as follows:

3.1.1.1 ***Reference:*** there are two types of reference

- *Exophora* (situational)*:* An exophoric item makes a reference to the context of the situation and does not name anything in particular [50]

  Example: That must be very expensive. (1.3).

  In this example we don't know whether the "that" is anaphoric or exophoric. When references to the situation are made, the instance seems incomplete because the presupposition is not satisfied. This kind of text often is difficult to interpret.

- *Endophora* (textual)*:*
  - *Anaphoric reference:* In the example (1.1) "Clean and dry your tools. Put them on the shelf.", the word "them" form the second sentence presupposes "your tools" which occurs in the first sentence, therefore when the reference occurs at an earlier point in the text this is called *anaphoric reference.*
  - *Cataphoric reference*: occurs when the referent has not yet appeared but will be provided after the supposing element.

Example: When he arrived, Tom was surprised to find his apartment painted. (1.4)

3.1.2.1 Substitution

Substitution is the replacement of one linguistic item by another, the replacement of one word/phrase with another word/phrase and it is used to avoid the repetition of a particular item.

We distinguish three types of substitutions:

- ✓ *Nominal substitution: one, ones, same*

Example: My desk is broken. I must get a new one.

In this example the pronoun "one" from the second sentence substitutes "desk" from the first sentence and this provides cohesion between the two sentences.

- ✓ *Verbal substitution: do*

Example: Did you go to the movie theatre last night? Yes, I did.

In this example "did" from the second sentence replaces the verbs "go to" from the first sentence and this provides cohesion between the two sentences.

- ✓ *Clausal substitution: so, not*

Example: Did Claudia say she is coming? Yes, she said so.

In this example "so" from the second sentence replaces the clause "she is coming" and this provide cohesion between the two sentences.

3.1.2.2 Ellipsis

The ellipsis can be regarded as the omission of an item or "substitution by zero". In other words, an ellipsis is the absence of that word.

Example: Tom brought some books and Adriana some pencils.

In this example we can understand the first sentence “Tom brought some books”, and it is implied in the second sentence that Adriana brought some pencils. The word “brought” was omitted from the second clause.

3.1.2.3 Conjunction

Conjunctive elements are not directly cohesive as they do not make anaphoric or cataphoric references but they express meanings that presuppose the presence of some other components in the discourse [50].

Example: Connie needs to go to the vet. *And* she has to fix her cat.

In this example the two sentences are made coherent by the conjunction “and” at the beginning of the second sentence.

3.1.2.4 Lexical cohesion

Returning to the example (1.2) “Clean and dry your tools. Put the tools on the shelf.”, the repetition of the word “tools” creates a cohesive effect called lexical cohesion, while the definite article “the” from the second sentence refers to the same “tools” from the first sentence [50, 51].

3.1.3 Cohesion

The concept of cohesion is defined as a semantic relation between elements in a text. Cohesion gives the text texture and has a decisive role in understanding of it. In other words cohesion is defined as the links that holds a text together and gives it meaning.

Returning to the example (1.1) “them” has an anaphoric reference to “tools” and that will create the cohesion between the two sentences and will constitute a text. The meaning of each sentence within a text is context dependent including the cohesive relation with other sentences; hence a text is able to function as a single meaningful unit [50].

3.2 Information

3.2.1 Definition of Information

Information is an indispensable resource in our world as well as part of who we are. Understanding the meaning of information and its use is critical within the context of a “goal-oriented information problem” [52]. Information is defined as: “news or facts about something; knowledge communicated or received concerning a particular fact or circumstance” [53]; also information can be defined as message incorporating relevant meaning [54].

Information is described as “one or more statements or facts that are received by a human and that have some form of worth to the recipient” [55]. Information is composed of a number of data parts and their descriptions, and knowledge is the ability of the individual to understand information and describe the manner in which they handle, apply and use it in a given situation. There are some relations between data, information, meaning and knowledge. There are many examples in where we can see these relations.

When reading an article we avoid elements that are not relevant for us and pay attention only to the parts of information that have some meaning, hence our perception of the

meaning may be different from the one that the author tried to present us. Hence the meaning can be linked to any type and any size of information processed by humans, the difficulty lies in the question of how correctly we are able to manage the connections between the information in order to have a good comprehension [56]. We conclude the fact that the relationship between the pieces of information is critical for the creation of knowledge; "knowledge builds on information that is extracted from data"[57].

In conclusion, information (of any type and any size) can be seen as the input for the process of understanding while the output of this process is the meaning. When information is restructured, it implies that the knowledge is modeled; in other words meaning is the result of understanding. Definitions of data, information, knowledge and wisdom are shown in Table 10, and the relationship between them in Figure 5, also known as DIKW hierarchy.

Table 10: Definitions of data, information, knowledge and wisdom [58]

Description
Data: symbols defining proprieties of objects, events and their environment, being results of observations. Data is considered as raw material but processed in some way it can be transformed in information.
Information: is data that has been processed into a form that has meaning, and add value to the understanding of a subject. Information can answer to the following questions: who, what, when and how many.
Knowledge: "is information combined with understanding and capability; it lives in the mind of people" [59]; is "know-how, and is what makes possible the transformation of information into instruction, and can be obtained either by transmission from another who has it, by instruction, or by extracting it from experience" [58].
Wisdom: "is the ability to increase effectiveness" [58].

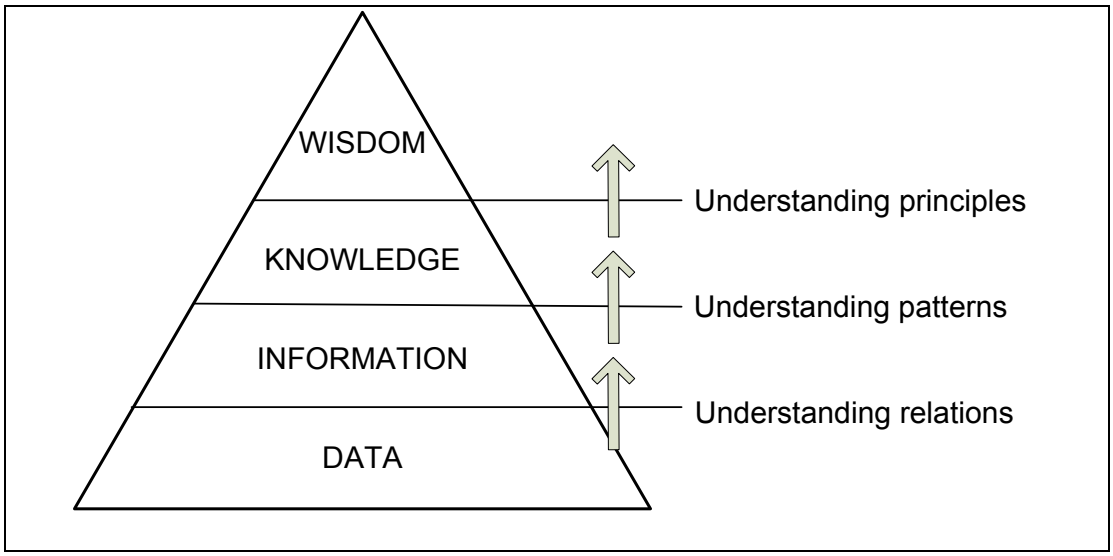


Figure 5: DIKW hierarchy [58]

As shown in Figure 5, understanding the relations between the data will make possible the transition to the next level which is the information. Understanding the patterns on how to manage information will make possible the transition to the level of knowledge. Transition from one level to another within DIKW hierarchy is possible only through understanding [60].

3.2.2 Characteristics of Information

There are many characteristics of information which can be considered during a text analysis process, these characteristics may refer to:

- ✓ The *shape* of information: which can be processed and accessed; but the information can be generated and created, transmitted, stored, sent, distributed, produced and consumed, searched for, used, compressed, and duplicated.
- ✓ The form of information: this can be qualitative and quantitative, numerical and graphic, summary and detailed.

- ✓ The accuracy of information: this refers to the fact that information must not contain any error; is accurate.
- ✓ The *accessibility* of information: this means that the authorized users should be able to access the information whenever they need it.
- ✓ The *completeness* of the information: information must be complete; to contain all important and related data about a particular subject otherwise only having parts of the information will lead to wrong interpretation.
- ✓ The *format* of the information: information should be available in the desired format.
- ✓ The *flexibility* of the information: information should be flexible enough to be used for different reasons.
- ✓ The r*elevance* of the information: that means when a person uses information, that information must be relevant to the current problem, otherwise the information is not relevant and will not help in solving the problem, therefore will not add value to understanding.
- ✓ *Current:* That means that the information must be actually as a fact of today.
- ✓ The *security* of information: information must be used only by authorized persons
- ✓ The *simplicity:* Information must be easily understandable and usable, because complex information is difficult to use and may not serve its purpose.

Information in which the above characteristics are included is valuable information and can be used by individuals and/or organizations to achieve goals and can be used for other different purposes such as managing and continuously improving processes and decision making [61].

3.2.3 Classification of Information

Information can be classified in different ways as it is shown in Table 11 and Table 12.

Table 11: Information classification

Classification	Description	Exemplification
Presentation	Oral information	Verbal communication, conference, music
	Written (documents, text)	Letters, press releases, news Reports (accounting, scientific, technical...) Scientific publications (articles, books) Textbooks, literature (novels, short stories, essays, poems) Legislative, historical diagrams, drawings, spreadsheets Images, animation, movies
Communication channel	Read	Textual, numerical, or combination thereof, graphical
	Listen	Audio
	Watch	Video, graphical, textual, numerical data or combination thereof
Content	Scientific	Data: numeric (accounting, finance, experimental), alphabetic, alphanumeric, geodesic (geometric, trigonometric), astronomical, demographic. Graphic documents that can contain graphics, drawings, technical drawings etc. and can be viewed by displaying on the computer monitor, printer or print their drawings making device (plotter),etc..
	Literature	Organized texts in the form of documents, pages of text, paragraphs, sentences, words and characters, intended to be processed with appropriate software for editing and typing text, grammatical and semantic control of words, and then put in the form of written text in the page
	Art	Audio sequences generated by the human voice, phenomena of reality, musical instruments or electronic voice and sound synthesizer. Animated nature scenes video film, often accompanied by the sound information: voice or sound
Complexity	Complex	Domain knowledge
	Simple	General knowledge

Structure	Formal	Textual (structured) may be numeric, alphabetic or symbolic, or combination thereof. Pictorial (structured) any visual image according to an accepted standard Verbal (explanative) is the information which provides elaborate information's from the beginning with clearly defined subjects and predicates.
	Informal	Textual (unstructured) information may be incomplete, the topic and context may not be clearly defined. Pictorial (unstructured) contain incomplete information is similar to textual unstructured information. Verbal (conversational) may include information subjects and predicates that are not clearly defined. During the conversational process, information units are added or removed or altered as the discussion progresses. Memory information is those elements that are within-person such as past experiences, and/or which content and importance might be unclear. Expressions comprised the physical expressions and intonations in the voice [62].

Table 12: Information classification [63]

Ways	**Type of information**
By source	Internal, external, primary, secondary, government
By nature	Quantitative, qualitative, formal, informal
By level	Strategic, tactical, operational
By time	Historical, present, future
By frequency	Continuous(real time), hourly, daily, monthly, annually
By use	Planning, control, decision making
By form	Written, aural, visual, sensory
By occurrence	At planned intervals, occasional, on demand
By type	Detailed, summarized, aggregated, abstracted

3.3 Interpretation-Aided Mechanisms

3.3.1 Network Text Analysis (NTA)

Text can be coded and analyzed as networks of concepts and is often referred to as: maps, semantic networks, networks of concepts, networks of words, or networks of centering words [64]. Text analysis means the analysis of text using different automated computation techniques. However, the methods of text-analysis range from the automated computation to human interpretation. In human interpretation there are not specific procedures or goals to be followed such as in automated computation [65].

NTA is one of the techniques used in text interpretation, in fact it is a specific text analysis method which encodes the links among concepts or themes in a text and constructs networks with the linked concepts and themes. This method is based on the assumption that language and knowledge can be represented as networks of words and that relations between them, and each concept has a place in this network [66]. These networks among concepts and themes enable us to discover and determine the structure of the text, to extract and analyze the meaning of the text, respectively summarize the text, and also serve as a guide in the efficient and effective representation of the complex network structure that can be represented in texts. There are advantages for representing text as a network. Text networks maintain all of the words and show the relationships. The interesting structural characteristics of text can be easily identified and then analyzed, these can be manipulated without difficulty and represented efficiently in a computer [67-69].

In the literature, there are different ways to classify the text interpretation aided methods. On the one hand these methods are classified into Centering Resonance Analysis (CRA), Functional Depiction (FD), Knowledge Graphing (KG), Map Analysis (MA), Network Evaluation (NE), and Word Network Analysis(WNA) [65].

On the other hand, these methods are classified into quantitative and qualitative text analysis methods [70-73]. In fact, the same author [70] considered that the methods: are quantitative if they are deductive, statistical and confirmatory, and it can be qualitative if they are inductive, non-statistical and exploratory. In quantitative research, the researcher is not influencing the study; he will act only as an objective observer. A hypothesis is necessary before research starts [73]. In addition, the method is quantitative if it generates data matrices from which probabilistic inferences can be drawn [73]. In the case of qualitative research, the researcher is participating and/or "absorbed" in the study. For qualitative research, the hypothesis is not needed. In both quantitative and qualitative methods, the information is carefully analysed in order to achieve a conclusion [74]. Choosing quantitative or qualitative method depends on several factors, such as the purpose for which the method will be applied, the allocated time and money, the researcher's own experience and the researcher's orientation and other resources. Hence, the goal of both methods is to understand texts. A classification of qualitative and quantitative methods can be seen in Table 13.

Table 13: Text analysis classes of methods

TEXT ANALYSIS CLASSES OF METHODS	
Qualitative text analysis methods [71-73]	**Quantitative** text analysis methods [70-73]
Positivist approaches: Understanding arises through the identification of non-random variations in text *Examples of positivist approaches:* ✓ *Content analysis* ✓ *Verbal protocol analysis* ✓ *Script analysis*	***Thematic text analysis:*** Analyze the occurrences of themes (or concepts)
Linguistic approaches: Understanding comes from studying the type and structure of utterances *Examples of linguistic approaches:* ✓ Speech act analysis ✓ Discourse analysis	***Semantic text analysis:*** Analyze sentences (or clauses) in which themes are interrelated
Interpretivist approaches: Understanding comes from intrusive methods in which researchers try to understand how culture and experiences influence text interpretation *Examples of interpretivist approaches:* ✓ Hermeneutics analysis ✓ Intentional analysis	***Network text analysis:*** Analyze themes and/or sentence locations within networks of interrelated themes.

3.3.2 Cognitive Map

A cognitive map is the mind's representation of concepts [75]. Cognitive maps are defined as "dimensional representations of knowledge structure" [76]. Cognitive map models the semantic distances between concepts. These semantic distances are obtained by analyzing proximity data using multidimensional scaling (MDS), cluster analysis or principal component analysis. Hence the most commonly used procedure is MDS. The

relationship between concepts presented in cognitive map depends on individual's judgment of that relationship [76].

3.3.3 Mind Map

Mind maps are diagrams representing relationships between words, ideas or concepts. In the case of mind map the elements are arranged around a central key word or idea intuitively according to the importance of the concepts, classified into groupings, branches or areas. The concepts are connected through labeled lines representing only associations. The goal is the representation of semantic or other connections between the portions of information. Mind maps focus on only idea or concept. An example of a mind map is given in Figure 6.

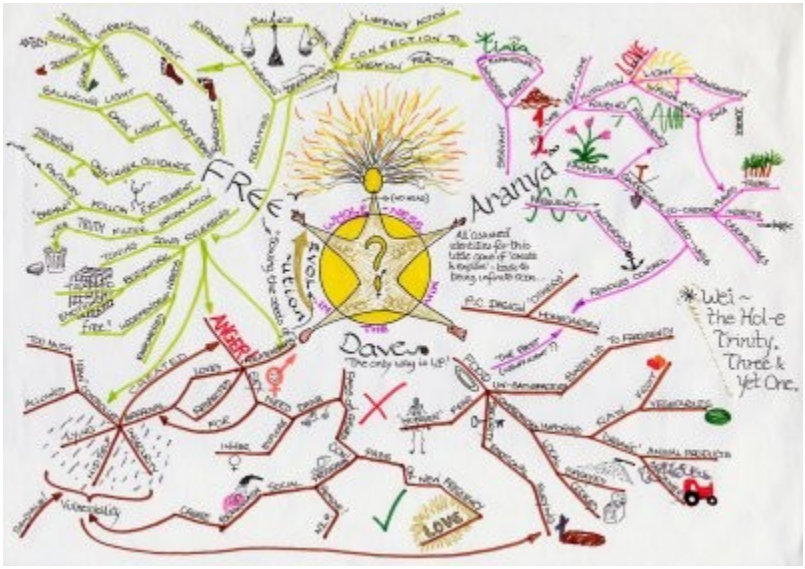


Figure 6: Example a hand-drawn mind map [77]

Mind maps can be used for taking notes**,** recall (allow ideas to be quickly noted as they occur, in an organized manner), problem solving issues, planning, and presentations.

Mind maps help in improving creativity.

3.3.4 Concept Map

Concept maps are semantic organization tools showing spatial representation of concepts and their relationships. Usually these concepts are represented as a network of concepts where the nodes are represented by nouns or noun phrases (objects) connected by verbs and verb phrases (relations) [61]. These maps are created in a downward-branching hierarchical structure with the most important concept on the top of the map followed by the subordinate and detailed concepts of the next lowest levels.

An example of a concept map is given in Figure 7.

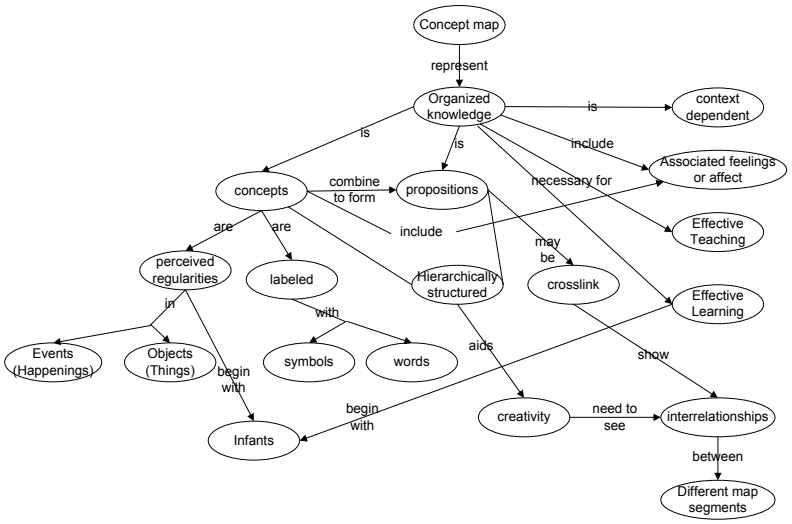


Figure 7: Example concept map [78]

Concept maps improve the creativity, develop logical thinking and study skills, through the identification of the new relationships between ideas, images or words. Concept maps enable a better understanding of how individual ideas form a larger whole [76, 78]. The reason behind developing concept maps is to improve meaningful learning, which means to link new information to existing knowledge structures. The concepts are expressed by propositions which will determine the relationships between concepts. Concept maps can be drawn in any content area, and on any level of detail depending upon the proposed use

of the map [76, 79]. Concept maps are used to stimulate idea generation (brain-storming), communicate complex ideas and arguments, increase learning ability, improve language ability, increase new knowledge creation, facilitate the creation of shared vision and shared understanding within a team or organization, and much more.

Concept maps show not only which concepts are related, but through the labels also how those concepts are related [76]. However, it was observed that the use of concept maps lead to greater level of comprehension, better performance on standardized achievement test and reduce anxiety levels associated with learning a content area [80].

3.3.5 Topic Maps

Topic Maps are similar to concept maps and mind maps, the difference being that topic maps are standardized, topic maps are "a form of semantic web technology" [81]. As usual topic maps are used to collects the key concepts described in database and the documents of the organization and connect all the concepts together in order to structure the information of the organization. A topic map is focused on information finding [82]. An example of topic map is given in Figure 8.

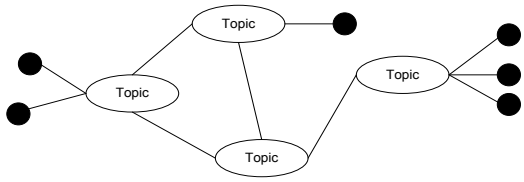


Figure 8: Example topic map [81]

As is shown in Figure 8 a topic map represents the information by topics (representing any concept), and the relationships between them.

4 Methodology

4.1 Semantics in Recursive Object Model (ROM)

As we have mentioned before, a text is composed of a collection of complex sentences with clauses or multiple sentences that are tied through some words. In order to process a text we address the following main steps: lexical analysis, syntactic analysis and semantic analysis.

- Lexical analysis: determines the property of a word in the sentence
- Syntactic analysis: determines the role of a word or phrase in a sentence and identifies the sentence pattern
- Semantic analysis: focuses on the relationships between sentences, phrases, and words

4.1.1 Lexical Analysis

Lexical analysis is considered as the first step used in processing text in order to achieve understanding because it determines the property of a word in a sentence. Without this we could not proceed to the next step. The word is the most important and smallest unit of meaning in a language. The English language has eight traditional parts of the speech and classifies English words into eight lexical categories: noun, verb, pronoun, adjective, adverb, preposition, conjunction, and interjection. A brief description about each of the above elements is as follows:

- ✓ Noun: is a word used to name a person, place, thing, quality, idea, event and a series of abstract concepts. In a sentence a noun can function as the subject or object of a verb.

- ✓ Pronoun: is a word used as substitute for a noun or noun phrase in a sentence
- ✓ Verb: is a word used to express the action from/to/an object (e.g. to run, to build), or the state of an object (e.g. to be, to stand). There are four principal verb types: linking, transitive, intransitive and auxiliary, as shown in Table 14. The corresponding ROM diagrams for each type are illustrated in Table 15.

Table 14: Classification of verb types [11]

Verb types	**Definition**	**Examples**	**Type of relation**
Linking verb	Connect the subject to the complement	Is, am, are, etc.,	Predicate
Transitive verb	Express an action from one object to another.	Move, change, rivet, etc.,	Predicate
Intransitive verb	Involves only one object, express a relation on itself, which indicates a state of a noun.	Stay, fly, walk, etc.,	Predicate
Auxiliary verb	Shade the meaning of the main verb in some desired manner.	Can, do, may, shall, etc.,	Constraint

- ✓ Adjective: modifies a noun or a pronoun by identifying, describing, or quantifying words
- ✓ Adverb: can modify a verb or verbal phrase or an adjective. These determiners are used in front of nouns, they are necessary in sentences but they don't describe the sentences. Adjectives, adverbs, and determiners in a ROM diagram are represented by constrained relations, as depicted in Table 16.

Table 15: Graphic representation of the relations defined by verbs [11]

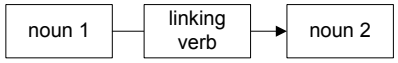
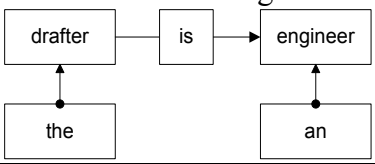
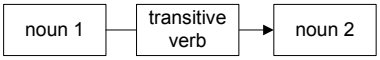
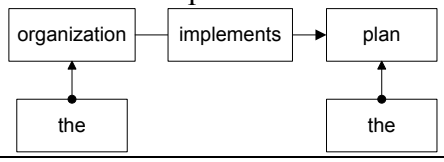
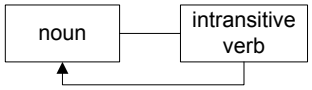
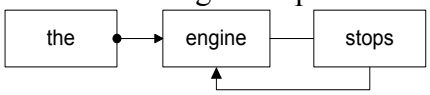
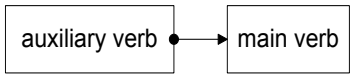
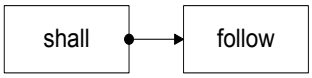
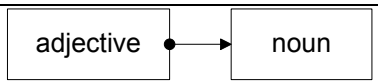
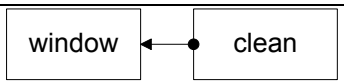
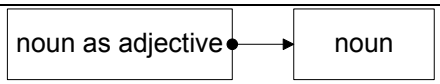
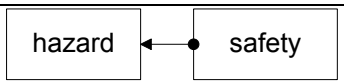
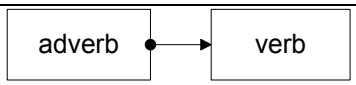
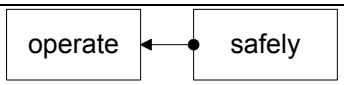
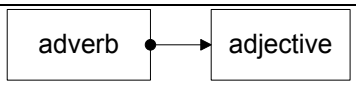
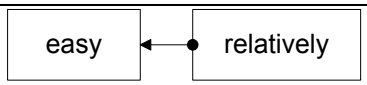
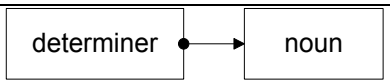
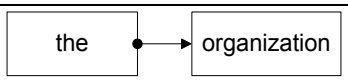
Type	Graphic Representation	Example
Linking		The drafter is an engineer 
Transitive		The organization implements the plan 
Intransitive		The engine stops 
Auxiliary		Shall follow 

Table 16: Graphic representation of the relation defined by adjectives, adverbs, and determiners [11]

Part of Speech	Graphic Representation	Example
Adjective		
		
Adverb		
		
Determiner		

- ✓ Preposition: introduces the prepositional phrases indicating the relation between things mentioned in a sentence but by itself does not describe a clear idea. The most used prepositions are "of", "to", "in", "for", "with", and "on".
- ✓ Conjunction: connects two words, sentences, phrases, or clauses together that do not modify each other. Conjunctions in ROM diagram are represented by connection relations.

4.1.2 Syntactic Analysis

The second step in text analysis is syntactic analysis. A phrase is defined as a group of related words functioning as a single unit in the syntax of a sentence that does not have a subject, or a predicate, or both. In a ROM diagram, a phrase will be represented as a compound object. Phrases may be classified as follows: prepositional phrases, noun phrase, verb phrase, verbal phrase, and gerund phrase, as shown in Table 17.

Table 17: Composition and functions of phrases [11]

Type of phrase	Composition	Part of speech	Examples
Noun phrase	Consists of a noun or a pronoun with any associated modifiers.	Noun	The red **car**. The **car** on the **street**.
Verb phrase	Consist of a verb and any auxiliary verbs.	Verb	**Drink** water. **Move** from left to right.
Verbal phrase Infinitive	An infinitive and its object with any modifiers	Adjective, adverb or noun	**To** connect correctly words in sentences is his goal today.
Participial	A participle and its object with any modifiers	Adjective	The car **sliding out of control** towards the building will likely hit the window [83].
Gerund phrase	A gerund and its object with any modifiers	Noun	**Raising chickens** can be a very exhausting job.
Prepositional phrase	Consist of a preposition and its objects and its modifiers	Adjective, adverb	The cat is asleep **on** the sofa.

Example: The likelihood of introducing food safety hazards to the product through the work environment

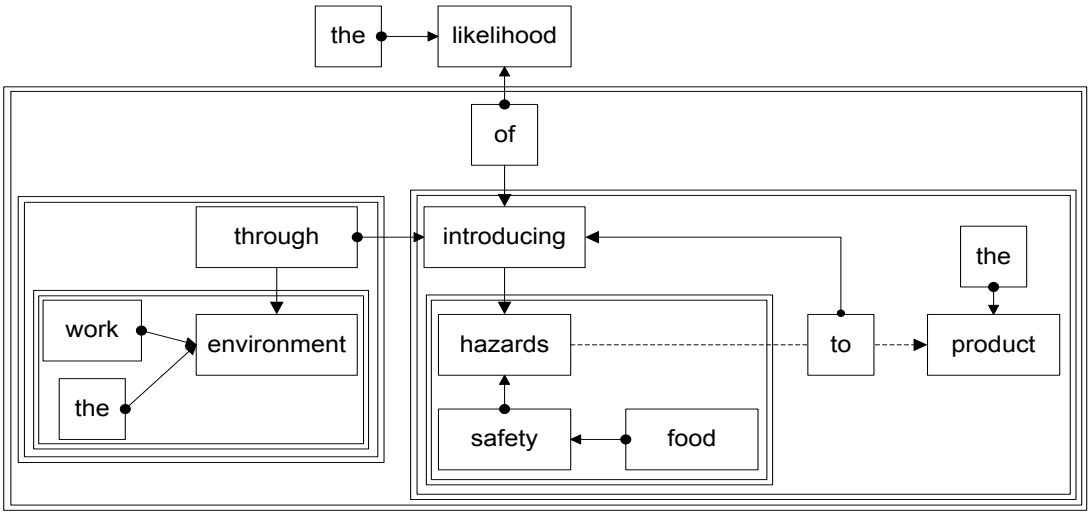


Figure 9: ROM diagram structure of a complex phrase [11]

In Figure 9, we have a combination of noun, gerund and prepositional phrases represented by simple and compound objects. The noun phrases are “the likelihood”, “the work environment” and “food safety hazards”. The gerund phrase is “introducing food safety hazards”. The prepositional phrase is “to the product” and it links to the compound object “food safety hazards” through connection relation.

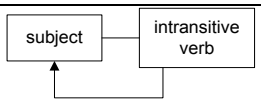
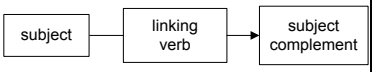
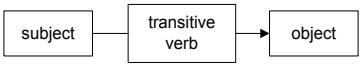
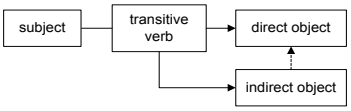
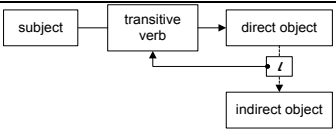
4.1.3 Semantic Analysis

As we have seen earlier, lexical and syntactical analysis identifies the property of words in a sentence and the sentence patterns. In the final step in processing texts we apply semantic analysis which has a decisive role in understanding the meaning of complex sentences and paragraphs. Semantic is the study of meaning and focuses on the relationships between words, phrases, sentences, and paragraphs. The purpose of the semantic analysis is to find the connection between sentences. To achieve this goal, firstly we need to explore concept of sentence. A sentence is “an expression in natural language” [84]. Composed of one or more clauses, a sentence is the largest independent grammatical unit that expresses a complete idea. In the English language, we distinguish the following types of sentences: declarative, interrogative, imperative, and exclamatory. In the present thesis, we consider only declarative sentences in the context of engineering applications.

Sentences that have the structure of “subject + predicate” are called basic sentences, and express only one thought. The predicate may be only a verb or a verb plus other elements, such as a complement, direct object, indirect object, and objective complement. Taking

into account only the possible predicate structures, we distinguish five basic sentence patterns which are listed in Table 18.

Table 18: Sentence patterns of the English language [11]

Pattern #	Sentence Structure	ROM representation	Example
Pattern 1	Subject + intransitive verb		Bus stay. Birds fly. I walk every day.
Pattern 2	Subject + linking verb + subjective complement		He is a student. Alan is the neighbour of Maria. Your ears feel cold.
Pattern 3	Subject + transitive verb + direct object		Tom kicked the ball. Maria moved the table into his office.
Pattern 4	Subject + transitive verb + indirect object + direct object		You give me a book. Kate brings me a letter.
Pattern 5	Subject + transitive verb + direct object + objective complement	 Note: The connection ℓ can be "to", "for", or nothing.	The class elected Gabi president. You found the movie interesting.

- ✓ The subject of a sentence is the person, thing, place or idea carrying out an action. We can find the subject of a sentence if we can identify the verb. Subject can be a noun, noun phrase, or pronoun. In a declarative sentence, the subject usually appears before the verb. Example: *Statues* never laugh
- ✓ The predicate is the part of sentence which modifies the subject. Predicates complete the sentence.

- ✓ The object is defined as a word or group of words functioning as a noun, or a pronoun, that is influenced by a verb (direct object), a verbal (indirect object), or a preposition (object of a preposition) [85]. Example: Tom sold *me* **his book.** In the present example the indirect object is represented by "me" and the direct object is represented by "his book".
- ✓ The complement is any word or phrase that completes the sense of a subject, an object, or a verb.

A *subject complement* follows a linking verb and modifies or refers to the subject. An *object complement* follows and modifies or refers to a direct object. It can be a noun or adjective or any word acting as a noun or adjective. A *verb complement* is a noun phrase that acts as the direct or indirect object of a verb. The relation between sentences constitute the foundation for understanding the semantics of complex sentences and paragraphs [11]. There are four types of relations which are described in the following sections [11].

4.1.3.1 Relations between Independent and Dependent Clauses

First we define the notion of dependent and independent clause:

- An independent clause: is the clause, whose meaning does not depend on the meaning of other sentences, therefore it is a complete clause by itself, and it makes sense alone.
- A dependent clause: the meaning depends on the meaning of other clauses in the same sentence, and a dependent clause does not express a complete thought.

A dependent clause and independent clause can be joined by subordinating conjunctions. List of subordinating conjunction are presented in Table 19 [11].

Table 19: Subordinating conjunctions [11]

Group I	**Group II**				
Indicates place, object, people	**Indicates time**	**Indicates manner**	**Indicates reason**	**Indicates condition**	**Indicates concession**
Where, wherever, who, which, that	After, before, since, when, whenever, while, until, as, ones, as long as	As if, as though, how	Because, since, so that, why, in order that, now that, as, so	If, unless, until, in case(that), provided that, assuming that, even if, only if, if only, whether or not, that	Although, though, even though, while, whereas, rather than

The elements from this table can be divided in two groups:

I. The first group, composed by the elements indicating places, people and objects. The elements from this group modify a noun.

II. The second group, composed by elements indicating time, manner, reason, condition and concession. The elements from this group modify a verb.

In ROM, the relationship in both cases will be represented by a constrained relationship.

<u>*Example for the first group:*</u> *It will be manufactured in a specific workshop, which has specified requirements.*

The corresponding ROM diagram for this complex sentence is shown in Figure 10.

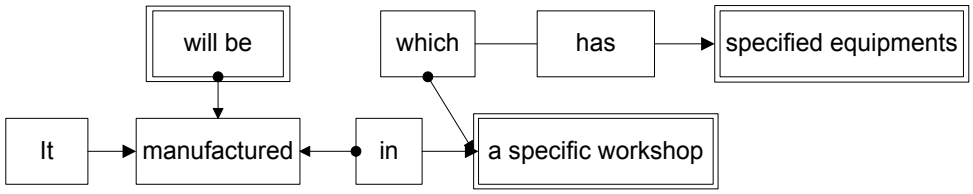


Figure 10: Example ROM diagram

subordinating conjunction indicating an object [11]

In this sentence the key words are "manufactured" and "specific workshop". The dependent clause is joined to independent clause by the subordinate conjunction "which". Hence the compound object "specified equipments" constrain the compound object "specific workshop". In the dependent clause, the key word is the compound object "specified equipments".

Example for the second group: It will affect the movement of the passenger's legs if the garbage bin is put under the table.

The corresponding ROM diagram for this complex sentence is shown in Figure 11.

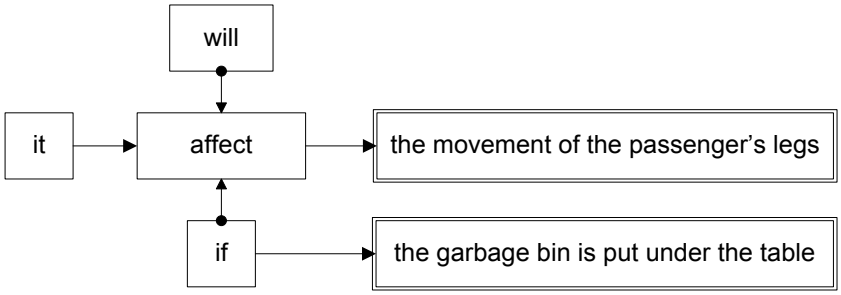


Figure 11: Example ROM diagram

subordination conjunction indicating a condition [11]

This complex sentence is composed by an independent-clause (in bold) and a dependent clause. Both are joined together by the subordinating conjunction "if".

4.1.3.2 Relations between Independent Clauses

A compound sentence contains two independent clauses, joined by a coordinating conjunction and punctuation. Hence coordinating conjunctions are used to link words, phrases and clauses together. The coordinating conjunctions are as follows: **f**or, **a**nd, **n**or, **b**ut, **o**r, **y**et, **s**o [86]. In ROM the relationship between two clauses will be represented by a connection relation.

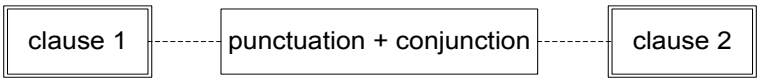


Figure 12: ROM diagram representing the relations between independent clauses [11]

Example: It will affect the movement of the passenger's legs if the garbage bin is put under the table; thus, the only place is under the seats.

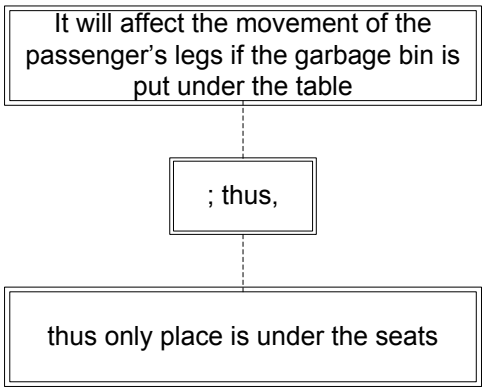


Figure 13: Example Relation between independent clauses [11]

4.1.3.3 Relations between Clauses (Complex Sentences)

Complex sentences consist of one independent clause in combination with one or more dependent clauses. A complex sentence always has a subordinator such as because, since, after, although, or when or a relative pronoun such as that, who, or which.

4.1.3.4 Relations between Words in Two Clauses

Previously we mentioned that, there are five types of cohesive relationships between words and sentences: reference, substitution, ellipsis, conjunction and lexical cohesion.

In the ROM diagram, all these three types of cohesive relationship are represented by connection relationship.

Example: It will affect the movement of the passenger's legs if the garbage bin is put under the table.

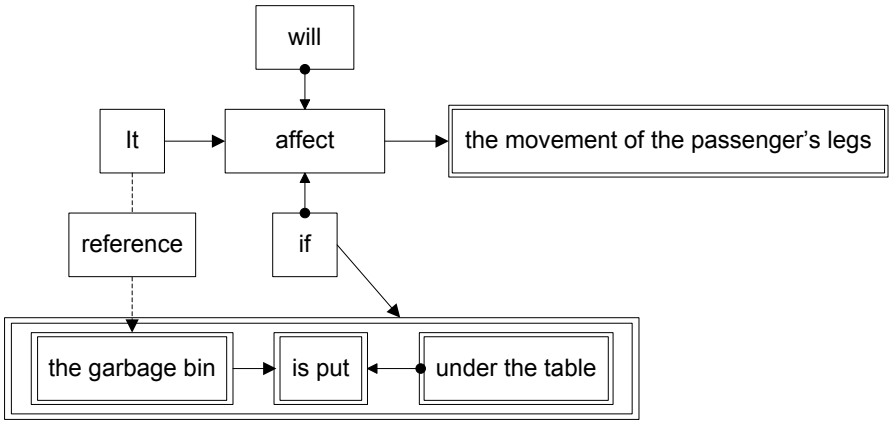


Figure 14: Cohesion relationships between words and sentences [11]

4.2 Method Procedures

The present thesis focuses specifically on ISO 9000:2005(E) Quality Management Systems - Fundamentals and vocabulary. The ISO 9000:2005(E) explains the fundamentals and vocabulary used for the ISO 9000 family of standards. This standard has some specific characteristics: (1) it explains the fundamentals of the quality management systems (QMS) as the basis of the ISO 9000 family; (2) it explains the associated terms in the ISO 9000 QMS; (3) it is used as a guidance and aid document for the QMS; (4) it is not a certifiable standard [87].

Applying the ROM to the ISO standard enables us to easily understand the whole document (structure, terms and definitions, clauses, specifications as well as requirements) easy to understand. To understand is to be able to see the relations between concepts. Therefore, in order to identify the relationships between the concepts defined in the ISO 9000:2005 (E) Standard, we apply the question-asking technique. The question-asking method was originally developed to elicit customer requirements [48].

The procedure to ask questions is described as follows and is depicted in Figure 15:

1) Identify center words from the ROM diagram, center words are words that have the most number of constrained relationships.

2) Identify the constraint(s), define the constraint(s).

3) Define center word.

The process repeats from 1) to 3) until all the words have been defined. Through the application of the ROM, combined with the question-asking technique, it is possible to find meaning from the content of the standard.

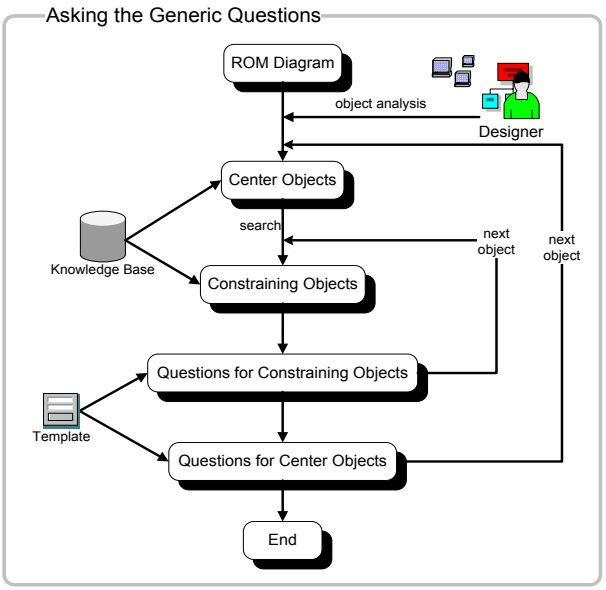


Figure 15: Asking the generic questions [48]

The procedure for the current method, based on [48], is described as follows:

Step 1: Create ROM diagram.

ROM diagram is generated for the text

Step 2: Generate generic questions.

Based on the ROM diagram generated in step 1, generic questions are raised for objects that have not been yet clearly defined. The generation of questions is based on a set of predefined rules and a question template [48] as presented in Table 20 and Table 21.

In Step 2 we have to follow the rules given in Table 20 for object analysis:

Table 20: Rules for object analysis [48]

• Rule 1	Before objects can be further defined; the objects constraining them should be refined.
• Rule 2	An object with the most undefined constraints should be considered first.

Table 21: Question template for object analysis [48]

T1	For a concrete, proper, or abstract noun *N*	Question: What is *N*?
T2	For a noun naming a quantity *Q* of an object *N*, such as height, width, length, capacity, and level, such as height, width, length, capacity, and level	Question: How many / much / long / big /… is the *Q* of *N*?
T3	For a verb *V*	Question: How to *V*? Or Why *V*?
T4	For a modifier *M* of a verb *V*	Question: Why *V M*?
T5	For an adjective or an adverb *A*	Question: What do you mean by *A*?
T6	For a relation *R* that misses related objects	Question: What (who) *R* (the given object)? Or (the given object) *R* what (whom)?

Question asking in the present step is related to the previously defined objects using ROM diagrams. Each object defined in a ROM diagram is analyzed and categorized either as a center object or as a constraining object that needs to be identified or further clarified according to the type of the relationship the object has with other objects. The procedures and rules for asking questions are summarized in Figure 15 and Table 21.

Step 3: Collect answers.

Answers for the questions generated in step 2 are collected. ROM diagram is constructed for each answer and merged together.

Repeat steps 2 and step 3 until no more generic questions can be asked.

4.3 Understanding ISO 9000:2005(E) Standard

4.3.1 Concept of Quality Management System

4.3.1.1 Round 1

Starting with the title of the ISO document: *"Quality Management Systems – Fundamental and vocabulary"* [13]

Step 1: Create a ROM diagram based on the title of the document.

The ROM diagram for the title of the standard is given in Figure 16.

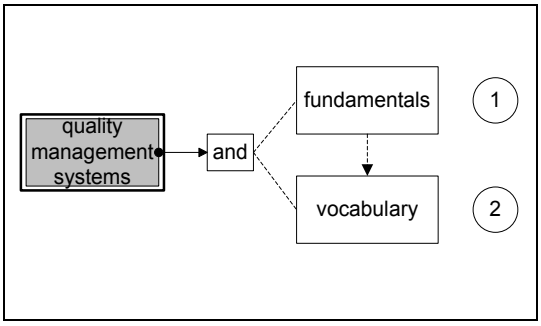


Figure 16: ROM diagram for the title of the standard

In Figure 16, based on the rule in Table 14, the *quality management system* needs to be defined first because it is the constraint of both *fundamentals* and *vocabulary*. The ROM diagram for the term QMS is given in Figure 17.

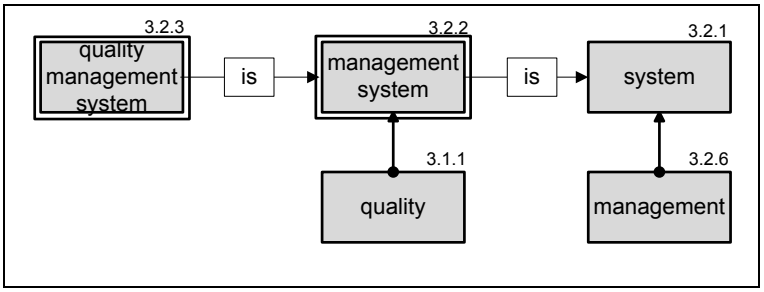


Figure 17: The ROM diagram for the compound object *quality management system* (3.2.3)

Figure 17 and Table 22 shows the network of connections between the objects and the type of relationships between them, respectively.

Table 22: Type of relationships related to the compound object quality management system

Object	**Object**	**Type of Relationship**
quality management system	management system	Predicate
quality	management system	Constraint
management system	system	Predicate
management	system	Constraint

✓ *Quality management system* is a compound object that can be decomposed into the *management system* compound object, which is constrained by the *quality* object.

✓ *Management system* compound object, as well, can be decomposed into a *system* object, which is constrained by *management* object.

✓ Each object and compound object shown in the diagram will be defined based on a further understanding of the terms and definitions of the ISO standards.

Step 2: Generate questions based on the ROM diagram: The list of questions based on the ROM diagram generated in Step 1 is given in Table 23.

Table 23 Questions for Step 1

•	**Q1**	What is Management?
•	**Q2**	What is System?
•	**Q3**	What is Quality?
•	**Q4**	What is Management System?
•	**Q5**	What is Quality Management System?

Step 3: Collect answers for the generated questions: Based on the questions generated in Table 23, we look for the answers in the ISO standard. The answers to the questions found in the standard are presented in Table 24; the number in brackets is the section number in the ISO standard. A ROM diagram is drawn for each answer and all the ROM's are merged to generate a new ROM.

Table 24 Answers for Step 1

•	**A1**	Management (3.2.6) is the coordinated activities to direct and control an organization (3.3.1)
•	**A2**	System (3.2.1) is a set of interrelated or interacting elements
•	**A3**	Quality (3.1.1) is the degree to which a set of inherent characteristics (3.5.1) fulfills the requirements (3.1.2)
•	**A4**	Management system (3.2.2) is a system (3.2.1) to establish policy and objectives and to achieve those objectives
•	**A5**	Quality management system (3.2.3) is a management system (3.2.2) to direct and control an organization (3.3.1) with regard to quality (3.1.1)

Each answer should be analyzed by using ROM:

A1: Management (3.2.6) is the coordinated activities to direct and control an organization (3.3.1).

The ROM diagram for A1 is given in Figure 18.

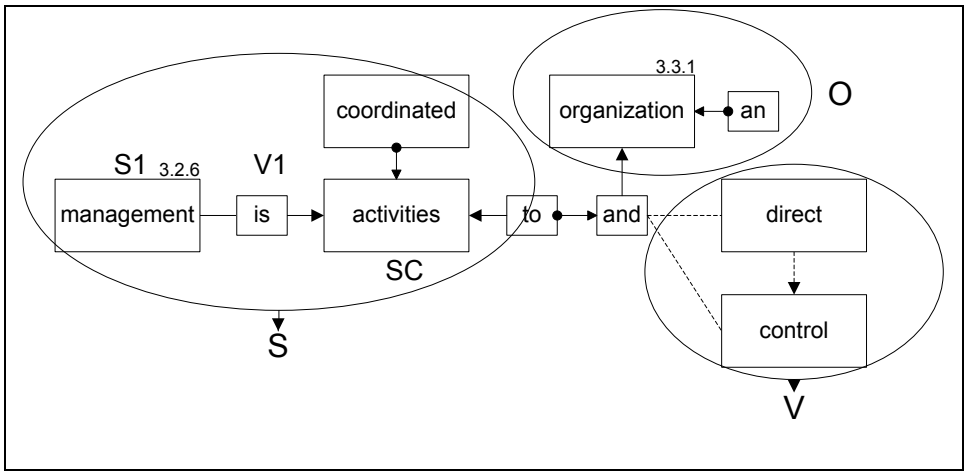


Figure 18: ROM diagram for A1

Syntactic analysis enables us to identify the subject (S, S1), object (O), the main verb(s) (V) and the subject complements (SC), which are shown in Figure 18. The object management (3.2.6) marked with (S1) is the subject of the first sentence and is connected to the coordinated activities marked with (SC), which is the subject complement of the sentence linked with the verb *is*, marked with (V1). Between the objects *management* and *activities* we have a predicate relationship; between the objects *activities* and *coordinated* we have constraint relationship. This section of the ROM diagram shows us in fact only one part of the definition of the object *management*, which is defined as *coordinated activities*. Further, the main verbs are *direct* and *control* marked with (V). *Management,* which is *coordinated activities* (S), has a constraint relationship with the main verb (V).

The main verb (V) is connected to the object (O) *organization* through a predicate relationship.

Therefore, the meaning of this concept is that: *management* is *coordinated activities* to *direct* and *control* an *organization*. In the same manner, we will proceed to the next concepts.

A2: *System* (3.2.1) is a set of interrelated or interacting elements.

The ROM diagram for A2 is given in Figure 19.

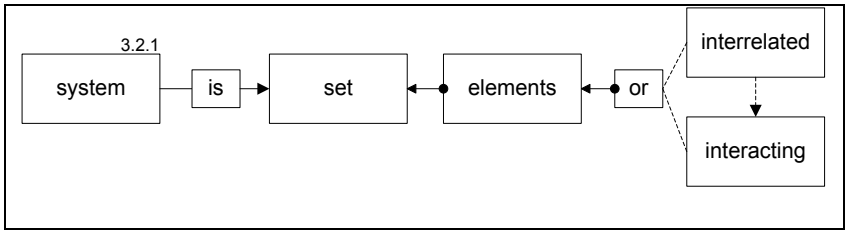


Figure 19: ROM diagram for A2

A3: *Quality* (3.1.1) is the degree to which a set of *inherent characteristics* (3.5.1) fulfills *requirements* (3.1.2).

The ROM diagram for A3 is given in Figure 20.

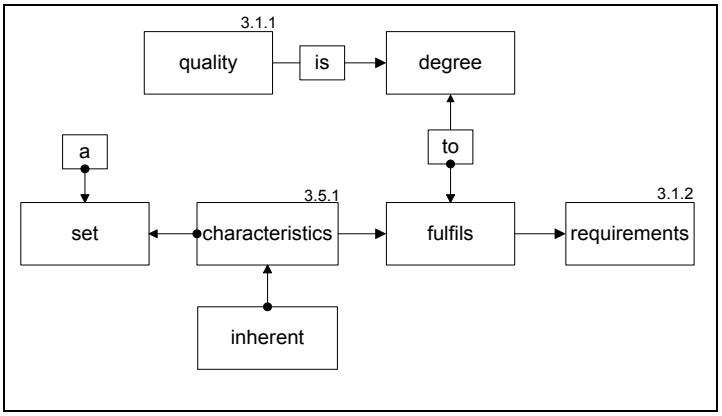


Figure 20: ROM diagram for A3

A4: *Management system* (3.2.2) is a *system* (3.2.1) to establish policy and objectives and to achieve those objectives.

The ROM diagram for A4 is given in Figure 21.

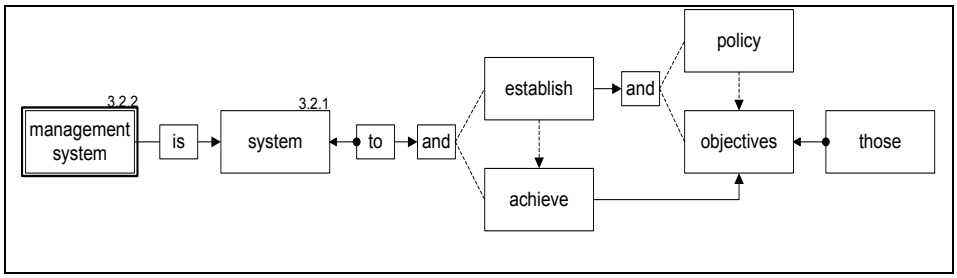


Figure 21: ROM diagram for A4

A5: *Quality management system* (3.2.3) is a *management system* (3.2.2) to direct and control an *organization* (3.3.1) with regards to *quality* (3.1.1).

The ROM diagram for A5 is given in Figure 22.

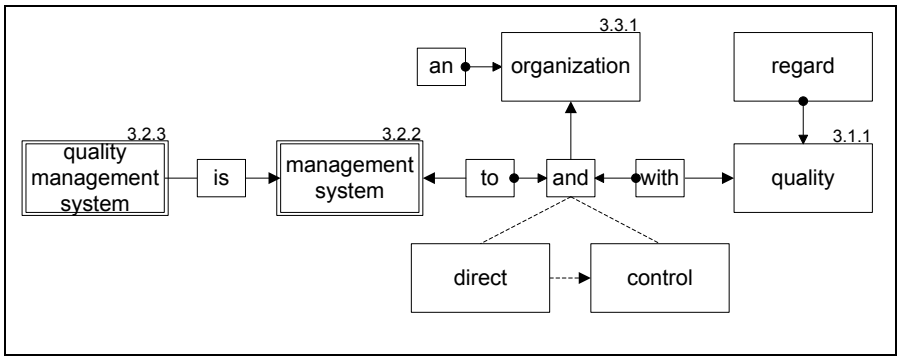


Figure 22: ROM diagram for A5

The new ROM diagram is shown in Figure 23, which merges together the ROM diagrams of Figure 18, Figure 19, Figure 20, Figure 21, and Figure 22 into the original ROM diagram of Figure 17.

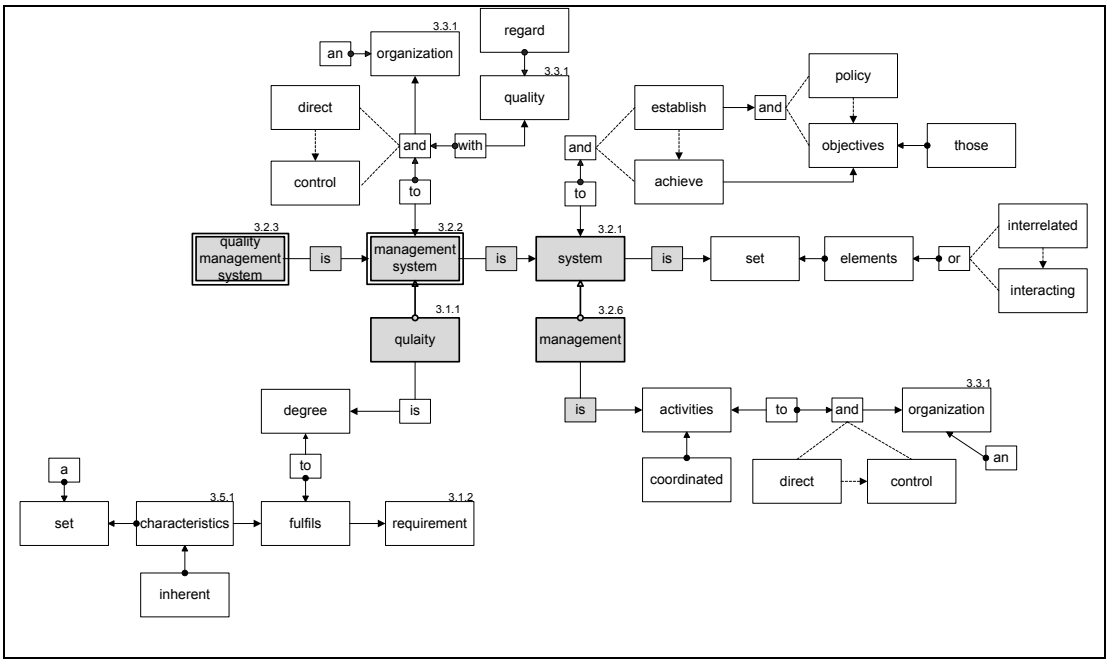


Figure 23: Preliminary merged ROM diagrams for Step 4

4.3.1.2 Round 2

Step 2 - Generate questions based on the ROM diagram: For each ROM sub-diagram, we extend the diagram by refining each node. The following objects are analyzed: *organization* (3.3.1), *requirement* (3.1.2), and *characteristics* (3.5.1)

Table 25: Questions for Step 2

•	**Q6**	What is *organization* (3.3.1)?
•	**Q7**	What is *requirement* (3.1.2)?
•	**Q8**	What are *characteristics* (3.5.1)?

Step 3 - Collect answers for the generated questions: Based on the questions generated in Table 25, we look for the answers in the ISO standard. The answers to the questions

found in the standards are presented in Table 26. A ROM diagram is drawn for each answer and all the ROM's are merged to generate a new ROM.

Table 26: Answers for Step 2

•	**A6**	*Organization* (3.3.1) is a group of people and facilities with an arrangement of responsibilities, authorities and relationships
•	**A7**	*Requirement* (3.1.2) is a need or expectation that is stated generally implied or obligatory
•	**A8**	*Characteristics* (3.5.1) are distinguishing feature

A6: *Organization* (3.3.1) is a group of people and facilities with an arrangement of responsibilities, authorities, and relationships. The ROM diagram for A6 is given in Figure 24.

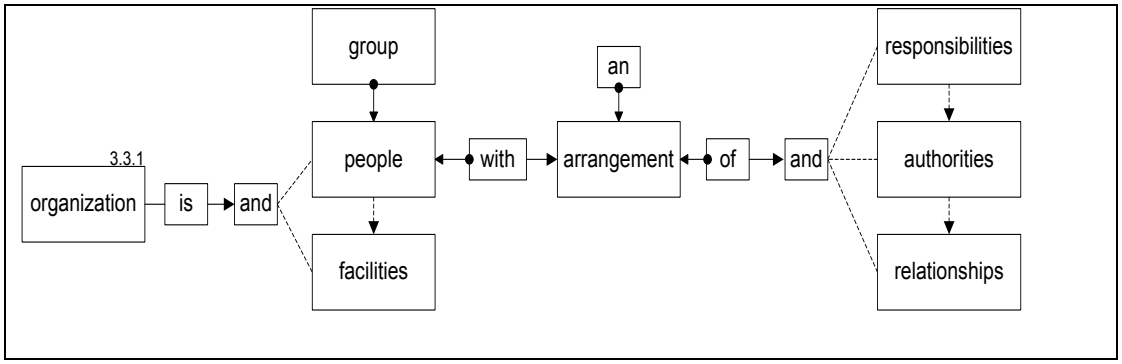


Figure 24: ROM diagram for A7

A7: *Requirement* (3.1.2) is a need or expectation that is stated, generally implied or obligatory.

The ROM diagram for A7 is given in Figure 25.

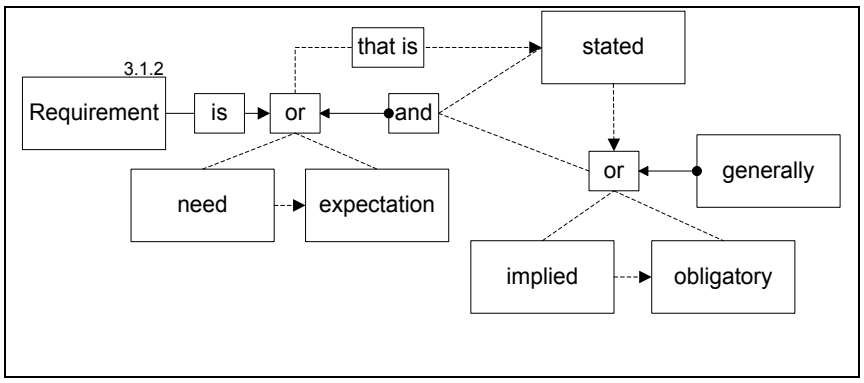


Figure 25: ROM diagram for A8

A8: *Characteristics* (3.5.1) is a distinguishing feature.

The ROM diagram for A8 is given in Figure 26.

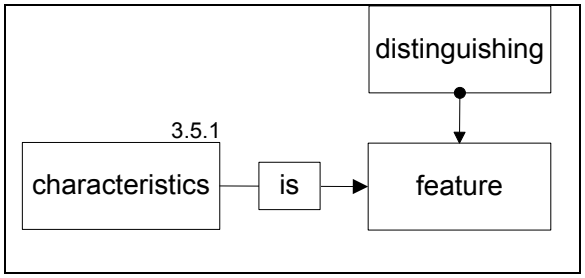


Figure 26: ROM diagram for A9

Based on the merged ROM diagram, we repeat steps 2 to step 3 until no more questions can be asked or until all the definitions in the ISO standard have been addressed. The new ROM diagram shown in Figure 27 is the merged diagram of Figure 23, Figure 24, Figure 25 and Figure 26.

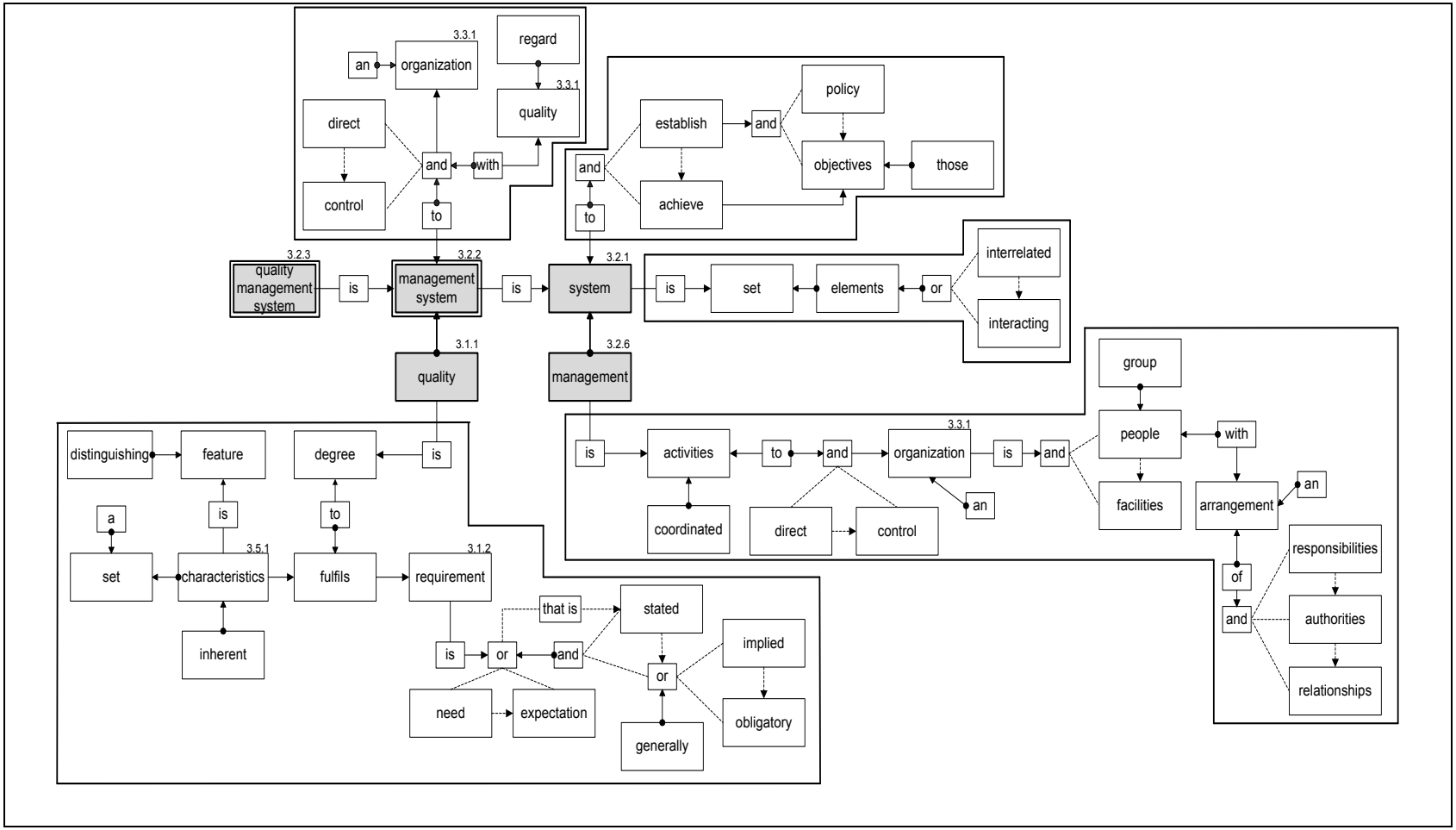


Figure 27: Merged ROM diagram for the concept *quality management system*

Figure 27 shows the quality management system concept. ROM enables us to easily see the QMS concept in relation with other concepts such as organization (3.3.1), requirement (3.1.2), or characteristics (3.5.1), which are not related directly to QMS.

Moreover, through this methodology we are able to show other hidden relationships between concepts that are not defined in the present standard, ROM provides us a whole view about the concept quality management system.

ROM diagram Figure 33 shows us all the QMS-related concepts, which are clearly identified, linked, and described as follows:

- ✓ Quality management system is a management system to direct and control an organization with regard to quality.
- ✓ Quality refers to the degree to which requirements are fulfilled. A requirement is a need or an expectation that is stated, generally implied, or obligatory. A requirement is fulfilled by a set of inherent characteristics. A characteristic is a distinguishing feature.
- ✓ A management system is a system to establish policy and objectives and to achieve those objectives.
- ✓ A management refers to coordinated activities to direct and control an organization. An organization is a group of people and facilities with an arrangement of responsibilities, authorities, and relationships.
- ✓ A system is a set of interrelated or interacting elements.

This clarification helps us to understand the concept not only by providing us with a clear and detailed explanation but also by providing us with an interpretation of this. Hence, the explanation and interpretation covers the first two levels of understanding [35]. The ROM diagrams related to *Paragraph 3 Terms and definitions* used for the present standard can be found in [88].

4.3.2 Definition of Fundamentals of Quality Management System

4.3.2.1 Round 1

Starting with the title of the paragraph

Step 1: Generate ROM for the title of the paragraph

The ROM diagram for the title of the paragraph is given in Figure 28

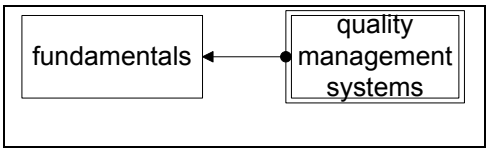


Figure 28: ROM diagram for

Fundamentals of quality management system

Step 2: Generate generic questions based on the ROM diagram: The list of questions based on ROM diagram generated in Step 1 is given in Table 27.

Table 27: Questions for Step 1

•	**Q9**	What are the fundamentals of quality management system?

According to the questions generated in Table 27, we look for all the available information given the present standard; the answers can be found in Table 28, (ISO Standard Clause 2)

Step 3: Collect answers for the questions generated in Step 2

The corresponding answers for Step 3 are given in Table 28.

Table 28: Answers for Step 3 [13]

• **A9**	The fundamentals of quality management systems are the following:	
	✓ 2.1	Rationale for quality managements systems
	✓ 2.2	Requirements for quality management systems and requirements for products
	✓ 2.3	Quality managements systems approach
	✓ 2.4	The process approach
	✓ 2.5	Quality policy and quality objectives
	✓ 2.6	Role of top management within the quality management system
	✓ 2.7	Documentation
	✓ 2.8	Evaluating quality managements systems
	✓ 2.9	Continual improvement
	✓ 2.10	Role of statistical techniques
	✓ 2.11	Quality managements systems and other management system focuses
	✓ 2.12	Relationships between quality managements systems and excellence models

The ROM diagram for some answers from A9 is given in Figure 29.

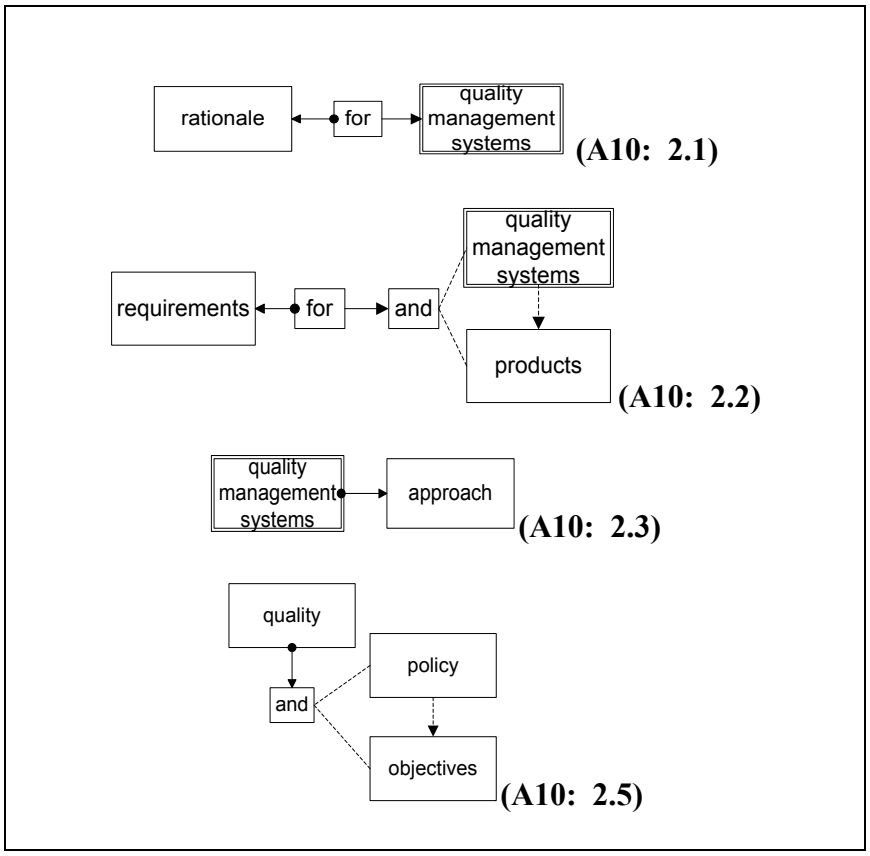


Figure 29: ROM diagram for Step 6

By analysing Figure 29, we can see that the *quality management systems* object and as well as the *quality* object is present in each paragraph (A9: 2.1; A9: 2.2; A9: 2.3; and A9: 2.5). As an example, we pick the paragraph A9: 2.1 for analysis.

4.3.2.2 Round 2

Step 2: Generate generic questions based on the ROM diagram:

Table 29: Question for step 2

Q10:	What is the *rationale* for *quality management system*?

Step 3: Collect answers for the generated questions:

Table 30: Answers for step 2

A10: "Quality management systems can assist organizations in enhancing customer satisfaction. Customers require products with characteristics that satisfy their needs and expectations. These needs and expectations are expressed in product specifications and collectively referred to as customer requirements. Customer requirements may be specified contractually by the customer or may be determined by the organization itself. In either case, the customer ultimately determines the acceptability of the product. Because customer needs and expectations are changing, and because of competitive pressures and technical advances, organizations are driven to improve continually their products and processes. The quality management system approach encourages organizations to analyze customer requirements, define the processes that contribute to the achievement of a product which is acceptable to the customer, and keep these processes under control. A quality management system can provide the framework for continual improvement to increase the probability of enhancing customer satisfaction and the satisfaction of other interested parties. It provides confidence to the organization and its customers that it is able to provide products that consistently fulfill requirements"[13].

In order to process this paragraph the following steps should be followed: each of the sentences above is analyzed individually; a ROM diagram is drawn for each sentence and all the ROM's are merged to generate a new ROM diagram. The first sentence in the present paragraph is given in Figure 30.

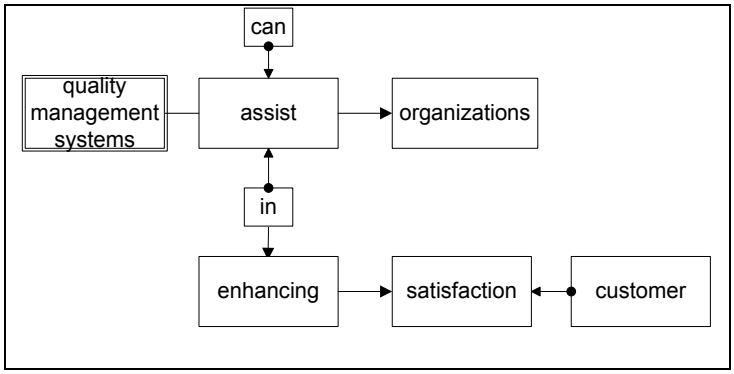


Figure 30: ROM diagram first sentence

The present ROM diagram for this sentence shows us the role of a quality management system in helping organizations to increase customer satisfaction. In the same manner, we generate ROM for all other sentences. The merged ROM diagram for the whole paragraph Rational for quality management systems can be seen in Figure 31.

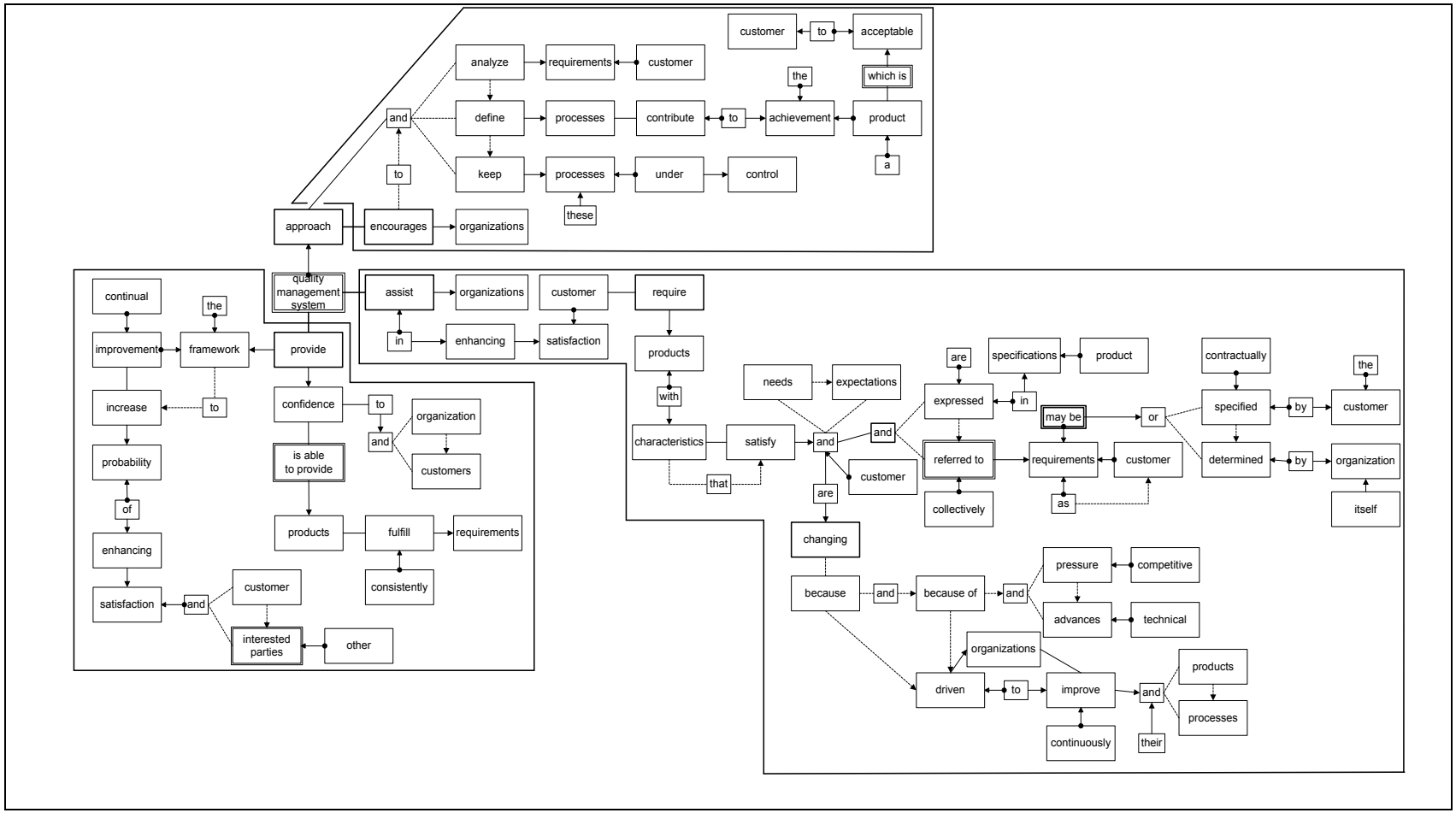


Figure 31: ROM diagram for *Rationale for quality management systems*

The rationale behind the concept *quality management systems* (QMS) is clearly identified, linked and described as follows:

- ✓ *Quality management systems* (QMS) assist organizations in enhancing customer satisfaction. Customers require products with characteristics that satisfy their needs and expectations.
- ✓ *The Quality management systems* (QMS) approach encourages organizations to: analyze customer requirements; to define the processes that contribute to the achievement of a product that is acceptable to the customer, and to keep these processes under control.
- ✓ *Quality management systems* (QMS) provide the framework for continual improvement to increase the probability of enhancing customer satisfaction and the satisfaction of other interested parties. QMS also provides the organization and its customers with the confidence that it is capable of producing products that consistently fulfill requirements.

5 Extraction of Meaning from ISO Standard

5.1 Definition of Meaning

In this section, we define meaning as the relations between concepts. Meaning is a result of understanding, and understanding is defined as bringing concepts into relation in order to develop a network of connections, and interdependences [32]. Therefore, understanding a text is to bring the text into relations in order to create a network of connections. In the following section we show how the meaning of ISO standard is extracted.

5.2 Meaning of ISO Standard

5.2.1 Clarification of Quality Management System

The ROM diagram in Figure 27 shows us the definition of the compound object quality management system (QMS).

Applying ROM method, we are able to show connections between the following concepts: *management system* (MS), *quality* (Q), *system* (S), and *management* (M) which in turn will facilitate the understanding. Therefore, *quality management system* (QMS) is defined as a *management system* (MS) constrained by *quality* (Q), which means *quality* (Q) should be defined before the *management system* (MS).

Quality (Q) is defined by clarifying the following concepts related to quality.

- ✓ Requirements (3.1.2)
- ✓ Characteristics (3.5.1)

Similarly, *management system* (MS) is a *system* (S) constrained by the *management* (M), which means that, to define the *system* (S), *management* (M) should be defined first.

Management (M) is defined by clarifying the following concept:

- ✓ Organization (3.3.1)

Therefore from the ROM diagram, all the concepts related to QMS are clearly identified and linked.

5.2.2 Clarification of Fundamentals of Quality Management Systems

The ROM diagram in Figure 31 shows us only one part from the definition of Fundamentals *of quality management system*. Applying ROM method, we are able to show connections between the concept *quality management systems* (QMS) with the following concepts: organization, product, process, characteristics, continual improvement and customer. Moreover, ROM clearly shows the role of QMS within and outside an organization. Internally, QMS encourages organization to analyze customer requirement, satisfy customer requirements, define processes and keep the process under control. Externally, QMS provides product that fulfils requirements.

5.3 Comparison with Existing Models

5.3.1 Comparison of ROM with the Concept Diagram

In this section, we compare ROM with the concept diagram: Concepts relating to management (3.2), Appendix A of the ISO 9000:2005(E). The concept diagram shows the relations between concepts in a thematic group. There are three types of relationships:

generic (depicted in three diagrams), partitive (depicted in a rake), and associative (depicted in a double-headed arrow). The concept diagram relating to *management* (3.2) is shown in Figure 32.

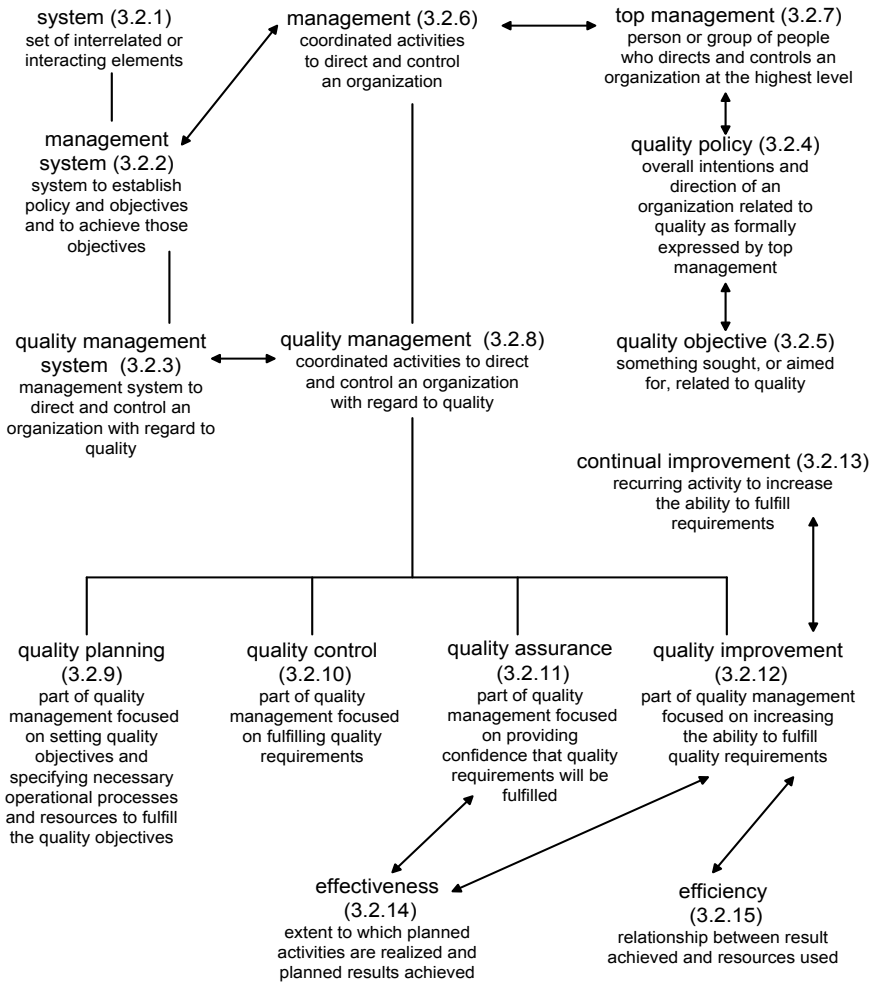


Figure 32: Concept diagram for management [13]

The concept diagram can show only connections between concepts within a thematic grouping whereas ROM can show relations between concepts within and across thematic groups. For example, in ROM there are relationships between organization and management whereas in concept diagram there is no relationship between organization and management because the concepts belong to two different thematic groups.

Table 31: Number of connections between concepts found in concept diagram versus in ROM for QMS concept

No.	Concept	Concept diagram	ROM
1	system(3.2.1)	1	2
2	management system(3.2.2)	3	5
3	quality management system(3.2.3)	2	1
4	management(3.2.6)	3	5
5	quality management(3.2.8)	6	5
6	top management(3.2.7)	2	2
7	quality policy(3.2.4)	2	3
8	quality objectives(3.2.5)	1	1
9	quality planning(3.2.9)	1	2
10	quality control(3.2.10)	1	2
11	quality assurance(3.2.11)	1	2
12	quality improvement(3.2.12)	4	2
13	continual improvement(3.2.13)	1	1
14	effectiveness(3.2.14)	2	1
15	efficiency(3.2.15)	1	1

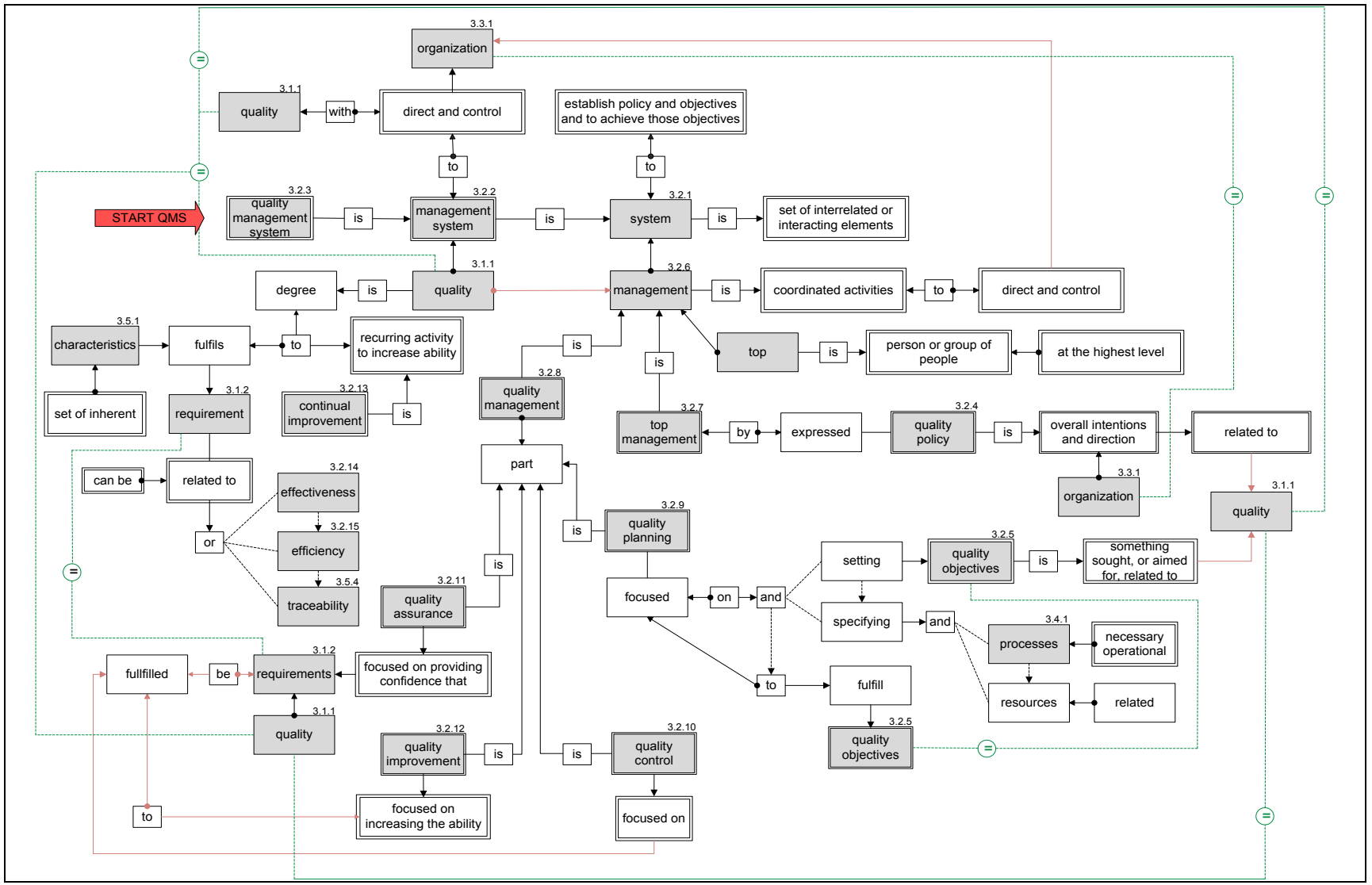


Figure 33: ISO standards' concepts relationships

The comparison between the concept diagram and the ROM diagram for *quality management system* concept in Table 31 shows that not all the relationships between the concepts can be drawn in a ROM diagram as well as in concept diagram. However, ROM enables us to identify more connections between concepts (across thematic group), as presented in Figure 33, that are not identified through concept diagrams. The comparison between the concept diagram and the ROM can be seen in Table 32.

Table 32: Results of the comparison of the concept diagram with the ROM diagram

	Concept diagram	**ROM diagram**
Strength	Shows hierarchical relationships	Shows relations between concepts across the thematic groups Shows the connections between primitive terms within a concept Show keywords Build network of texts in a systematic manner
Weakness	Shows relations between concepts limited to a thematic group. There are relations between concepts that the concept diagram does not show.	There are relations between concepts that cannot be directly visualized in ROM.

5.3.2 Comparison of ROM with Cognitive, Mind, Concept, and Topic Maps

These maps enable us to see the connection between concepts/ideas we already know; they help us to connect new concepts/ideas; also they enable us to organize concepts/ideas in a logical and flexible structure.

Table 33: Comparison of different methodologies with ROM

Methodology						
No.	**Comparison criteria**	**Cognitive Map [76, 89-91]**	**Mind Map [77, 89, 91]**	**Concept Map [76, 78, 89, 91]**	**Topic Map [81]**	**ROM**
1	Types of relationships between concepts	User-defined relationship	User-defined relationship	User-defined relationship	Undefined relationship	Predefined set of three types of relationship
2	Structure	Network	Tree	Network	Network	Network
3	Limitation in number of connections	No limitation in the number of ideas that we can link to one another	Typically does not use multiple links between ideas.	No limitation in the number of ideas that we can link to one another	No limitation in the number of ideas that we can link to one another	No limitation in the number of ideas that we can link to one another
4	Target	Several focuses	One main or central concept	Several focuses	Several focuses	One main or central concept
5	Organizer of knowledge structure	Yes	Yes	Yes	Yes	Yes
6	Relatively easy to learn	No*	Yes	Yes	Yes	Yes
7	Interpretation	Can be sometimes difficult	Easy to interpret	Can be sometimes difficult	Easy to interpret	Easy to interpret
8	Construction method	By computer (extremely difficult to construct without computers)	Manually or by computer	Manually or by computer	Manually or by computer	Manually or by computer

Note *: because the method requires the use of advanced statistical routine, such as multidimensional scaling, principal components, or cluster analysis

6 Conclusion and Future Work

Effective understanding of ISO standards is a decisive factor before and during the implementation of a quality management system; the effectiveness of understanding will lead to less misuse of valuable resources such as time and money. The purpose of the present thesis is to provide a new way to facilitate the understanding of ISO 9000:2005(E) standard Quality Management Systems – Fundamentals and vocabulary. The procedure in applying ROM methodology is divided into three steps: 1) generate ROM diagram for the text, 2) generate questions based on the ROM in step 1, 3) collect answers, generate ROM for the answers and merge all the ROMs. The process continues until no more questions are asked, or until all the definitions in the ISO document have been covered. The final ROM shows the relations between concepts, which facilitate understanding.

The advantage of ROM method is that it helps user build a network of connections between concepts in a systematic way. From ROM diagram, user can see keywords and related concepts. Moreover, ROM reveals hidden relations between concepts that are not defined in a document. Therefore, not only can user identify important concepts but also see the whole picture. Therefore, this method can be used in training session for ISO implementation. However, ROM diagrams are hard to manage, especially when the size of the diagram becomes too significant. All the ROM diagrams in this study have been manually constructed. The process, therefore, took a lot of time and effort. Currently, in-house software is being developed to generate ROM automatically.

In the future, we intend to apply ROM to study other standards and other types of documents such as ITAR regulation, EAR regulation, product requirements, etc. In addition, we will conduct experiment to validate the effectiveness of ROM in document understanding. We expect that those who use ROM will improve performance in reading comprehension and that ROM will facilitate knowledge accumulation.

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